Proceedings of the 69th Western International Forest Disease Work Conference

Hotel Santa Fe

Santa Fe, New Mexico

September 9-13, 2024

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Compiled by:

Adam R. Carson
Swiss Needle Cast Cooperative
Department of Forest Engineering Resources and Management
Oregon State University
Corvallis, Oregon

Papers are formatted and have minor editing for language and style but otherwise are printed as they were submitted. The authors are responsible for content.

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Conference photo contributors:
Robin Mulvey (cover photo)
Adam Carson
Mee-Sook Kim
Chrissy McTavish
Greg Reynolds
Kristen Chadwick
Betsy Goodrich

Contents

Conference Agenda 5

Welcome 13

Keynote Address, 2024 Western International Forest Disease Work Conference 14

Jacob Pederson 14

Panel: Graduate student special papers 15

A Bole Lotta Trouble: Changes in gene expression indicate aspen susceptibility to an emerging canker disease in Alaska 16

Jorda Kovash[*], Hannah Glesener[1], Tomás Engl[2], Loretta Winton[3], Roger Ruess[1], Mary Beth Leigh[1], and Ursel Schuette[1] 16

Monitoring aerial spread of white pine blister rust across the U.S. Rocky Mountains 19

Ashley E. Miller[1], Kelly S. Burns[2], Bradley M. Lalande[3], Maria Newcomb[4], Daniel S. Ott[5], Gregory J. Reynolds[6], Nicholas P. Wilhelmi[7], Anna W. Schoettle[8], Jane E. Stewart[1] 19

Panel: So you've got an invasive, now what? It's here, it's there, it's everywhere 21

Remote sensing for rapid ʻŌhiʻa death: innovation for managing Hawaiʻi's native forest health Crisis. 22

Brian Tucker[*], Nai'a Odachi[2*] 22

Plant community composition and forest structure changes in response to *Phytophthora ramorum* (sudden oak death) invasion and eradication: introduction to the Oregon SOD Permanent Plot Network 24

Ebba K. Peterson, Marie Tosa [1], Stephanie Chase[1], and Jared M. LeBoldus [1,2] 24

Prioritizing management options to mitigate impacts to high-5 pine species by novel stressors 25

Anna W. Schoettle[*] 25

Posters 34

Quantifying aerial inoculum densities and spore deposition rates of *Heterobasidion irregulare* in ponderosa pine forests of the northwestern United States 35

Patrick I. Bennett, I. Blakey Lockman[2], Brennan Ferguson[3], Betsy A. Goodrich[3], Dan Omdal[4], Rachel Brooks[4], Jill Hautaniemi[5], Holly S. J. Kearns[6], Matteo Garbelotto[7] 35

Sooty-bark canker disease (*Encoelia pruinosa*) inoculation study 40

James T Blodgett 40

Fire-driven changes to western conifer forest soil microbiomes & implications for microbiome-based management of Armillaria root disease 44

Ada J. Fitz Axen, Ned B. Klopfenstein[2], Mee-Sook Kim[3], John W. Hanna[2], Patrick Bennett[2], Sara Ashiglar[4], Jane E. Stewart[1] 44

Pathogenicity and virulence assays of fusarioid fungi on conifer species 46

Grace E. Ganter, John T. Dobbs [1], Olivia Watson [1], Ned B. Klopfenstein[2], Greg Reynolds[3], Mee-Sook Kim[4], and Jane E. Stewart[1] 46

Midterm project updates for ongoing *Armillaria* surveys in California: DNA-based identification, bioclimatic modeling, and information for managing Armillaria root disease under changing environments 47

John W. Hanna, Mee-Sook Kim[2], Patrick I. Bennett[1], Ashley E. Hawkins[3], Chris A. Lee[4], Kim Corella[5], Charles W. Barnes[6], Wallis L. Robinson[7], Duncan R. Kroese[2], William C. Woodruff[8], Martin MacKenzie[9], Phil G. Cannon[10], Ned B. Klopfenstein[1] 47

Armillaria collection methods: tips and tricks 51

John W. Hanna, Aaron L. Smith[2,3], Mee-Sook Kim[4], Patrick I. Bennett[1], Ned B. Klopfenstein[1] 51

Changes in intensity of white pine blister rust on western white pine across time, space, and changing climate in the interior northwestern USA 59

Mee-Sook Kim, Jane E. Stewart[2], Marcus V. Warwell[3], John W. Hanna[4], Paul J. Zambino[5], Geral I. McDonald[4], Bryce A. Richardson[4], and Ned B. Klopfenstein[4] 59

Bioclimatic model-based predictions of potential distributions for four forest root disease pathogens under changing climates in western North America 64

Duncan R. Kroese, Daram Choi[1, 2], David C. Shaw[2], Patrick I. Bennett[3], Ned B. Klopfenstein[3], and Mee-Sook Kim[1] 64

Development of a rapid field-based detection assay for North American Onnia spp. 68

Noah Lindeman, Patrick Bennett[2], I. Blakey Lockman[3], Brytten Steed[4], Bradley Lalande[5], Maria Newcomb[4], Katherine Minnix[4], Jane E. Stewart[1] 68

Assessing the drivers of ponderosa pine (*Pinus ponderosa*) dieback and mortality 70

Michael McKee, Kelly Burns[2], Mee-Sook Kim[3], Ned B. Klopfenstein[4], Christine McTavish[5], Maria Newcomb[6], Jill Hautaniemi[6], Ashley Hawkins[7], Seth Davis[8], Jane E. Stewart[1] 70

Predicting and Reframing Hemlock Dwarf Mistletoe in Variable Retention Silviculture 71

Hanno Southam[*], Richard Hamelin[1] 71

Washington Office Presentation and Q&A 74

USDA Forest Service – Programmatic Update 74

Forest Health Protection – Washington, DC 74

Bruce Moltzan, PhD – September 12, 2024 74

Panel: Economics of Forest Pathology 75

Examining biological and financial effectiveness of stump removal for controlling *Armillaria* root disease. 76

Michael P. Murray, David Huggard[2] 76

Economic analysis of sudden oak death and the impacts to local forestry 80

Sarah Navarro and Brandon Kaetzel[2] 80

Assessing and mitigating the effects of pests and diseases on forest carbon stocks in U.S. 82

Meg Dudley, Kurt Krapfl[1] 82

Panel: Special Papers 83

Post-harvest survivorship of endangered whitebark pine 84

Michael P. Murray 84

Panel: Genetics Talks 86

USDA Forest Service National Genetics Program 87

Arnaldo Ferreira ... 87

Lessons Learned from Successful Conifer Disease Resistance Breeding Programs in the Western United States 89

Richard A. Sniezko, Angelia Kegley[1] ... 89

Committee Reports ... 92

Dwarf Mistletoe Committee Meeting Notes ... 93

Chair: Brent Oblinger* ... 93

Foliar and Twig Committee Meeting notes ... 96

Chair: Adam Carson* (for Jared LeBoldus) ... 96

Nursery Committee Meeting Notes ... 98

Chair: Anna Leon* ... 98

Root Disease Committee Meeting ... 100

Chair: Patrick Bennett ... 100

Rust Committee Meeting Notes ... 103

Chair: Kelly Burns* (for Jane Stewart) ... 103

Climate Change Committee Meeting Notes ... 107

Chairs: Danny Norlander, Michael Murray[2], Susan Frankel[3], Alex Woods[4] ... 107

How do trees die? -The physiological mechanisms of tree mortality and their implications to forest ecosystem services. (Session: Climate Change) ... 108

Sanna Sevanto ... 108

Hazard Tree Committee Meeting Notes ... 112

Chair: Kristen Chadwick ... 112

Other Reports ... 115

2024 Student Awards Committee Report ... 116

Betsy Goodrich, Kelly Burns[2], Joey Hulbert[3] ... 116

... 116

Business Meeting Notes ... 117

Secretary: Adam Carson* ... 117

Treasurer's Report ... 120

Treasurer: Holly Kearns* ... 120

Outstanding Achievement Award Recipients ... 121

Outstanding Achievement Award Committee Members ... 123

Standing Committees and Chairs, 1994 - 2023 ... 124

Bylaws of the Western International Forest Disease Work Conference ... 125

Past Annual Meeting Locations and Officers, 1953—2023 ... 132

Group Photos ... 135

WIFDWC Members 138
Current WIFDWC Members 138
Honorary Members 142
Deceased Members 143

Conference Agenda

69th Western International Forest Disease Work
Hotel Santa Fe – Santa Fe, New Mexico
September 9-13, 2024

Monday, September 9

1300 – 1700: **Nature hike** (optional) Organizers: Greg Reynolds

Santa Fe National Forest. Exploring the Sangre de Cristo side of the National Forest and highlighting Douglas-fir dwarf mistletoe, aspen cankers, root diseases in mixed conifer stands, and defoliation by Douglas-fir tussock moth.

- Participants will need to bring their own food and water.
- Carpooling from Hotel Santa Fe will be required

1700 – 2100: **Registration**

Welcome social

Tuesday, September 10

0700 – 0830:	**Registration** (continued from Monday evening)		
0700 – 0830:	**Dwarf Mistletoe Committee** (breakfast)	Chair:	Brent Oblinger USFS Forest Health Protection
0845 – 0900:	**Welcome, Introductions, & Logistics**	Meeting Chair:	Lori Winton USFS Forest Health Protection
0900 – 1000:	**Keynote Address**		Jacob Pederson Resource Management Bureau Chief NMSF
1000 – 1015:	Break		
1015 – 1100:	**Grad Student Introductions and Flash-N-Dash**	Moderator:	Brad Lalande USFS Forest Health Protection
1100 – 1200:	**Grad Student Special Papers**	Moderator:	Brad Lalande USFS Forest Health Protection

1100 – 1130: **Jorda Kovash** – Department of Biology & Wildlife, Institute of Arctic Biology University of Alaska Fairbanks; Fairbanks, AK
A Bole Lotta Trouble: Changes in gene expression indicate aspensusceptibility to an emerging canker disease in Alaska.

1130 – 1200: **Ashley Miller** – Department of Agricultural Biology, Colorado State University; Ft. Collins, CO
Monitoring aerial spread of white pine blister rust across the U.S. Rocky Mountains

1200 – 1330:	**Foliage amd Twig Committee** (lunch)	Chair:	Adam Carson (for Jared LeBoldus) Oregon Sate University
1330 – 1500:	**Pannel: So You've Got an Invasive, Now What?**	Moderator:	Danny Norlander Oregon Department of Forestry

1330 – 1400: **Brian Tucker and Nai'a Odachi** – University of Hawaiʻi at Mānoa, Pacific Cooperative Studies Unit, University of Hawaiʻi at Hilo, Spatial Data Analysis & Visualization Research Lab
Remote sensing for rapid ʻŌhiʻa death: innovation for managing Hawaiʻi's native forest health Crisis..

1400 – 1430: **Ebba Peterson** – Department of Botany and Plant Pathology, Oregon State University; Corvallis, OR
Plant community composition and forest structure changes in response to Phytophthora ramorum (sudden oak death) invasion and eradication: introduction to the Oregon SOD Permanent Plot Network.

1430 – 1500: **Anna Schoettle** – USDA Forest Service, Rocky Mountain Research Station; Fort Collins, CO
Prioritizing management options to mitigate impacts to high-5 pine species by novel stressors.

1500 – 1530: Break

1530 – 1700: **Business Meeting** Chair: Lori Winton, USFS Forest Health Protection

1700 – 1900: Dinner (on your own)

1900 – 2100: **Poster session** Organizer: Patrick Bennett, USFS RMRS Research

Ice cream social Organizer: Local arrangements

Silent auction Organizer: Betsy Goodrich, USFS Forest Health Protection

Wednesday, September 11

0700 – 0830:	**Nursery Committee** (breakfast)	Chair:	Anna Leon Weyerhaeuser Company
0830 – 1700:	**Field trip** (lunch & snacks provided)	Organizer:	Greg Reynolds USFS Forest Health Protection
	0830 – 0900: Bus **loads**		
	0900 Bus **leaves**		
	1700 Bus **returns**		
1800 – 2000:	**Banquet & Outstanding Achievement Award – 2024**	Chair / Organizer:	Lori Winton Kristen Chadwick USFS Forest Health Protection
	1800 – 1830: Social		
	1830 – 1930 Banquet		
	1930 – 2000 *"What year was your first WIDFWC?"*		

Thursday, September 12

0700 – 0830:	**Root Disease Committee** (breakfast)	Chair:	Patrick Bennet USFS RMRS Research
0830 – 0845:	**Welcome Back and Round Up**	Meeting Chair:	Lori Winton USFS Forest Health Protection
0845 – 0945:	**Washington Office Presentation and Q&A**	Organizer	Bruce Molzen USFS National Pathologist
0945 – 1000:	Break		
1000 – 1200:	**Panel: Economics of Forest Pathology**	Moderator:	Danny Norlander Oregon Department of Forestry

1000 – 1040: **Michael Murray** – British Columbia Ministry of Lands and Natural Resource Operations; Nelson, BC, Canada
Biological and Cost-effectiveness of stump removal for controlling Armillaria root disease.

1040 – 1120: **Sarah Navarro, Brandon Kaetzel** – USDA Forest Service, Forest Health Protection, Portland, OR; Oregon Department of Forestry, Salem, OR
Economic analysis of sudden oak death and the impacts to local forestry.

1120 – 1200: **Meg Dudley** – ACR at Winrock International; Little Rock AR
Assessing and mitigating the effects of pests and diseases on forestcarbon stocks in U.S.

1200 – 1330:	**Rust Committee** (lunch)	Chair:	Jane Stewart Colorado State University
1330 – 1430:	**Special Papers**	Moderator:	Danny Norlander Oregon Department of Forestry

1330 – 1400: **Gary Chastagner** – Department of Plant Pathology, Puyallup Research and Extension Center, Washington State University; Puyallup, WA
Climate-Induced Stress and Root Diseases in PNW Christmas TreePlantations.

1400 – 1430: **Michael Murray** – British Columbia Ministry of Lands and Natural Resource Operations; Nelson, BC, Canada
Post-harvest survivorship of whitebark pine retention

1430 – 1530: **Panel: Genetics Talks** Moderator: Danny Norlander
Oregon Department of Forestry

1430 – 1500: **Arnaldo Ferreira** – USDA Forest Service National Genetics Program; Washington office
Forest Service Genetic Resources Programs on Disease ResistanceScreening and Breeding.

1500 – 1530: **Richard Sniezko** – USDA Forest Service, Dorena Genetic Resource Center, Cottage Grove, OR
Lessons Learned from Successful Conifer Disease Resistance BreedingPrograms in the Western United States

1530 – 1600: Break

1600 – 1730: **Climate Change & Disease Committee** Moderators: Michael Murray, Danny Norlander
BC Ministry of Lands; Oregon Department of Forestry

1600 – 1630: **Sanna Sevanto** – Earth and Environmental Sciences Division, Los Alamos National Laboratory; Santa Fe, NM
How do trees die? -The physiological mechanisms of tree mortality and their implications to forest ecosystem services.

Friday, September 12

0700 – 0830:	**Hazard Tree Committee** (breakfast)	Chair:	Kristen Chadwick USFS Forest Health Protection
0830 –0900:	**Welcome Back and Round Up**	Meeting Chair:	Lori Winton USFS Forest Health Protection
945 – 1000:	Break		
1000 - 1130:	**Santa Fe river walking tour**	Tour Guide:	Victor Lucero New Mexico Department of Energy, Minerals and Natural Resources
1145:	**Closing Comments and Adjourn**	Meeting Chair:	Lori Winton USFS Forest Health Protection

WIFDWC 2024 organizers

Planning Committee & officers

- *Meeting Chair*: **Lori Winton** – U.S. Forest Service, Forest Health Protection; Fairbanks, AK
- *Program Chair*: **Danny Norlander** – Oregon Department of Forestry; Salem, OR
- *Secretary*: **Adam Carson** – Oregon State University; Corvallis, OR
- *Treasurer*: **Holly Kearns** – U.S. Forest Service, Forest Health Protection; Sandy, OR
- *Web site*: **Danny Norlander** – Oregon Dept of Forestry, Forest Health; Salem, OR
- *Historian*: **Brennan Ferguson** – U.S. Forest Service, Forest Health Protection; Wenatchee, WA
- *Local arrangements*:

  Greg Reynolds – USDA Forest Service; Albuquerque, NM

  Nick Wilhelmi – USDA Forest Service; Flagstaff, AZ

Committee chairs

- *Climate Change & Disease Committee:*

  Michael Murray – British Columbia Ministry of Forests; Nelson, BC

  Danny Norlander – Oregon Dept of Forestry, Forest Health; Salem, OR
- *Dwarf Mistletoe Committee:*

  Brent Oblinger – U.S. Forest Service; Bend, OR
- *Foliage & Twig Committee:*

  Adam Carson (standing in for Jared LeBoldus) – Oregon State University; Corvallis, OR
- *Hazard Tree Committee:*

  Kristen Chadwick – U.S. Forest Service, Forest Health Protection; Sandy, OR
- *Nursery Committee:*

  Anna Leon – Forest Pathologist, Weyerhaeuser Company; Centralia, WA
- *Root Disease Committee:*

  Patrick Bennette – U.S. Forest Service; Moscow, ID R
- *Rust Committee:*

  Jane Stewart – Colorado State University, Dept of Agricultural Biology; Fort Collins, CO

Award & meeting-event coordinators

- *Student Travel Awards*: **Betsy Goodrich** – U.S. Forest Service, Forest Health Protection; Wenatchee, WA
- *Graduate Student Flash-n-Dash*: **Brad Lalande** – U.S. Forest Service, Forest Health Protection; Boise, ID
- *Outstanding Achievement Award Committee*:

  Kristen Chadwick – U.S. Forest Service, Forest Health Protection; Sandy, OR

  Jane Stewart – Colorado State University, Dept of Agricultural Biology; Fort Collins, CO

  Alex Woods – British Columbia Public Service; Smithers, BC
- *Poster session*: **Patrick Bennett** – U.S. Forest Service, Rocky Mountain Research Station; Moscow, ID
- *Silent auction*: **Betsy Goodrich** – U.S. Forest Service, Forest Health Protection; Wenatchee, WA

Welcome

Attendees gathering in the main room (photo: Adam Carson)

Keynote Address, 2024 Western International Forest disease Work Conference

Jacob Pederson[1]

Keynote Summary

- Jacob Pederson welcomed workshop attendees, and spoke about unique historical, geographic, cultural, and climatic context related to managing forest health in New Mexico.
- Resource management decisions on forest health in New Mexico are closely entwined with the wildfire crisis.
- The 2022 Hermit Peak-Calf Canyon, the largest wildfire in New Mexico History, and the South Fork-Salt Fires in Ruidoso in 2024 have tested state resources and prompted rapid development of post fire programs, funding, and interagency coordination.
- As the state, tribes, federal agencies, and local governments struggle to keep up with mounting disasters and forest health needs, partnerships that help resource managers keep up to date on best management practices, monitoring techniques, and best science are ever more critical.
- Examples of efforts that the New Mexico Forestry Division have pursued include:
    - A partnership with the US Climate Alliance, the University of New Mexico, and the University of Maryland to establish baseline data for above ground biomass in New Mexico through a NASA Carbon Monitoring System prototype. This work was completed in 2024, and future phases of this project are being designed to identify tree mortality associated with forest diseases statewide on an annual basis using satellite-based LiDAR systems and an enhanced CMS.
    - The New Mexico Shared Stewardship Portal (NMSSP.org) is an open resource where resource managers across the state can actively plan projects and enter activities, with integrations to Forest Service projects and the New Mexico Vegetation Treatment Database.
    - Development of standards for modelling, monitoring, and managing “green islands,” or surviving stands of trees that have the potential to contribute to natural regeneration of forests following wildfire events.
- A lot of project work is happening across New Mexico, the Forestry Division invites participants in the Conference to reach out at any time to engage with our teams, share your work, access NMSSP.org data, and generally get involved with our efforts.

[1]EMNRD Forestry Division Resource Management Bureau Chief

Panel: Graduate Student Special Papers

Moderator: Brad Lalande

Graduate student attendees Michael McKee, Noah Lindeman, Grace Ganter, Ada Fitz Axen, Ashley Miller, Hanno Southam, Kellee Boyer, and Jorda Kovash gathering for a group shot (photo: Mee-Sook Kim)

A Bole Lotta Trouble: Changes in gene expression indicate aspen susceptibility to an emerging canker disease in alaska

Jorda Kovash[1*], Hannah Glesener[1], Tomás Engl[2], Loretta Winton[3], Roger Ruess[1], Mary Beth Leigh[1], and Ursel Schuette[1]

Interior Alaska is experiencing widespread mortality in trembling aspen (*Populus tremuloides*) one of only three deciduous tree species in the boreal forest, due to a rapidly spreading fungal pathogen, *Neodothiora populina*. In 2015, *N. populina* was identified as the causal agent of an aspen running canker that girdles the tree bole and often causes tree death within a single season (Figure 1; Ruess et al. 2021; Winton et al. 2022). Yet an assessment of the molecular mechanisms of aspen defense response remains preliminary and the ability of *N. populina* to cause such rapid infection in aspen remains poorly understood.

Figure 1. Aspen running canker on trembling aspen in Interior Alaska. The brown, necrotic tissue on the left side of the bole shows infection caused by *N. populina*, identifiable by the bright orange outline that marks the edge of the canker.

[1]University of Alaska Fairbanks, Department of Biology & Wildlife, Institute of Arctic Biology; Fairbanks, AK, USA
[2]University of Chemistry and Technology; Prague, Czech Republic
[3]USDA Forest Service, Alaska Region, Forest Health Protection; Fairbanks, AK, USA
*jkovash@alaska.edu

We used differential gene expression analyses (transcriptomics) to interpret changes in molecular function between healthy aspen and aspen infected with *N. populina.* Samples were collected from margin (face of canker) and green (visually healthy) woody tissues in infected trees as well as neighboring healthy trees. We found that infected aspen tissues demonstrated greater magnitudes of change and increased significance in upregulated genes compared to downregulated genes (Figure 2). Our analyses indicated gene expression changes in biochemical pathways associated with known aspen defense mechanisms, such as MAPK signaling and plant hormone signal transduction, as well as in pathways associated with regulatory processes, such as the circadian rhythm and carbon metabolism (Figure 3; Ullah et al. 2022; Zeng et al. 2023). Our results suggest a potential successful defense response due to an upregulation in salicylic acid biosynthesis. However, a potential weakness in defense may be indicated by the upregulation of negative regulators in the jasmonic acid plant hormone signal transduction pathway.

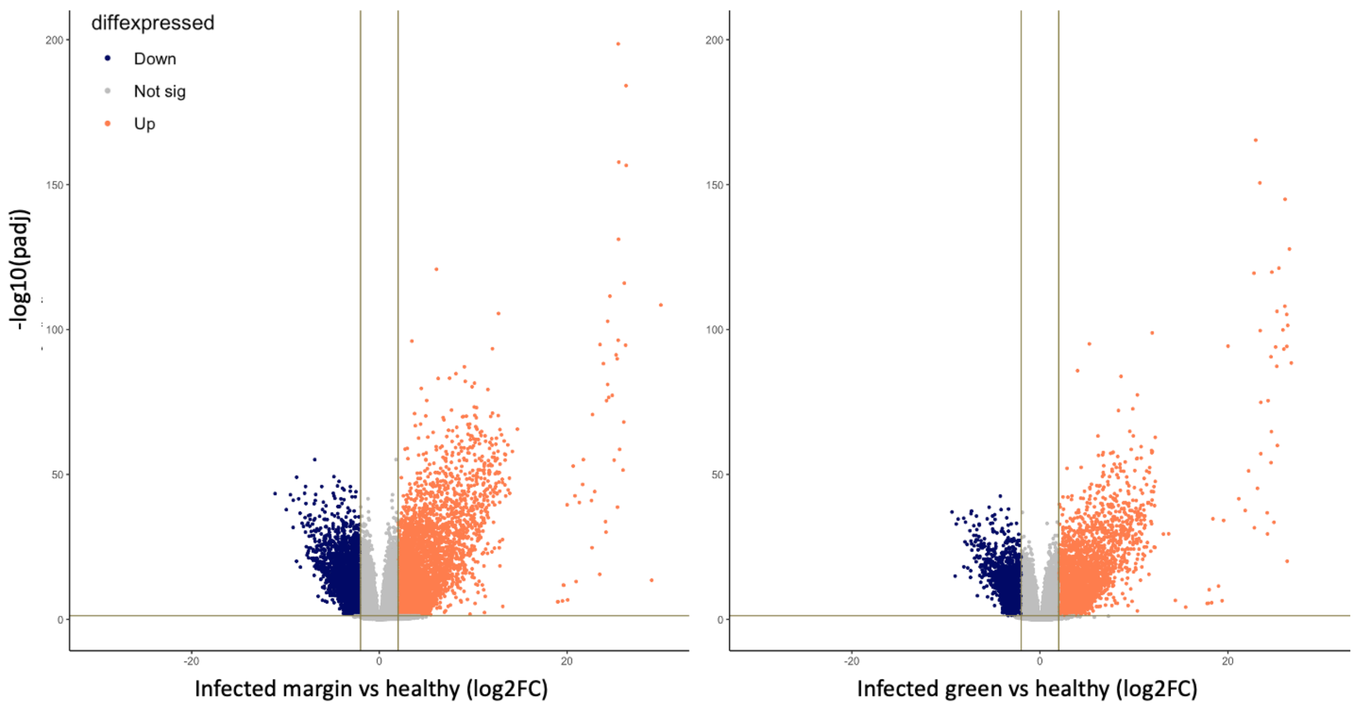

Figure 2. Volcano plots demonstrate greater magnitudes of change in significantly upregulated genes versus downregulated genes. The y-axis values represent adjusted p-values (padj) calculated to demonstrate gene significance across sample types. X-axis values show magnitude of gene change in log2 fold change. Upregulated differentially expressed genes have a greater range of significance and log2FC in margin (n = 18) and green (n = 20) infected tissue samples when compared to healthy (n = 21) samples. Blue represents downregulated genes identified by log2FC values < 2.0. Orange represents upregulated genes identified by log2FC values > 2.0. Differentially expressed genes have adjusted p-values < 0.05. Gray points indicate genes that are not significant.

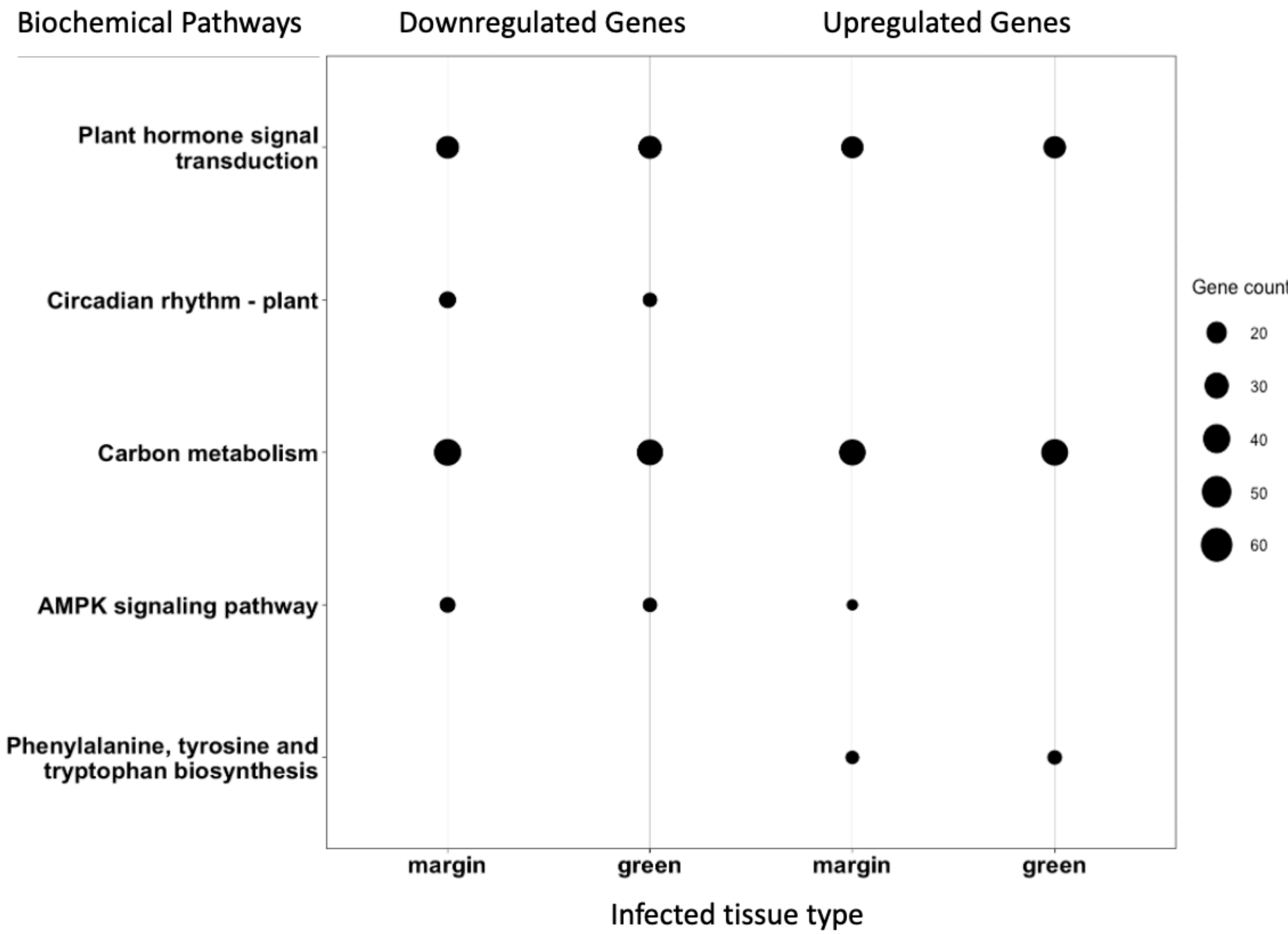

Figure 3. Biochemical pathways relevant to plant defense and regulatory processes are experiencing changes in gene expression. Pathway enrichment analysis compared groups of functional genes belonging to the same pathway; pathways that included above average gene expression were identified. Dot presence indicates pathway enrichment. Differentially expressed genes have a p-adjusted value < 0.05. Margin (n = 18) indicates samples collected from the face of aspen running canker infection and green (n = 20) indicates samples collected from visually healthy tissue in infected aspen. Gene annotations were made using BlastKOALA (https://www.kegg.jp/blastkoala).

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Monitoring Aerial spread of white pine blister rust across the U.S. Rocky Mountains

Ashley E. Miller[1], Kelly S. Burns[2], Bradley M. Lalande[3], Maria Newcomb[4], Daniel S. Ott[5], Gregory J. Reynolds[6], Nicholas P. Wilhelmi[7], Anna W. Schoettle[8], Jane E. Stewart[11]

White pine blister rust (WPBR) is a disease fatal to five-needle white pine trees caused by the invasive fungal pathogen *Cronartium ribicola*. Since the introduction of WPBR to North America in the early 1900's, it has caused widespread tree decline and mortality of white pines (Brar et al., 2015), notably affecting whitebark pine (*Pinus albicaulis*) (U.S. Fish and Wildlife Service, 2022; Schoettle et al., 2022). White pines hold great ecological significance as foundation and keystone species, particularly in mountainous, high-elevation regions, where they serve as a vital food source for wildlife and stabilize rocky slopes, preventing erosion (Resler & Tomback, 2008).

C. ribicola relies on aerial transmission and spores can travel viably for hundreds of miles. As the latent period of *C. ribicola* can span years, it is crucial to monitor for presence of aerial inoculum to predict disease establishment in naïve, albeit, at-risk forests, and for determining pathogen phenology in changing climates. The monitoring method in this study utilized spore traps to capture and characterize aerial *C. ribicola* spores. This work is part of a three-year project designed to monitor the aerial movement of *C. ribicola* with three primary objectives: (1) characterize the temporal patterns of aerial movement of *C. ribicola* spores across five western states, (2) analyze the environmental conditions associated with the presence and advancement of WPBR, and (3) associate aerial *C. ribicola* with phenological patterns of WPBR disease over time, providing insight into the roles of host species in contributing to aerial inoculum.

Field sites were established in 2022, 2023, and 2024 in Colorado, Wyoming, Utah, New Mexico, and Arizona in collaboration with the USDA Forest Service. Each site included three to four plots with a spore trap positioned in the center of each plot. The spore trap design was adapted from the design reported by Quesada and others (2018). To trap airborne spores, petroleum jelly was applied to glass microscope slides, and four slides were hung from a spinning motor. Slides were collected weekly from each trap and samples were processed to extract DNA. Quantitative PCR (qPCR) was used to assess *C. ribicola* DNA amounts within samples. Phenology data of all host species, such as bud burst and leaf senescence, was recorded weekly in each plot. The presence and progression of WPBR disease development was observed and quantified on all host species. Sample processing and data analysis is ongoing. Current efforts are focused on examining associations between the quantity of aerial *C. ribicola* spores and various factors, including weather conditions, host-species presence and abundance, phenology, spore production on host plants, and site characteristics such as slope, elevation, and tree density. Preliminary findings indicate that high quantities of aerial *C. ribicola* spores are associated with cool, wet conditions. Aerial *C. ribicola* collection occurred across four states (Colorado, Wyoming, New Mexico, and Arizona) and was present in large quantities at various times throughout the growing season. However, *C. ribicola* was not detected at the northern Utah site on Powder Mountain. On the landscape scale, a low but persistent aerial spore load was observed throughout the sampling campaign in 2023,

[1]Department of Agricultural Biology, Colorado State University, Ft. Collins, CO 80523 USA
[2]USDA Forest Service Region 2 Forest Health Protection, Lakewood, CO 80401 USA
[3]USDA Forest Service Region 2 Forest Health Protection, Gunnison, CO 81230 USA
[4]USDA Forest Service Region 1 Forest Health Protection, Missoula Field Office, Missoula, MT 59804 USA
[5]USDA Forest Service Region 4 Forest Health Protection, Ogden Field Office, Ogden, UT 84403 USA
[6]USDA Forest Service Region 3 Forest Health Protection, New Mexico Zone, Albuquerque, NM 87102 USA
[7]USDA Forest Service Region 3 Forest Health Protection, Arizona Zone, Flagstaff, AZ 86001, USA
[8]USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO 80526 USA

which spanned from May to October. Importantly, sampling site significantly influenced aerial *C. ribicola* DNA ($p < 0.05$). Notable variations in aerial spore load and timing were observed both between sites within the same year and at individual sites across different years, underscoring the critical role of local environmental conditions in *C. ribicola* sporulation and aerial dispersal. Furthermore, aerial *C. ribicola* DNA was detected at two sites near Flagstaff, AZ and Durango, CO in areas where no previous records of WPBR exist. These findings highlight the effectiveness of this monitoring method, not only for tracking spore dispersal but also as a valuable tool for the early detection of pathogens advancing along a disease front.

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Panel: So You've Got an Invasive, Now What? It's Here, It's There, It's Everywhere

Moderator: Danny Norlander

Nathan Schroeder, Restoration Division Manager (Santa Ana Pueblo Department of Natural Resources) addressing the group during the fieldtrip (photo: Adam Carson).

Remote sensing for rapid ʻŌhiʻA Death: innovation for managing hawaiʻi's native forest health crisis

Brian Tucker[1*], Nai'a Odachi[2*]

Ceratocystis lukuohia and *C. huliohia* are fungal species that cause Rapid ʻŌhiʻa Death (ROD) of Metrosideros polymorpha, Hawaiʻi's most abundant and ecologically important native species. Since ROD's discovery in 2014, over a million ʻōhiʻa trees across Hawaiʻi are estimated to have died due to the fungal pathogen. In response to this forest health crisis, the survey and monitoring of Hawaiʻi's forests has remained a top priority for our multi-agency, multidisciplinary ROD working group that consists of land managers and researchers. Monitoring methods such as biannual aerial surveys as well as remotely sensed imagery from a variety of platforms inform us about the continued persistence, severity and spread of the disease. Follow-up sampling of dead ʻōhiʻa is necessary to confirm disease presence. Each dataset has unique advantages and disadvantages, so we analyze multiple, overlapping datasets over time to gain a deeper understanding about the disease behavior. This information is then used to support management and research projects across the state.

High-resolution satellite imagery obtained with assistance from federal partners and funding from the National Geospatial Agency and National Reconnaissance Office has been used to expand monitoring and track ʻōhiʻa mortality over 304,817 hectares in East Hawaiʻi from 2013 to 2023. We compared these results with biannual helicopter-based digital mobile sketch mapping (DMSM) surveys from 2016 to 2023. Currently we are working to include imaging spectroscopy data collected via the Global Airborne Observatory (GAO) from 2016 to 2019 to the comparison. These datasets complement one another and broadly reaffirm observed mortality patterns. We are in the initial stages of creating an automated suspect identification system using Python-based DeepForest 1.3.2 which will identify outbreak areas and potentially infected trees from satellite imagery.

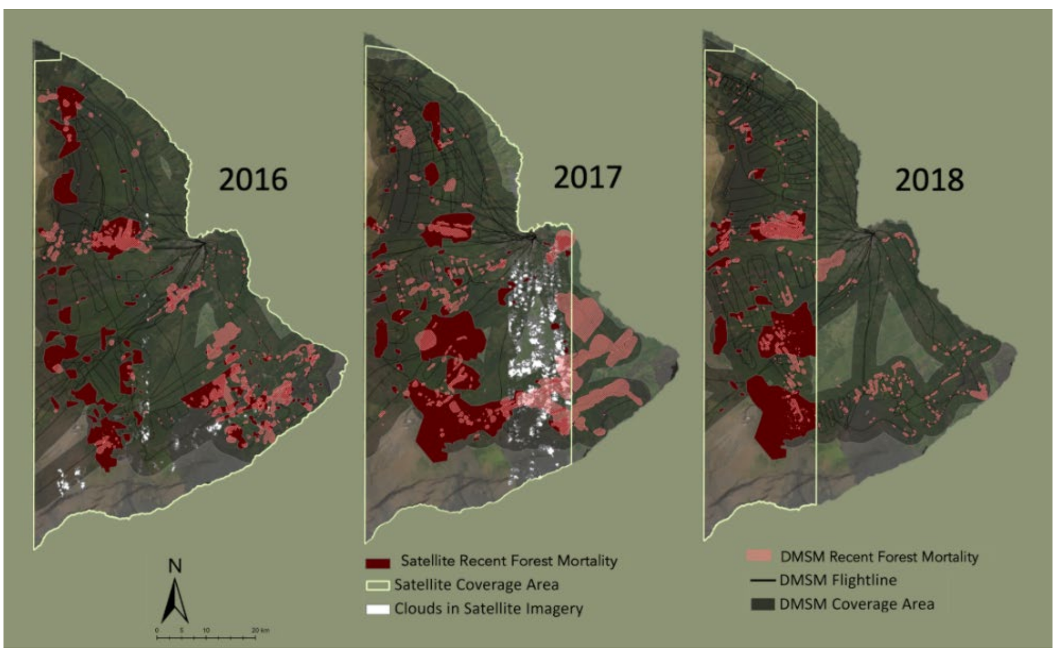

Figure 1. Time series map of East Hawai'i comparing mortality mapped from remote sensing of high-resolution satellite imagery and helicopter-cased digital mobile sketch mapping (DMSM) surveys.

[1]University of Hawaiʻi at Mānoa, Pacific Cooperative Studies Unit
[2]University of Hawaiʻi at Hilo, Spatial Data Analysis & Visualization Research Lab
*bjtucker@hawaii.edu and nodachi@hawaii.edu

Observations through survey and monitoring have resulted in several important findings, perhaps most notably that feral hooved animals play a critical role in the destructive impacts this disease has on Hawaiʻi's native forests. We find that there is significantly less mortality in areas that are fenced and managed for hooved animal removal. This is due to less wounding of ʻōhiʻa trees and less spread of infested beetle frass locally. We created a StoryMap about this, and the link is https://storymaps.arcgis.com/stories/7f7a2bfd3ed142218998a7326f6006be

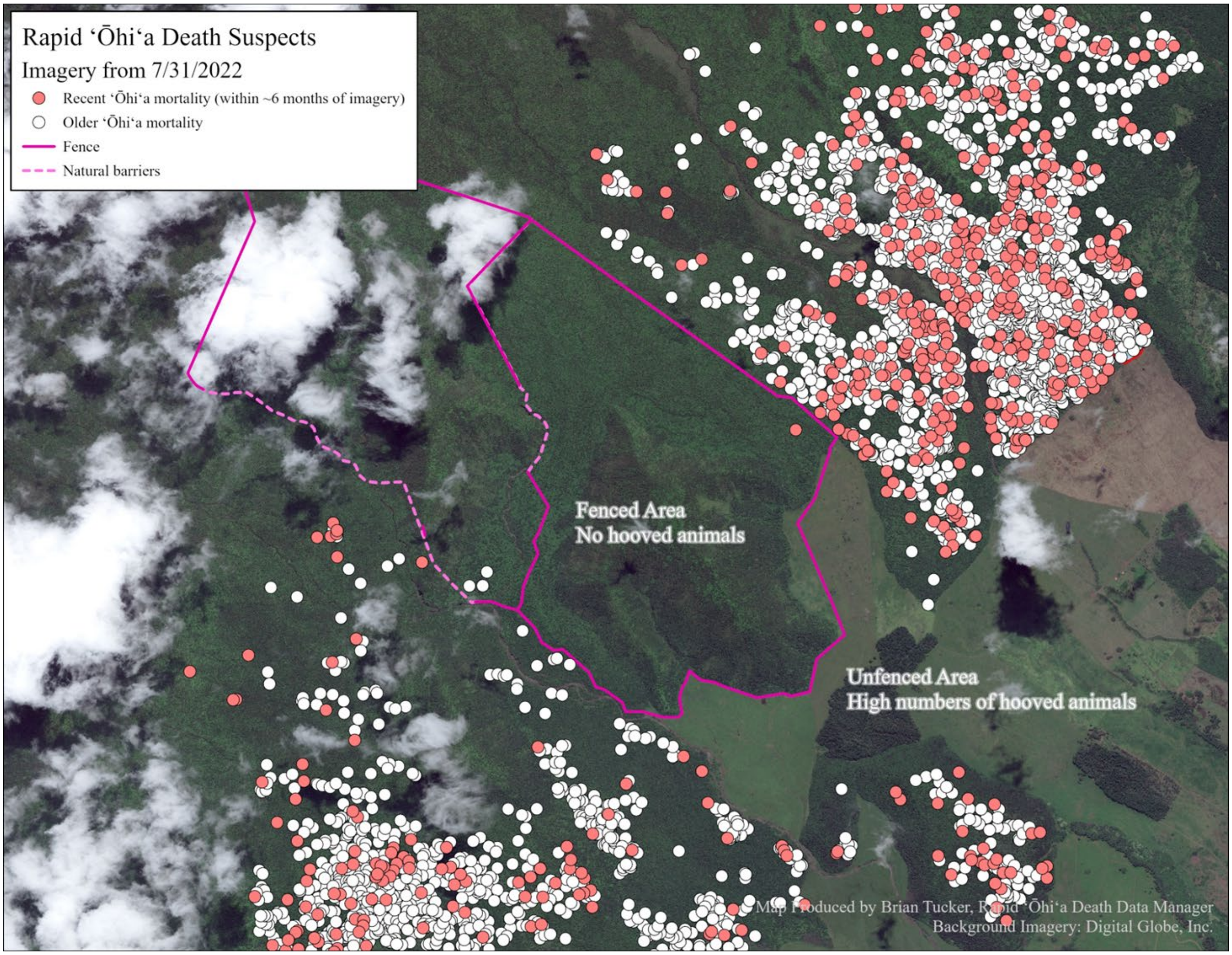

Figure 2. Map of ʻŌhiʻa mortality using high-resolution satellite imagery, comparing areas inside and outside of a fence unit managed for non-native, invasive hooved animal exlcusion.

Plant Community Composition and forest structure changes in response to *Phytophthora Ramorum* (sudden oak death) invasion and eradication: introduction to the Oregon SOD Permanent Plot Network

Ebba K. Peterson[1], Marie Tosa [1], Stephanie Chase[1], and Jared M. LeBoldus [1,2]

Over 20 years have passed since *Phytophthora ramorum* was first detected in Oregon. In response, the Oregon Department of Forestry and USDA Forest Service, with other Federal and private partners, mounted an eradication effort built on the early identification of new infection centers and rapid removal of the main overstory hosts. To date this has culminated in the removal of tanoak from over 3,500 ha of coastal forest. Despite some successes, *P. ramorum* continues to spread and treatments now focus on the leading edges of the epidemic. The invasion of forest pathogens, particularly those capable of removing dominant overstory species, can have cascading impacts on local biological communities as well as the region's ecosystem processes. These impacts likely differ depending upon the means by which trees are lost (i.e. SOD eradication vs. SOD mortality), which may have long-term ecological impacts.

To investigate the long-term effects of SOD, and notably SOD management, we established a monitoring plot network assessing forest and plant community structure within SOD-impacted areas. In total, 88 circular plots (each 500 m^2) were established, including 34 uninfested and untreated plots (untreated-negative), 35 plots in which *P. ramorum* was detected and eradication treatments were undertaken (treated; surveyed 3-15 years post-eradication), and 19 plots in which *P. ramorum* was detected and no eradication was performed (untreated-positive; surveyed 0-8 years since the first evidence of mortality). In each we performed a full forest inventory of all tree stems >1 cm diameter and tabulated total plant diversity and tree recruitment.

Tanoak and Douglas-fir were widely distributed throughout the plot network. Basal areas for these two species in untreated-negative plots comprised an average of 29.5 and 35.8 m^2/ha, respectively; in comparison, average basal area for the next most widely distributed tree species, red alder, comprised only 1.5 m^2/ha. As expected, tanoak rarely reached breast height within plots in early stages of treatment recovery (3-8 years post-eradication). Within treated plots, however, tanoak dominance was re-established roughly 10 years after eradication had taken place. This response was driven by sprouting, where stem densities were 3-4 times greater than that observed in any of the untreated plot classes. We observed increases in plot-level tanoak mortality 3-5 years after SOD-detection in untreated-positive plots, with some having as little as 20% of living tanoak stems remaining upon survey. However, the extent to which SOD eradication can serve as a proxy for SOD mortality remains unknown, particularly as these plots are in the early-stages of invasion. Vegetation and recruitment inventories indicate some similarities between treated and untreated-positive plots. For example, herbaceous species diversity was similar (elevated in comparison to untreated-negative plots), but we observed differences in tree recruitment.

Our intent is to resurvey these plots throughout time to inform future management decisions meant to control invasive forest species. Further investigations are assessing how these forest changes are impacting soil microbiome community structure, invertebrate diversity, bird and mammal usage of the plots. Fortunately, re-infection of tanoak within eradicated plots remains incredibly uncommon. Ideally eradication has contributed towards the re-establishment of tanoak within Oregon coastal forests, although repeated introductions of *P. ramorum* and further spread of established populations are a continuous threat.

[1] Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR, USA
[2] Department of Forest Engineering, Resources, and Management, Oregon State University, Corvallis, OR, USA

Prioritizing management options to mitigate impacts to high-5 pine species by novel stressors

Anna W. Schoettle[1*]

Introduction

High-elevation forests and alpine treelines in many western mountain ranges are often defined by the presence of high-elevation five-needle white pines (High-5). The High-5 may have a disproportionally large effect on ecosystem functioning and biodiversity relative to their abundance (i.e., serving as keystone species) and they often define ecosystem structure and functional dynamics (i.e., serving as foundation species). The loss of keystone and foundation species could destabilize ecosystems through loss of biodiversity and changing species interactions.

The High-5 species occurring in western North America are whitebark pine (*Pinus albicaulis* Engelm.), limber pine (*P. flexilis* James), southwestern white pine (*P. strobiformis* Engelm.; SW white pine), Rocky Mountain bristlecone pine (*P. aristata* Engelm.; RM bristlecone pine), Great Basin bristlecone pine (*P. longaeva* D.K. Bailey; GB bristlecone pine), and foxtail pine (*P. balfouriana* Grev. & Balf.). Tree mortality in High-5 forests over the past decades is attributed to the non-native pathogen *Cronartium ribicola* Fisch. which causes the often-lethal disease white pine blister rust (WPBR) and climate-driven increases in intensity and extent of mountain pine beetle (*Dendroctonus ponderosae* Hopkins; MPB) outbreaks, drought stress, and wildfire size, frequency, and severity (Figure 1).

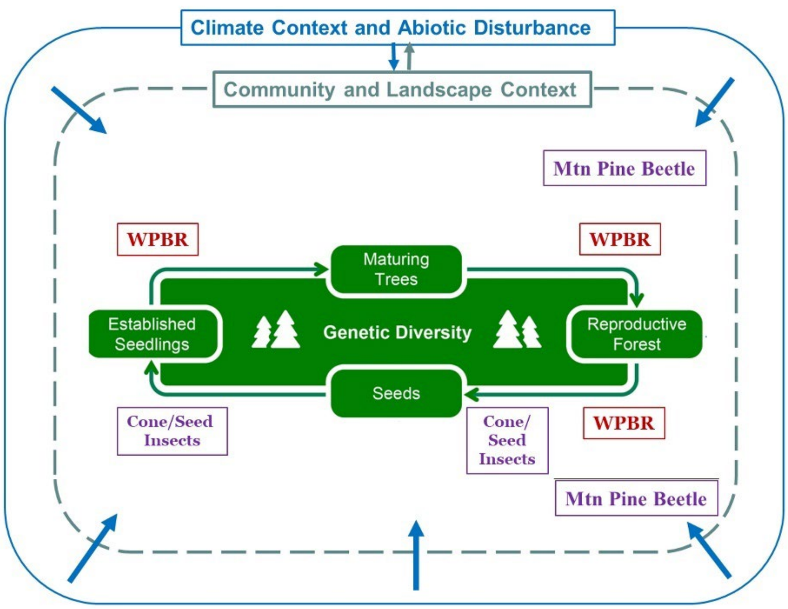

Figure 1. Biotic and abiotic stressors affecting the High-5 life cycle. Genetic diversity and High-5 generation time (i.e., time for one revolution of the life stages – green inner portion of the diagram) are foundations for population viability. Specific biotic stressors may affect only one life-history stage while others impact all age or size cohorts. The community and landscape context can affect the prevalence of a stressor. Climate affects every aspect of the ecosystem and its components, directly or through the community and landscape context. See Schoettle et al. (2022a) for a detailed discussion of climate change interactions with each stressor. (Adapted from Schoettle et al., 2022a)

[1] USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO 80526
* Anna.Schoettle@USDA.gov

Whitebark pine stands have more dead than live trees for all but the smallest diameter class, although this varies regionally. Limber pine is showing similar but lagging trends in mortality in the U.S. compared to whitebark pine (Goeking and Windmuller-Campione, 2021). In December 2022, Whitebark pine was listed as Threatened under the U.S. Endangered Species Act. Whitebark pine is listed as endangered nationally in Canada and limber pine is proposed for endangered listing under the Canadian Species at Risk Act. Mortality of the other High-5 species in the U.S. is lower than that of whitebark pine or limber pine (Goeking and Windmuller-Campione, 2021) and will likely rise with greater exposure to stressors and disturbances. While all the High-5 are being impacted only whitebark pine has a National US program supporting restoration efforts.

The primary objective in managing the High-5 species is to ensure the persistence of viable populations capable of retaining their evolutionary potential. The concept of Minimum Viable Population (MVP), defined as the smallest population size required to avoid an unacceptably high probability of extinction, offers a valuable framework for restoration planning (Jenkins et al., 2022). However, MVP thresholds have yet to be estimated for any of the High-5 species and are likely to vary across species and habitat types. Without precise MVP thresholds, we operationally define an evolutionarily stable population as one that can sustain sufficient genetic diversity over time to support adaptive potential and long-term resilience. For detailed discussions, refer to Jenkins et al. (2022).

One determinant affecting the size of an evolutionarily stable population is the adaptive capacity of the species. Therefore, management that can accelerate adaptation to stressors while maintaining viable populations can help achieve the overarching management goal. In 2022, I and others published an evaluation of the adaptive capacity and future trajectory of each of the High-5 pine species (Schoettle et al., 2022a). The WIFDWC presentation at the 2024 conference was an update of the state of the science related to that analysis. Here, I'll summarize the species-specific vulnerabilities to infer trajectories and how this information can be used to prioritize management options to provide a pathway for adaptation to mitigate impacts to each of the High-5 species. Refer to Schoettle et al. (2022a) for the more detailed analysis and for the references for statements within this summary. More recent papers that were not included in the 2022 publication are referenced herein.

Components and treatments to promote adaptation

Key information needed to make decisions to facilitate adaptation to WPBR in the pines include: (1) current and projected condition and population decline; (2) the frequency and durability of genetic resistance to WPBR; (3) rates of natural regeneration and conditions that affect population recovery; (4) genetic diversity and viable population size for evolutionary potential; and (5) the intensity of other mortality factors and their interactions. A conceptualization of how these factors interplay in the three phases of adaptation is shown in Figure 2. During the first phase, less adapted individuals are selected against by the change in the biotic or abiotic environment, leading to mortality and population decline (dark red line). In the second phase, population growth offsets mortality stabilizing the population at a low size. For the duration of the time the population is at the minimum (dark red line below the black horizontal line), the population is at high risk for extirpation by stochastic mortality factors (pink dashed line). Sexual reproduction provides individuals with new combinations of adaptive genes on which selection can continue to act, resulting in an increase in the allele frequency of these genes and associated adapted phenotypes in the population (blue line). If extirpation is avoided, the population enters the third phase when less adapted individuals are increasingly rare, and establishment of adapted individuals dominates; the population is recovering and continues to adapt to the stress by an increase in the adaptive allele frequency that increases fitness under the new environment.

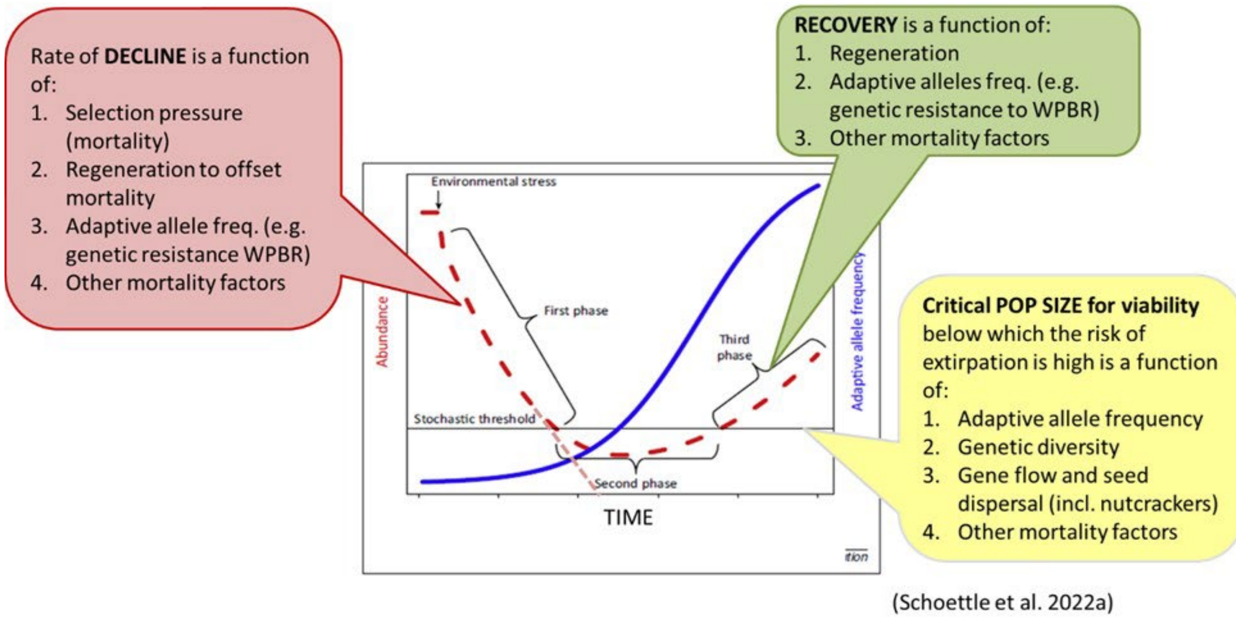

Figure 2. Conceptual representation of the three phases of adaptation to a novel stressor as they affect population abundance and adaptive allele frequency. (Adapted from Schoettle et al., 2022a)

Effective forest management requires prioritization of when, where, and how to implement interventions to sustain viable populations and preserve ecological functions. Proactive management actions need not be delayed until significant impacts are evident. Implementing measures before large-scale mortality occurs can better prepare the landscape to follow a trajectory that supports long-term population viability and ecosystem resilience. Moreover, the effectiveness of management actions may diminish if populations have already experienced significant declines, underscoring the importance of early intervention. The prioritization of specific actions is context-dependent, varying with species, habitat conditions, and ecological objectives. Furthermore, trade-offs associated with different management treatments will vary not only among species but also within species across diverse ecological contexts. By tailoring actions to these nuanced differences, managers can optimize outcomes, balancing immediate needs with long-term sustainability.

Figure 3 is a flow diagram of the forest regeneration cycle (green arrows) showing intervention options (blue arrows) to increase the population size, genetic resistance to white pine blister rust, and contribute to host population adaptative capacity and sustainability. Maintaining all compartments of the regeneration cycle and their connections is essential for multigenerational population persistence and to provide individuals with genetic combinations on which natural selection can act for species adaptation. In a functioning forest, overstory densities in the reproductive forest need to be sufficient to support seed production and natural regeneration yet structured to maintain the vigor of the established seedlings to enable recruitment into the overstory in a reasonable amount of time. On a landscape basis, however, natural regeneration or planting can be accomplished outside the forest in nearby canopy openings to develop a mosaic of areas of different age classes. The lower arrows in Figure 3 depict an intervention to stimulate natural regeneration in a healthy High-5 population that contained genetic resistance to increase the number of individuals and the genetic combinations to accelerate natural selection for genetic resistance and increase the frequency of genetic resistance in the population in the presence of white pine blister rust. The upper arrows depict interventions that can be implemented in forests where the regeneration cycle is intact (proactive) or impaired (restoration) to increase or restore population size and introduce seedlings with genetic resistance into the population to accelerate adaptation.

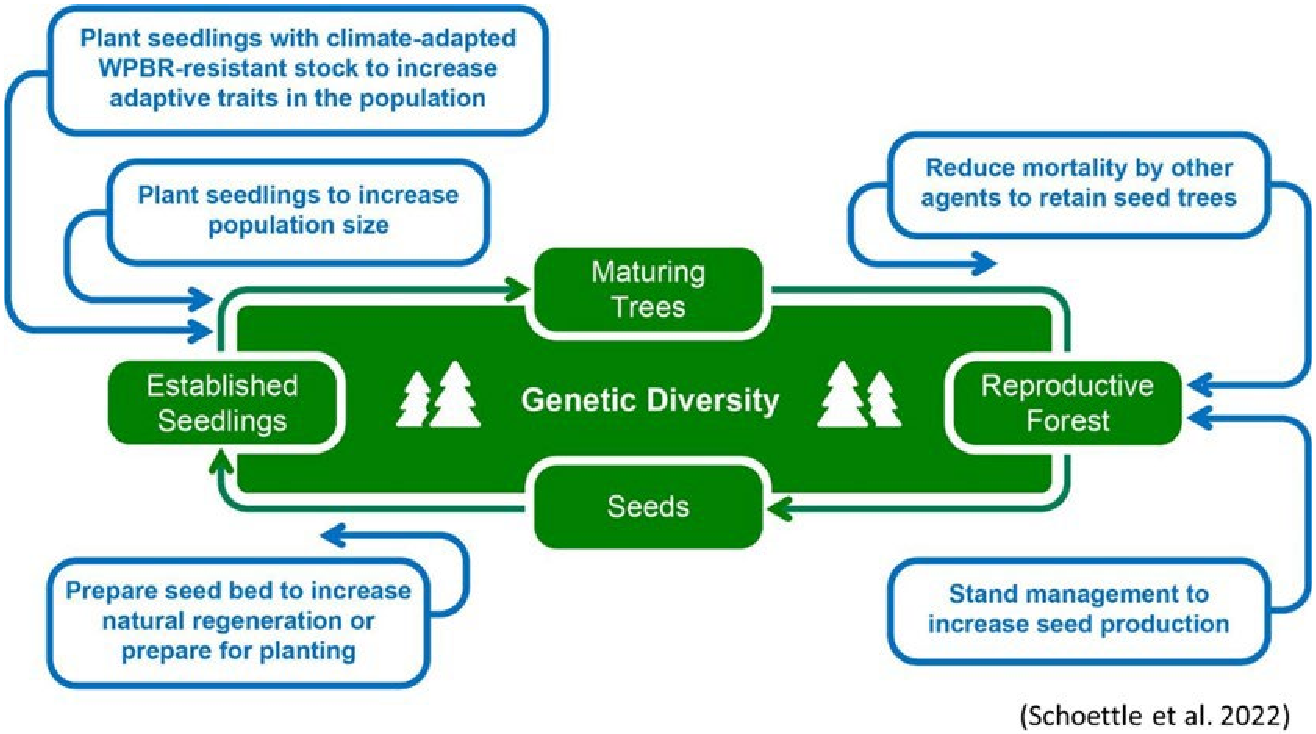

Figure 3. A schematic of the objectives for management. (Schoettle et al. 2022a Suppl. Material)

High-5 Species Traits

Applying an evolutionary perspective to evaluate the trajectory for each of the High-5 has revealed differences among the species that can help focus research and management attention on the critical vulnerabilities of each species (Table 1). Estimating trajectories involved two steps: a review of the biotic and abiotic stressors that threaten each of the High-5, and specific components of population vulnerability, resilience, and adaptive capacity. The strong selection pressure of WPBR alone is formidable, and adaptation to WPBR is imperative to sustain or restore future self-sustaining viable High-5 populations as the pathogen continues to spread. This challenge is further complicated by pressure from other mortality factors, most notably drought, MPB, and wildfire that are at risk of increasing in a warming climate.

High-5 Pine Species 4	Primary Stressors			Adaptive Capacity	
	WPBR susceptibility[1]	Drought sensitivity	MPB Susceptibility	Regeneration Potential	Genetic Diversity
Whitebark	High	High	Very High	Moderate[3]	Moderate
Limber	Very High[2]	Low	Very High	Moderate[3]	Moderate
SW white	High	Moderate	Moderate	High	Moderate
RM bristlecone	Moderate	Moderate	Low	Low	Very Low
GB bristlecone	Moderate[2]	Moderate	Very Low	Very Low	Moderate
Foxtail - N	Very High[2]	Moderate	Low	High	Low
Foxtail - S	Very High[2]	Moderate	Low	Very Low	Low

1 Estimated ratings of baseline frequencies of quantitative resistance in naïve populations.
2 Estimated on limited data; range-wide information is lacking.
3 Currently reduced by WPBR mortality in some populations.
4 Note: There is within species variation in vulnerabilities and adaptive capacity
Schoettle et al. 2022

Table 1. Summary of some key components of adaptive capacity for the High-5 species. Estimated ratings are relative among these species and based on the best available, but incomplete, knowledge. (Schoettle et al., 2022a)

Adaptive Capacity of Each High-5 Species

Whitebark Pine

Whitebark pine is a keystone species integral to biodiversity and ecosystem function over much of its distribution. It has sustained high levels of mortality which have compromised the sustainability of many of its northern populations; southern locations are less impacted.

Key vulnerabilities for whitebark pine are its high susceptibilities to WPBR and MPB. Its delayed maturity and modest seed production also constrains adaptation and population recovery. Because of its broad distribution, strategic investments in management where it will be most effect is recommended (Jenkins et al., 2022; Tomback et al. 2022; Schoettle et al., 2022a, Keane et al., 2022).

The Crown of the Continent Restoration Strategy is a pioneering advancement in restoration planning for whitebark (Jenkins et al., 2022) and is a foundation for the Fish and Wildlife Service Recovery Plan. It highlights the need for the application of the concepts of viable population size, connectivity, and evolutionary potential to prioritize where, when, and how to implement management actions.

Recommendations include (1) both restoration of impacted areas and proactive approaches in areas still healthy to spread investment and risk; (2) plant with seedlings stock with WBPR resistance traits for population recovery to sustain or restore viable populations, (3) protect seed trees that have WPBR resistance from disturbances, and (4) reduce competition by other conifers to increase seed production and growth (and increase defenses to MPB).

Limber Pine

Limber pine is an important habitat generalist, playing more than one functional role in forest communities. It has a wide geographic, elevation, and climatic range that overlaps with most forest types in the western US. It has broad tolerances to abiotic stresses and may be increasingly important in western forests in the future in a changing climate.

Key vulnerabilities for limber pine are its extreme susceptibility to WPBR, MPB, and other bark beetles. Consequently, mortality is outpacing recruitment in the US Rockies (Burns et al., 2023) and limber pine is declining range-wide in the US (Goeking and Windmuller-Campione 2021). Trees growing in habitats with high vapor pressure deficit (more arid) are less likely to be infected with WPBR but if they are infected, they are more likely to develop severe symptoms and die. Likewise, trees growing in habitats with longer growing seasons have an increased likelihood of WPBR presence and mortality (Burns et al., 2023). This suggests that future climates may exacerbate disease impacts for limber pine. Climate-driven increases in bark beetle populations in limber pine also leads to mortality. The frequency of major gene resistance to WBPR are high in some areas but is vulnerable to being overcome by the recent find of a virulent race of *C. ribicola* (vcr4) in Alberta specific to the limber pine major gene (Liu et al., 2024). No evidence of the virulent race in the southern Rockies or US have been found. The more durable quantitative resistance traits are very rare in limber pine and their frequencies may be too low to sustain viable populations and support recovery without active management (Schoettle et al., 2022b). The low frequency of quantitative resistance to WPBR is a key vulnerability. Also, hybrids of *C. ribicola* x *C. comandrae* (*C. x flexili*) have been found on limber in Colorado and Wyoming with unknown effects on the epidemiology of either disease or disease resistance expression (Kozhar et al., 2024).

Limber pine is a species of conservation concern in several US jurisdictions including national parks, BLM lands, Crown of the Continent Ecosystem (CCE), and state and county lands. A proactive limber pine conservation strategy for the southern Rockies is published and being implemented in Rocky Mountain National Park and has provided guidance for other areas. The CCE Restoration Strategy has also been extended to include limber pine and is being implemented in the US and Canadian portions of the CCE and beyond. Alberta has also developed a recovery plan for limber pine.

Recommendations include (1) prioritize screening for quantitative resistance to WBPR to develop select seed sources for planting in both impacted and healthy stands (proactive) to increase resistance frequences and adaptive capacity, (2) increase range-wide seed collection and protect seed trees that have WPBR resistance from MPB, and (3) protect population size from tree removal in fuels treatments or impacts from MPB or fire.

Southwestern White Pine

Southwestern white pine is an important component of the mixed-conifer forests upslope from pure ponderosa pine but does not reach treeline elevations. In the U.S., its distribution is fragmented among the southwestern sky islands. Recently, genomic techniques have confirmed that hybridization between limber pine and SW white pine has generated a broad hybrid zone across the U.S. portion of the SW white pine’s range.

Currently, SW white pine forest health is in good condition. SW white pine does not have a key vulnerability but will still be experiencing increased mortality from the compounding impacts of multiple stressors. WPBR is still spreading in Arizona and New Mexico and has not yet been found in Mexico. The increase in the variation in the monsoon in the future suggests that SW white pine may be increasingly exposed to prolonged drought in the future. It has greater regeneration capacity and faster growth rates than the other High-5 species, has moderate frequencies of genetic resistance to WPBR, and exhibits drought tolerance traits. Compared with other High-5 species, SW white pine may have a higher probability of adapting and persisting in the landscape.

SW white pine is a species of significant management concern in the southwestern United States and Mexico, particularly within the context of future climates and its associated ecological shifts. A comprehensive understanding of mixed-conifer forest dynamics under changing climatic conditions is essential, considering the complex interactions among species and the likelihood of novel community assemblages emerging. Engaging forest managers across the species' range is a crucial step in developing adaptive management strategies that align with forest conservation goals while addressing the dual challenges of climate adaptation and the mitigation of damaging agents. Such collaborative efforts will enhance the resilience of mixed-conifer forests, ensuring the persistence of southwestern white pine and associated ecosystems.

Rocky Mountain Bristlecone Pine

RM bristlecone pine forests currently exhibit overall health, with only localized, low levels of insect and disease damage. However, WPBR, which has not yet reached most of the species' distribution, poses a significant emerging threat. RM bristlecone pine is highly susceptible to WPBR, and the disease is expected to expand across much of the five-needle pine habitat in Colorado, potentially becoming a primary driver of population decline. Climate projections further complicate the species’ future, as distribution models predict that RM bristlecone pine’s current climatic niche may vanish from the Rocky Mountain region entirely by 2090. However, sub-population models, reflecting distinct genetic lineages, offer slightly more optimistic scenarios. Additionally, drought, already a persistent stressor for the species, is expected to intensify under increasing climatic variability, compounding challenges to its long-term survival and ecosystem function.

The combination of low genetic diversity, moderate population isolation, and a protracted regeneration dynamic puts RM bristlecone pine populations at risk for extirpation. The species has moderate rust resistance frequences suggesting a pathway to adaptation if population sizes can remain large and genetically diverse enough to be viable.

Proactive management, before populations decline, to increase the abundance of younger cohorts with more diverse genetic combinations will improve RM bristlecone pine’s adaptive capacity. Moderate rust resistance frequences suggest bulked wild seed collections can serve as seed stock for planting immediately. It is recommended that mix seed sources from multiple habitats and populations be used for planting stock to increase genetic diversity. Preserving genetic diversity and sustaining or increasing population sizes are paramount for RM bristlecone pine to have evolutionary potential.

Great Basin Bristlecone Pine

Currently, GB bristlecone pine forests are in good condition. GB bristlecone pine has not yet been found to be infected with WPBR in its native habitat, although it is susceptible to the disease under controlled conditions (Schoettle et al., 2022b). Climate warming, drought, and fire are the main stressors facing GB bristlecone pine.

The episodic recruitment pattern of GB bristlecone pine represents a critical vulnerability that limits the species' capacity to sustain viable populations under increasing selection pressures. The most recent pulse of successful seedling establishment occurred between 1955 and 1978, driven by cumulative climatic conditions rather than single-year events. This infrequent regeneration is reflected in the species' flat age-class structure across its range (Goeking and Windmuller-Campione, 2021), underscoring that populations rely on exceptional tree longevity rather than regular turnover for persistence. However, turnover-driven recruitment is essential for rapid adaptation, placing the species at significant risk in the face of accelerating environmental changes.

While species-specific management plans for GB bristlecone pine are lacking, the principles of proactive management are well-suited for addressing its vulnerabilities. A top priority is the proactive planting of seedlings to diversify age-class structures and increase population size, thereby enhancing resilience. The species' moderate resistance to WPBR and genetic diversity suggests that bulked seed lots, whether local or mixed, can serve as effective planting stock. Additionally, GB bristlecone pine is highly susceptible to population losses from fires originating in drought-stressed montane forests, emphasizing the urgency of proactive seed collections for long-term conservation and restoration efforts. These strategies are critical to maintaining the viability of this iconic and ecologically significant species under future environmental challenges.

Foxtail Pine

Foxtail pine has the most restricted distribution among the High-5 species, occurring in two disjunct regions: the Klamath Range in northern California and the southern Sierra Nevada, separated by approximately 500 km. These two populations differ markedly in their structure, composition, and diversity. In the Klamath Range, foxtail pine dominates isolated peaks but often exists within mixed subalpine forest communities. In contrast, the southern Sierra Nevada populations typically form extensive, low-diversity stands, occasionally co-occurring with whitebark pine and limber pine.

Like Great Basin bristlecone pine, the southern populations of foxtail pine exhibit infrequent regeneration and recruitment events, relying on tree longevity rather than population turnover to sustain populations. This episodic recruitment pattern impedes rapid recovery from mortality events and slows adaptation to direct stressors. Northern populations, however, are currently experiencing mortality due to WPBR. A major vulnerability across both northern and southern populations is their very low frequencies of genetic resistance to WPBR, further threatening long-term population viability.

To mitigate these threats, Schoettle et al. (2022a) recommend targeted management interventions. In the northern populations, the supplementation of seedlings is critical to offset past, ongoing, and anticipated mortality, ensuring that viable population sizes are maintained. For the southern populations, proactive planting of seedlings can diversify age-class structures and enhance adaptive potential to a range of stressors. Once WPBR-resistant seed sources are identified, aggressive planting campaigns can be implemented to establish young, resilient cohorts and increase the frequency of resistance within both northern and southern populations. These actions will help safeguard the future of foxtail pine under escalating environmental and biotic pressures.

Summary

The goal of intervention is to position or restore the populations to be self-sustaining and retain evolutionary potential. Management can reduce and slow population decline by maintaining genetic diversity and increasing population size via planting to keep population sizes above a critical minimum to support population recovery with adapted individuals (see Figure 2). Each of the High-5 species share vulnerabilities to the same stressors but they differ in their susceptibilities and life-history traits that affect their adaptive capacity (See Table 1). While the suite of management options is similar among species, the probability of their success and therefore their priority for implementation varies among species and current forest health condition.

Additional recommendations include encouraging managers to (1) retain High-5 trees when possible when doing other management (fuel treatments, thinnings, timber harvests, etc.), (2) collect High-5 seed for WPBR resistance testing and for planting and genetic conservation, (3) include High-5 seedlings in planting mixes for other subalpine projects for climate adaptation and to get more High-5 individuals on the landscape (e.g. restoration projects after spruce beetle outbreak or fire), (4) help articulate the need and utility of further WPBR resistance testing of all the High-5 species, (5) recognize that the threats challenge all the High-5 species, and (6) understand that there are priority actions that can be taken immediately that would benefit each of the High-5 species. Refer to Schoettle et al. (2022a) for further information on the current forest health condition, adaptive capacity, and management recommendations for each High-5 species.

Conclusions

The evolutionary approach applied here in an ecological context can be useful to organize and integrate information to develop management tools and priorities. It can help to prioritize treatments on the stage of invasion, forest condition, and species vulnerabilities and traits to increase the probability of treatment success. This approach can be applied to other populations being challenged by non-native species or threats that cause directional change. The cumulative and compounding effects of multiple stressors on forest ecosystems are necessitating the need to support collaborations to rapidly gain information from research and active management. Co-production of knowledge between managers, forest health professionals, and researchers will be increasing important to gain timely information to mitigate impacts to our forests.

Note: The findings and conclusions in this report are those of the author and should not be construed to represent any official USDA or U.S. Government determination or policy

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Posters

Moderators: Betsy Goodrich and Patrick Bennet

Robert Parmenter, Research Scientist (Valles Caldera National Preserve) discussing the history of the Valles Caldera during the fieldtrip. (photo: Chrissy McTavish)

Quantifying aerial inoculum densities and spore deposition rates of *Heterobasidion irregulare* in ponderosa pine forests of the northwestern United States

Patrick I. Bennett[1], I. Blakey Lockman[2], Brennan Ferguson[3], Betsy A. Goodrich[3], Dan Omdal[4], Rachel Brooks[4], Jill Hautaniemi[5], Holly S. J. Kearns[6], Matteo Garbelotto[7]

Introduction

Heterobasidion irregulare causes growth loss, mortality, and reduced carbon sequestration in ponderosa pine forests across the Pacific and Inland Northwest. Freshly cut stumps represent the primary infection court for airborne spores of *H. irregulare* and vegetative spread occurs through root contacts. Thus, disease incidence is related to prior stand management. Its persistence on infested sites creates challenges for managing ponderosa pine. The risk of *H. irregulare* infection varies according to stump size, inoculum abundance, and other factors. Previous studies suggest that a spore deposition rate (DR) of 5 spores m^{-2} hr^{-1} is sufficient to initiate infection and DR exceeding 10 spores m^{-2} hr^{-1} at the time of harvest significantly increases the risk of disease (Bérubé et al., 2017; Gonthier et al., 2005). Spore-initiated infections can be reduced or prevented by spraying the surfaces of freshly cut stumps with products containing inhibitory compounds such as disodium octaborate tetrahydrate (DOT) shortly after harvest. A biological control treatment that involves application of a competing fungus, *Phlebiopsis gigantea*, is available in the eastern U.S. and Canada and a formulation with native strains from the western U.S. is currently under development (Dovana et al., 2021; Poloni et al., 2021). These treatments are effective, but their application can add to the financial cost and logistical complexity of timber harvest operations. Assessments of spatial and temporal variation in inoculum availability would allow land managers to determine the relative risk of *H. irregulare* infection and could guide the efficient application of preventive chemical and silvicultural treatments for Heterobasidion root disease.

Objectives

The objectives of this study are to 1) develop protocols for collecting airborne spores of *H. irregulare* with mechanical spore traps and quantifying aerial inoculum using quantitative real-time polymerase chain reaction (qPCR); 2) compare molecular detection methods to the wood disk exposure method for estimating deposition rates of *H. irregulare*; 3) use estimates of aerial inoculum density (AID) and DR to assess infection risk in ponderosa pine stands.

Methods

Aerial inoculum sampling was conducted in south-central Washington in October 2022 and October 2023. Two transects were established in each of two ponderosa pine stands (HB2 and HB5) near Glenwood, WA where the presence of *H. irregulare* had previously been observed. One transect was installed in a dry lakebed approx. 500 m from the forest edge at the Conboy Lake National Wildlife Refuge, which allowed us to assess the background levels of aerial inoculum in the area and to infer the dispersal capabilities of *H. irregulare*.

Airborne spores were collected in transects using rotating-arm spore impaction devices (rotorods) and AID (spores m^{-3} h^{-1}) was quantified via real-time PCR (qPCR) (Lamarche et al., 2016). Ponderosa pine wood disks located in the

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[1] USDA Forest Service, Rocky Mountain Research Station, Moscow, ID, USA
[2] USDA Forest Service, Forest Health Protection, Pacific Northwest Region, Portland, OR, USA (Retired)
[3] USDA Forest Service, Forest Health Protection, Pacific Northwest Region, Wenatchee, WA, USA
[4] Washington Department of Natural Resources, Olympia, WA, USA
[5] USDA Forest Service, State, Private, and Tribal Forestry, Forest Health Protection, Northern Region, Missoula, MT, USA
[6] USDA Forest Service, State, Private, and Tribal Forestry, Forest Health Protection, Pacific Northwest Region, Sandy, OR, USA
[7] Department of Environmental Science, Policy, & Management, University of California, Berkeley, CA, USA

same transects were exposed to the open air for either 4 h, 24 h, or 72 h to determine optimal exposure times for these locations. Following exposure, wood disks were incubated for 7-10 days in the lab. Colonies of the conidial stage of *H. irregulare* were counted on each wood disk, with each colony representing one viable spore. Isolates were also sub-cultured from disks and identified via standard PCR with taxon-specific primers (Shamoun et al., 2019). The proportions of colonies identified as *H. irregulare* on each disk were used to calculate DR (spores m^{-2} h^{-1}).

Results and Conclusions

Estimates of AID and DR were higher in ponderosa pine sites than at the dry lakebed site (Fig. 1, Fig. 2), likely due to proximity to inoculum sources and relatively limited dispersal capabilities of *H. irregulare*. Average DR values in these ponderosa pine stands were sufficient for new infections to occur and exceeded threshold values established in previous studies indicating high risk of infection (Bérubé et al., 2017; Gonthier et al., 2005). There was some inter-annual variation in the estimates of AID and DR (Fig. 1, Fig. 2) that was likely due to differences in weather during the time of sampling. Sampling in 2022 followed a prolonged dry period, while 2023 was during a period of higher precipitation. Rain during the 2023 sampling negatively affected the wood disk exposure assay. Very few colonies grew on disks exposed while it was raining and these data were not included in the analyses. Estimates of DR from 2023 were calculated from disks exposed for 4 h preceding heavy rains, and those exposed for 24 h after the heavy rains subsided. The rotorod sampling appeared to be less affected by rain, as estimates of AID from the mechanical spore traps were similar between 2022 and 2023 (Fig. 1). Our results suggested that 24 h was the optimal exposure time for the wood disk deposition assays. While estimates could be obtained with exposure time of only 4 h in stands where disease incidence was high, this would likely not be sufficient in areas with lower disease incidence. The 72 h exposure time resulted in saturation of the disks, making it difficult to accurately count colonies.

We expected AID and DR to be directly related. However, there was some evidence to suggest that stand structure and/or environmental conditions influenced the relationship between AID and DR. For instance, in 2022, ponderosa pine site HB5 had greater AID than HB2 but lower DR than HB2 (Fig. 1, Fig. 2), suggesting that there were more spores in the air at HB5 but fewer spores were depositing and/or germinating on the surfaces of the wood disks. One possible explanation for this could be the difference in stand structure between these two sites, as HB5 had an open canopy with few overstory trees, while HB2 was a relatively dense ponderosa pine stand. Exposure to wind and/or UV radiation at HB5 may have caused the disks to dry out during exposure or may have affected deposition and/or germination rates of spores on the wood disks. This information will be useful for developing protocols for future surveys and monitoring.

Both *H. irregulare* and *H. occidentale* were present in the area where spore sampling was conducted, and the relative proportion of each species recovered from wood disks varied between the ponderosa pine stands the dry lakebed site (Fig. 3). This highlights the importance of using DNA-based identification methods for colonies from wood disks when sampling in locations where both species are known or suspected to co-occur. Without this information, the DR of *H. irregulare* would have been overestimated substantially.

When comparing the relative utility of the mechanical spore traps and the wood disk deposition assay, it is important to consider that the estimation of DR by counting colonies on wood disks reflects the quantity of viable *H. irregulare* spores that are capable of colonizing host tissues and potentially causing disease. The estimates of AID obtained from mechanical spore trapping and qPCR methods reflect the density of all *H. irregulare* spores in the air (both viable and inviable). Observing the relationship between AID and DR may allow for more accurate assessment of disease risk in ponderosa pine stands.

The estimation of AID by qPCR on spore samples collected with mechanical traps has some advantages over the use of the wood disk deposition assay. Quantification of aerial inoculum and assessments of relative disease risk can be accomplished much more quickly using the qPCR methods and this method detects and quantifies DNA of *H. irregulare* specifically. It is much less labor intensive because it does not require counting colonies and subculturing. It also appears to be more robust to the influences of inclement weather. However, the qPCR assay requires the use of specialized laboratory techniques and equipment operated by trained laboratory staff and this method does not distinguish viable spores from inviable spores. Future studies should evaluate the utility of the mechanical spore traps for long-term monitoring of spatial and temporal variation in AID across a wider network of plots.

Protocols outlining the use of these tools for monitoring AID in ponderosa pine forests, as well as a peer-reviewed publication detailing the results of 2022, 2023, and 2024 field studies are forthcoming.

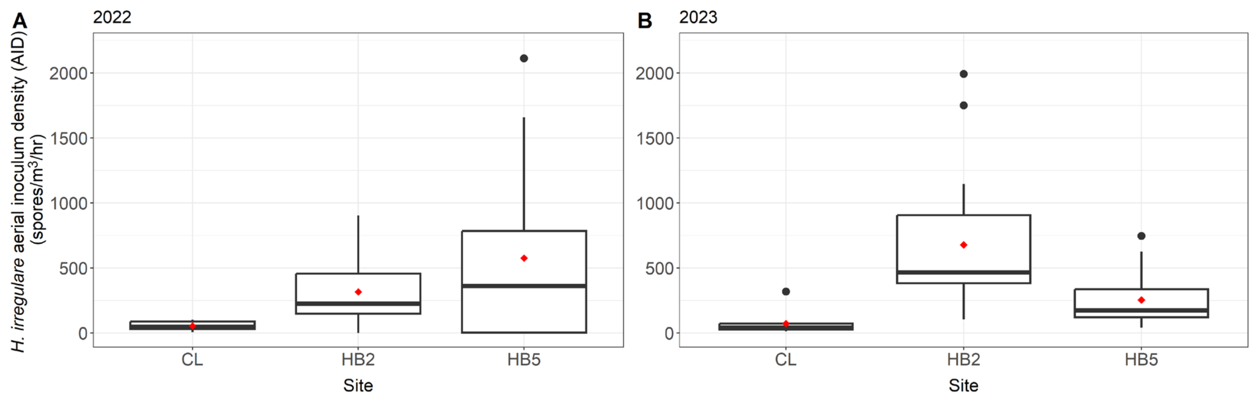

Figure 1. Boxplots showing variation in aerial inoculum density (AID) from (a) October 2022, and (b) October 2023, assessed via real-time PCR. CL = Conboy Lake (500 m from forest edge), HB2 and HB5 = ponderosa pine stands. Red points show mean AID for each plot. N = 9 samples/year for CL and 18 samples/year for each pine stand (HB2 and HB5).

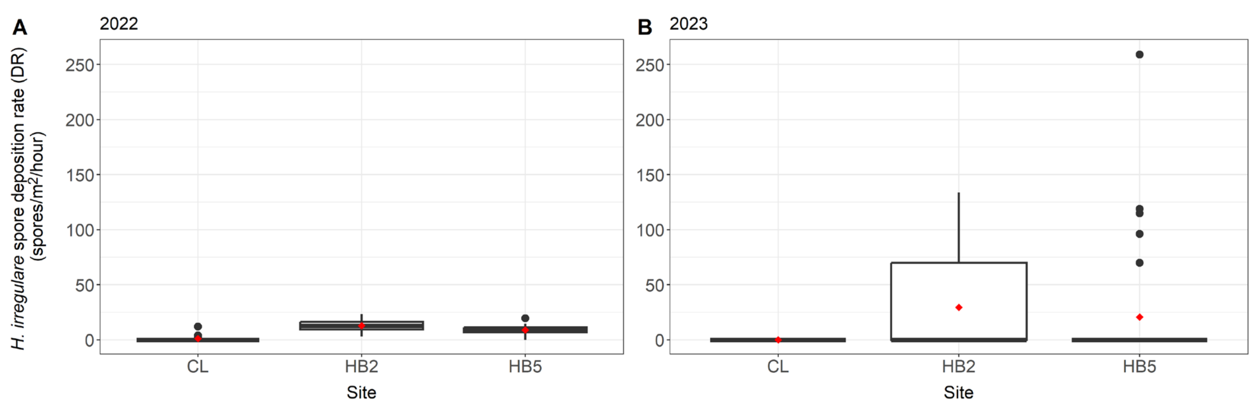

Figure 2. Boxplots showing variation in spore deposition rates (DR) on wood disks in October 2022 (a) and October 2023 (b). CL = Conboy Lake (500 m from forest edge), HB2 and HB5 = ponderosa pine stands. Red points show mean DR for each plot. N = 16 disks/year for CL, and 32 disks/year for each pine stand (HB2 and HB5).

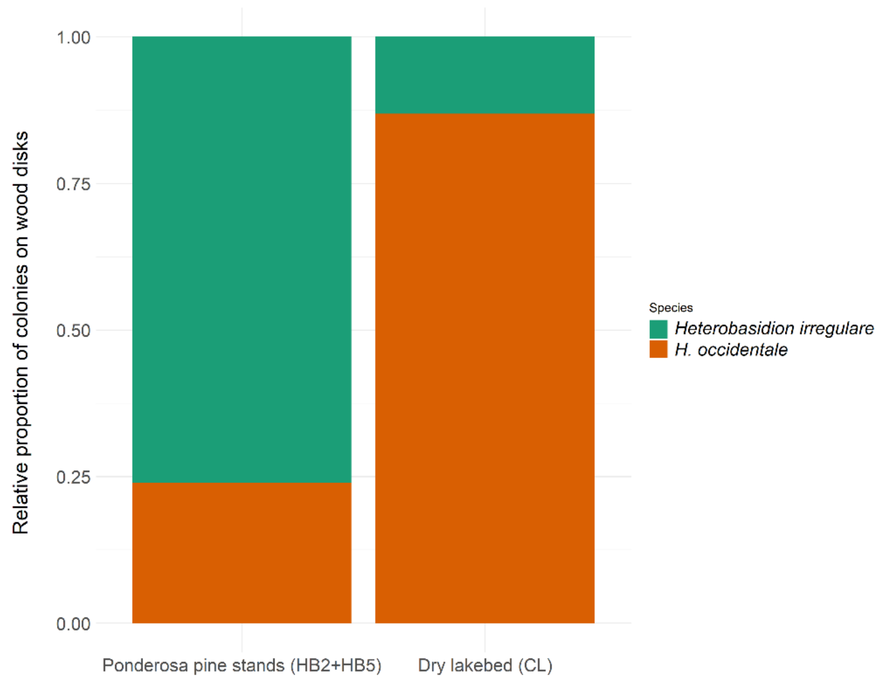

Figure 3. Relative proportions of colonies identified as either *H. irregulare* or *H. occidentale* for the wood disks placed in ponderosa pine stands (HB2 and HB5) and the dry lakebed site 500m away from the forest edge (CL). Colonies were sub-cultured from wood disks and identified using taxon-specific primers (Shamoun et al., 2019).

Acknowledgements

The authors thank Doug Schmidt and Tina Popenuck at UC Berkeley for their assistance with counting, isolating, and identifying Heterobasidion colonies from wood disks. The mechanical spore trap design was provided by Dr. Walt Mahaffee (USDA ARS). Funding for this project was provided by USDA Forest Service, State, Private and Tribal Forestry, Forest Health Protection, Special Technology Development Program (STDP) grant R6-2022-01 and the Rocky Mountain Research Station Forest and Woodland Ecosystems (FWE) Program.

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Sooty-bark canker disease (*Encoelia pruinosa*) inoculation study

James T Blodgett[1]

Introduction

Sooty-bark canker disease (*Encoelia pruinosa*) is the second most common damage agent in aspen (*Populus tremuloides*) in the Black Hills National Forest, South Dakota (Blodgett et al. 2020; **Fig. 1**). The study objectives were to: 1) classify early symptoms of sooty-bark canker disease, 2) determine rate of canker expansion, and 3) quantify the time it takes sooty-bark canker disease to cause aspen mortality.

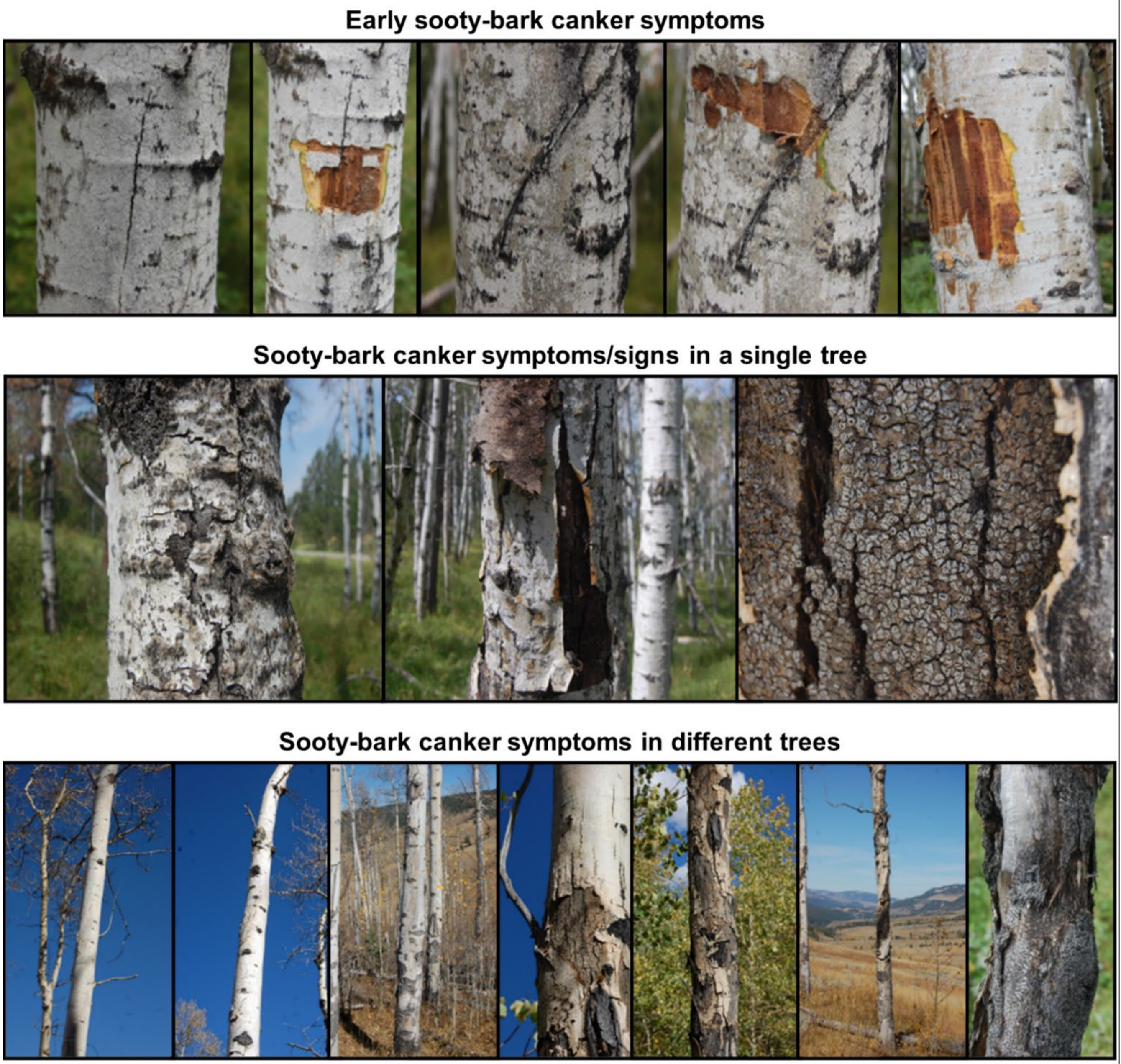

Figure 1. Range of sooty-bark canker disease symptoms (natural infections).

[1]USDA Forest Service, Rocky Mountain Region, Forest Health Protection, Rapid City, SD

Methods

Encoelia pruinosa apothecia (24 samples) and diseased aspen bark (50 samples) were collected from nine aspen stands in 2015. Small pieces of apothecia or phloem were transferred from newly exposed tissues to water agar containing streptomycin sulfate (Blodgett 2017; **Fig. 2**).

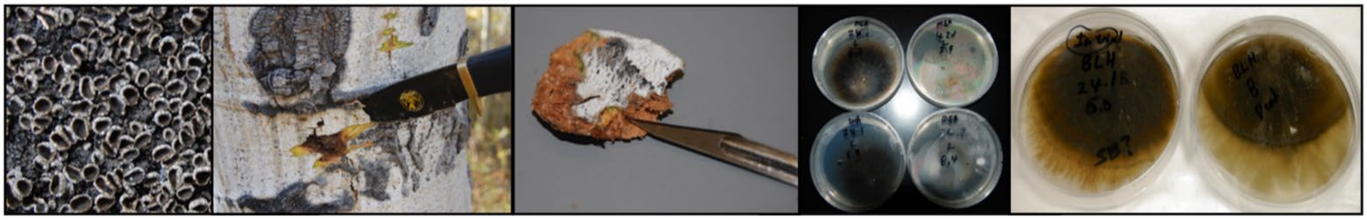

Figure 2. *Encoelia pruinosa* apothecia and bark samples were collected from aspen and small samples were transferred to agar plates. Dark-brown colonies formed with light-gray aerial hyphae.

Healthy aspen trees were inoculated in the Black Hills National Forest (**Fig. 3**). Wounded-inoculations included two isolates of *E. pruinosa* grown on water agar and controls (sterile agar). The study was replicated in two stands with eight replications per treatment in 2016 and in a single new aspen stand with twelve replications per treatment in 2021. Data collected included: host DBH, canker size (height and width), and photos to document disease progression. Canker expansion = canker size in two directions minus the mean control size. Control size = wound size and associated discolored tissue resulting from the wound.

Figure 3. Inoculation methods used.

Results and Discussion

Econelia pruninosa was isolated from 96% if apothecia and 37% of bark with sooty-bark canker disease symptoms. The inoculated trees averaged 8.1 cm DBH at the start and 8.8 cm DBH at the end of the study in 2019; and 16.9 cm DBH at the start and 18.0 cm DBH at the end of the study in 2024. Cracking and peeling bark and expanding cankers were apparent after 1 year and 4 months (**Fig. 4**). However, canker expansion stopped after 1, 2, 3, or 4 years (**Fig. 5** and **6**). Eighty three percent of the *E. pruinosa* inoculated trees produced cankers and none of the controls produced cankers. The mean canker size of *E. pruinosa* inoculated trees was significantly larger ($P <$ 0.001) than the controls. The mean canker height/width reached 7.3 cm/6.2 cm (maximum 16 cm/13 cm) in 2019, and mean canker height/width reached 2.0 cm/1.7 cm (maximum 9 cm/5 cm) in 2024. The mean cankered circumference reached 23% (maximum 47%) in 2019, and 9% (maximum 39%) in 2024. Canker expansion eventually stopped in all trees after 4 growing seasons in 2016; and appeared to stop in 2024 for trees inoculated in 2021.

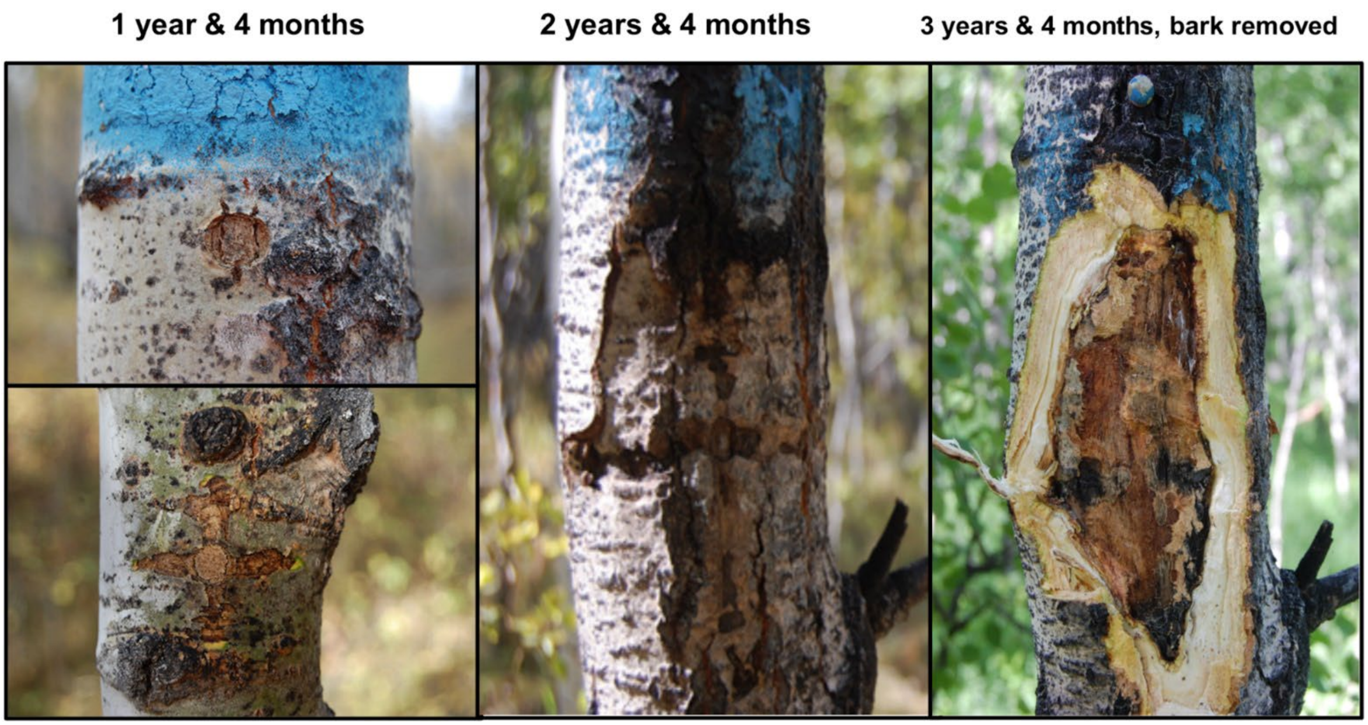

Figure 4. Symptoms in inoculated aspen after 2, 3, and 4 seasons.

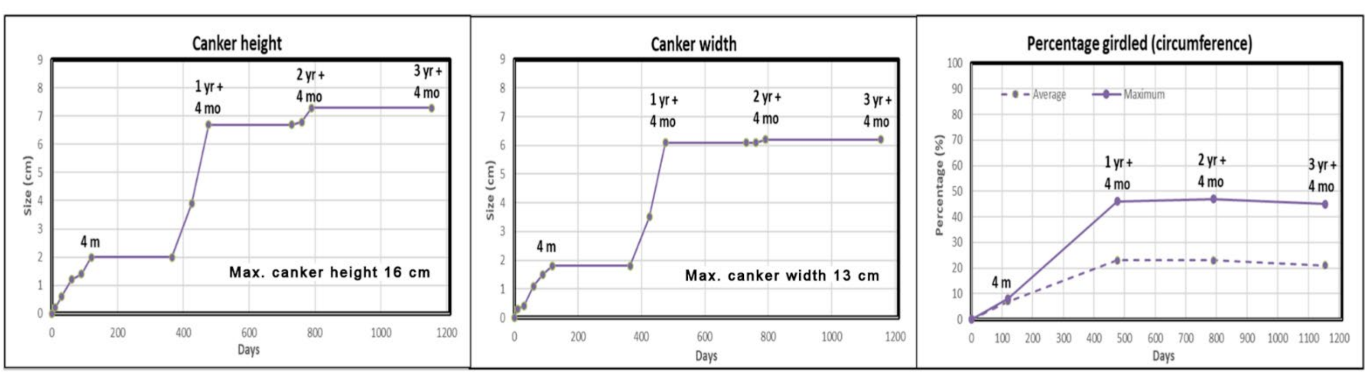

Figure 5. *Encoelia pruinosa* canker expansion (2016-2019).

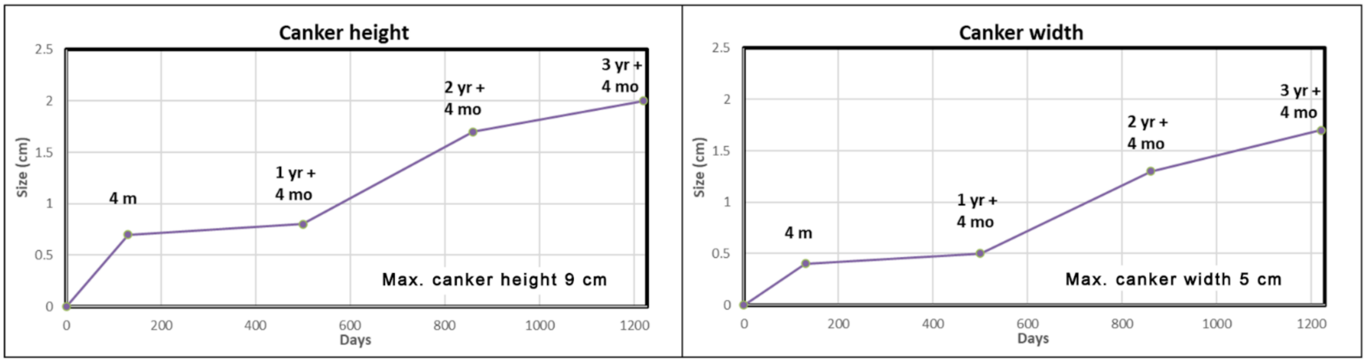

Figure 6. *Encoelia pruinosa* canker expansion (2021-2024).

This study confirms *E. pruinosa* is a pathogen. However, the expected "quick" mortality (3 to 5 years) never occurred. Sooty-bark canker disease canker expansion can be stopped by young, healthy aspen. Even with this relatively aggressive diffuse-canker pathogen, trees can recover, however, with extensive bark damage in some trees.

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Fire-driven changes to western conifer forest soil microbiomes & implications for microbiome-based management of Armillaria root disease

Ada J. Fitz Axen[1], Ned B. Klopfenstein[2], Mee-Sook Kim[3], John W. Hanna[2], Patrick Bennett[2], Sara Ashiglar[4], Jane E. Stewart[1]

Soil microbiomes play critical roles in numerous ecosystem processes, including regulating the behavior of soilborne plant pathogens. These microbiomes can impede or promote pathogen activity, respectively forming disease suppressive soils or pathobiomes. However, soil microbiomes are altered by disturbance events such as fires, which tend to reduce microbial diversity and abundance and shift community composition towards those taxa which can survive in the post-disturbance environment. The fungal pathogen *Armillaria solidipes* causes Armillaria root disease on conifers throughout the western USA, leading to white rot of tree roots and lower boles that can result in landscape-scale mortality and altered ecosystem composition. Manipulation of the soil microbiome has been suggested as a landscape-scale management method for Armillaria root disease in these forests, yet understanding how increasingly frequent and severe fire disturbances affect the soil microbiome in *A. solidipes*-dominated areas is essential for effective implementation of this strategy. This research aimed to examine shifts in soil microbiomes associated with *A. solidipes* following varying levels of burn severity, focusing particularly on how putatively beneficial species, such as biological control agents, are impacted by fire. At 15 months post-fire, soil samples associated with 15 western white pine (*Pinus monticola*) and 15 Douglas-fir (*Pseudotsuga menziesii*) trees were collected from a forest in northern Idaho, USA. Samples of *Armillaria* spp. were also collected throughout the site in the form of fruiting bodies, mycelial fans, and rhizomorphs. Microbial species were isolated from soil samples to test their antagonistic abilities against *A. solidipes*, and soil samples were also used to generate metabarcoding data for microbiome analysis. *Armillaria* spp. were isolated from the collected *Armillaria* samples for use in dual culture confrontation tests and for analyses of *Armillaria* spp. associations with microbial communities and burn severity levels. Results of this work revealed that bacterial alpha-diversity decreased incrementally with increasing burn severity, while fungal alpha diversity remained unchanged. In contrast, both bacterial and fungal communities showed compositional changes when unburned communities were compared to low- and high-severity burn communities. Compositional changes following fire included an abundance of *A. solidipes* and its associated bacterial and fungal taxa following high-severity burns, while *A. altimontana*, which can benefit tree health on sites where it co-exists with *A. solidipes*, and its associated microbial community were more abundant under low-severity burn and unburned conditions. Dual culture confrontation tests between putative biological control agents and *A. solidipes* revealed that isolates from the bacterial genera *Bacillus* and *Caballeronia* and isolates from the fungal genera *Trichoderma* and *Mortierella* displayed inhibition of pathogen growth or rapid colonization of artificial media and pathogen mycelia. Further, the relative abundance of these putative biocontrol agents did not change with burn severity. Finally, when *A. solidipes* and *A. altimontana* were co-inoculated on sterilized wooden disks, *A. altimontana* appeared to display abundant growth and superior saprophytic colonization. Results from this research have multiple implications for microbiome-based management of Armillaria root disease caused by *A. solidipes*. The increased relative abundance of certain *A. altimontana*-associated ectomycorrhizal fungi under low-severity burn conditions suggests the potential for controlled, low-severity burns to promote a microbiome that benefits tree health. In contrast, the increased relative abundance of *A. solidipes* and its community under high-severity burn conditions indicates that preemptive monitoring and management for Armillaria root disease is essential in these ecosystems

[1]Colorado State University, Department of Agricultural Biology
[2]USDA Forest Service, Rocky Mountain Research Station
[3]USDA Forest Service, Pacific Northwest Research Station
[4]USDA Forest Service, Nez Perce-Clearwater National Forest

following severe burns. Finally, promoting the abundance of the biological control agents that showed inhibition of pathogen growth or superior substrate colonization, including *A. altimontana*, within the soil microbial community may help to manage Armillaria root disease. However, a deeper understanding of *Armillaria* spp.-associated microbiomes and the relationship between fire and key players in *A. solidipes* pathobiomes and disease suppressive soils is required before these strategies can be implemented. Overall, this research improves our understanding of how forest ecosystem disturbances may impact the soil microbiome and subsequently affect prevalent forest pathogens.

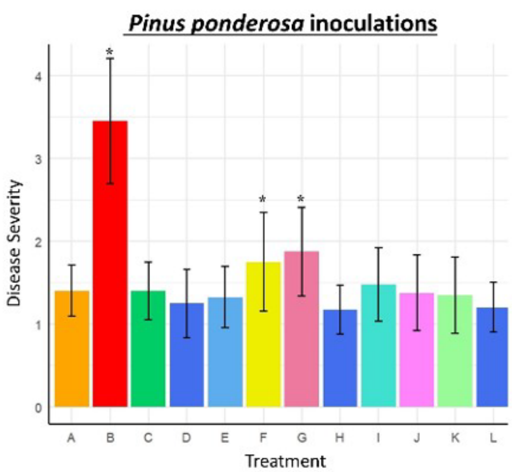
A published manuscript with more details of this study is now available:

Fitz Axen, A. J., Kim, M. S., Klopfenstein, N. B., Ashiglar, S., Hanna, J. W., Bennett, P., & Stewart, J. E. (2024). Fire-associated microbial shifts in soils of western conifer forests with Armillaria root disease. *Applied and Environmental Microbiology*, e01312-24.

Pathogenicity and virulence assays of fusarioid fungi on conifer species

Grace E. Ganter[1], John T. Dobbs [1], Olivia Watson [1], Ned B. Klopfenstein[2], Greg Reynolds[3], Mee-Sook Kim[4], and Jane E. Stewart[1]

Fusarioid pathogens, which are are common in both container and bareroot nurseries, cause a multitude of symptoms including pre- and post-emergence damping-off, root rot, stunting, yellowing and necrosis of needles, wilt, mortality, and increased transplant mortality. The risk of introducing Fusarioid pathogens into new landscapes after out-planting is elevated because the host range for most Fusarioid species is not well characterized. A critical step in preventing the spread of Fusarioid pathogens is identifying pathogenic species in the nursery before they are transported elsewhere. A recent survey from conifer-producing nurseries across sixteen states revealed twenty-six putative *Fusarium* or *Neocosmospora* pathogens. The goal of this project is to determine if fifteen of the Fusarioid species (*N. falciforme*, *F. fredkrugeri*, *N. solani*, *F. fujikuroi*, *F. lactis*, *F. avenaceum*, *F. flocciferum*, *F. luffae*, *F. torulosum*, *F. verticillioides*, *F. clavum*, *F. acuminatum*, *F. ipomoeae*, *F. inflexum*, and *F. oxysporum*) are pathogenic on dominant conifer species from the Pacific Northwest, Southwest, and Southeast USA [Douglas-fir (*Pseudotsuga menziesii*; PSME), ponderosa pine (*Pinus ponderosa*; PIPO), and loblolly pine (*P. taeda*)], respectively). Pathogenicity assays were completed on 6- to 8-month-old seedlings that were grown in potting media amended with inoculum at a 50:1 growing media to inoculum ratio. Seedlings were randomly placed in incubators at 25°C with a 12-hour photoperiod. After 20 days, seedling shoots and roots were assessed for health status. Additionally, 60% of the roots were collected and lesion-associated fungi were isolated to confirm/identify Fusarioid speciesusing DNA sequences of translation elongation factor 1-α and/or RNA polymerase II second largest subunit gene(s). Among the tested isolates, *F. fujikuroi* was identified as pathogenic on PIPO and PSME, on which it exhibited significant differences from control treatments and was successfully re-isolated from inoculated roots of both hosts. Weak virulence was observed for *F. avenaceum* and *F. fredkrugeri* on PIPO, but the other species, *F. inflexum*, *N. solani*, *N. falciforme*, *F. lactis*, *F. luffae*, and *F oxysporuum*, showed no significant pathogenic effects on PIPO. Similarly, on PSME, *N. falciforme* and *F. lactis* showed no significant pathogenic effects compared to the control (Figure 1). Pathogenicity/virulence of these fungi is likely influenced by environmental conditions. These findings highlight the variability in virulence among Fusarioid species and the need for further investigation into environmental factors affecting pathogenicity.



Color	Letter	Treatment
Orange	A	*Neocosmospora falciforme*
Red	B	*Fusarium fujikuroi*
Green	C	*F. lactis*
Blue	D	Control
Light blue	E	*N. solani*
Yellow	F	*F. avenaceum*
Rose	G	*F. fredkrugeri*
Blue	H	Control
Turquoise	I	*F. oxysporum*
Pink	J	*F. luffae*
Light green	K	*F. inflexum*
Blue	L	Control

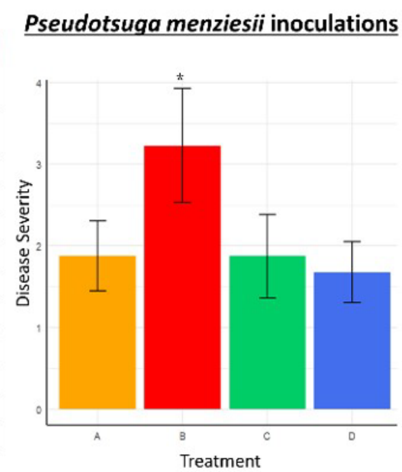


Figure 1. A. Mean disease severity of Fusarioid spp. when inoculated onto *Pinus ponderosa*. B. Mean disease severity of Fusarioid spp. when inoculated onto *Pseudotsuga menziesii*.

[1]Colorado State University, Department of Agriculture Biology
[2]USDA Forest Service, Rocky Mountain Research Station
[3]USDA Forest Service Forest Health Protection, Southwestern Region
[4]USDA Forest Service, Pacific Northwest Research Station

Midterm project updates for ongoing *Armillaria* surveys in California: DNA-based identification, bioclimatic modeling, and information for managing Armillaria root disease under changing environments

John W. Hanna[1], Mee-Sook Kim[2], Patrick I. Bennett[1], Ashley E. Hawkins[3], Chris A. Lee[4], Kim Corella[5], Charles W. Barnes[6], Wallis L. Robinson[7], Duncan R. Kroese[2], William C. Woodruff[8], Martin MacKenzie[9], Phil G. Cannon[10], Ned B. Klopfenstein[1]

Introduction

Although *Armillaria* has been previously surveyed in several western states of the USA, little definitive information on *Armillaria* species distribution in California has been provided in the last 20 years (e.g., Baumgartner and Rizzo 2001). Furthermore, it is well established that climate and climate change influence the distribution of *Armillaria* species that cause Armillaria root disease, which is a major cause of losses in forest growth and productivity (e.g., Lockman and Kearns 2016; Kim et al. 2021, 2022). This paper details recent progress towards identifying *Armillaria* for subsequent use in bioclimatic modeling to predict the influences of climate and climate change on the distribution of *Armillaria* species in California.

Objectives

The objectives of this project are to (i) culture and/or use DNA sequences to identify *Armillaria* species from collections/surveys across diverse forest areas in California; (ii) use *Armillaria* occurrence data to evaluate and refine bioclimatic models for predicting the present and future suitable climate space (geographic area that is climatically suitable for the species' survival) for representative *Armillaria* species in California; (iii) use bioclimatic models to produce predictive maps for *Armillaria* species to support forest management decisions in relation to Armillaria root disease; and (iv) document any new *Armillaria* species/host combinations within California. Resulting bioclimatic models can also be compared with predictive distribution models of important host tree species within the region.

Continued *Armillaria* surveys/collections are needed to supplement under-represented areas for *Armillaria* occurrence across California (Fig.1). To assist in this effort, we are soliciting help from collaborators to conduct surveys within these areas. *Armillaria* samples (e.g., mycelial fans on live trees indicating disease activity, rhizomorphs, and/or fruiting bodies) should be sent to USDA Forest Service RMRS and PNWRS Forest Patholog

[1] USDA Forest Service, RMRS, Moscow, ID, USA
[2] USDA Forest Service, PNWRS, Corvallis, OR, USA
[3] USDA Forest Service, FHP Region 5, Redding, CA, USA
[4] California Dept. of Forestry and Fire Protection, Forest Entomology and Pathology, Fortuna, CA, USA
[5] California Dept. of Forestry and Fire Protection, Forest Entomology and Pathology, San Luis Obispo, CA, USA
[6] USDA Forest Service, FHP Region 5, San Bernardino, CA, USA
[7] University of California Cooperative Extension, Eureka, CA, USA
[8] USDA Forest Service, FHP Region 5, Susanville, CA, USA
[9] USDA Forest Service, FHP Region 5, Sonora, CA, USA
[10] USDA Forest Service, FHP Region 5, Vallejo, CA, USA

laboratories for identification along with GPS information, associated host/environmental information, and photos.

Methods

Survey, collection, and bioclimatic modeling methods for *Armillaria* follow those as described in Kim et al. (2021, 2023), Hanna et al. (2024), and Hanna et al. (this WIFDWC proceedings volume). Thirty-one locations were used to construct a preliminary example model of potential *A. gallica* distribution based on contemporary bioclimatic data (1970-2000, Fick and Hijmans 2017) using ten replicate runs with the MaxEnt algorithm (Phillips et al. 2006).

Preliminary Results and Discussion

To date, approximately 59 *Armillaria* samples have been identified from California using translation elongation factor 1-alpha (*tef1*) gene sequences (36 *A. gallica*, 10 *A. altimontana*, 5 *A. sinapina*, 6 *A. nabsnona*, and 2 *A. mellea*) (e.g., Ross-Davis et al. 2012; Klopfenstein et al. 2017). Our initial goal for this project is to acquire 30 or more sample locations for each *Armillaria* species to conduct bioclimatic modeling. While species distribution models can be produced using as few as 3-5 locations, sample sizes less than 13-20 are known to potentially decrease model performance (Stockwell and Peterson 2002, Papes and Gaubert 2007, van Proosdij et al. 2016). Our bioclimatic modeling efforts will require expanded *Armillaria* collections within coastal forests from Eureka, CA to the Mexican border. We also hope to obtain *Armillaria* collections within the Trinity, Mendocino, Plumas, Stanislaus, and Sequoia National Forests. Additionally, we currently only have four confirmed samples from southern California where *A. mellea* is presumed to be the most prevalent species. For this reason, we hope to obtain more *A. mellea* samples to allow robust bioclimatic modeling.

Figure 1. *Armillaria* collections in California identified using translation elongation factor 1-alpha gene sequencing.

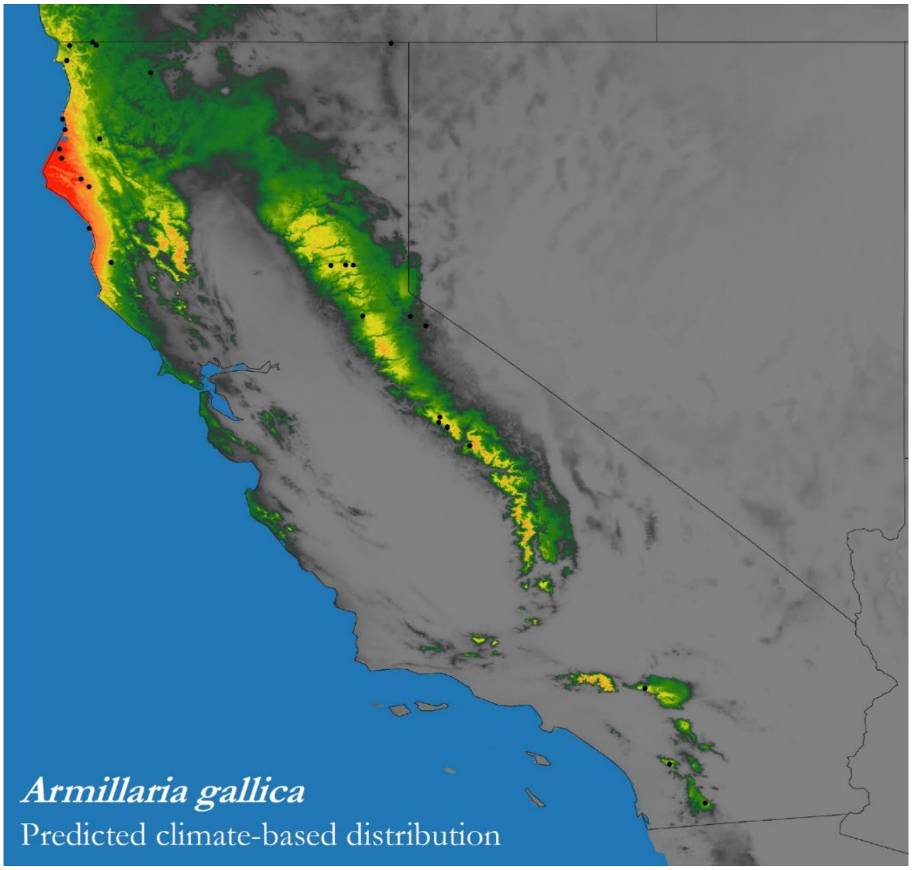


Figure 2. Preliminary bioclimatic model using MaxEnt to predict potential distribution of *Armillaria gallica* in California. Darkest gray represents the predicted empirical MaxEnt climate suitability, with dark green, light green, yellow, orange, and red indicating increased probabilities of climatic suitability, respectively.

Acknowledgements

This project is supported by USDA Forest Service, State, Private and Tribal Forestry, Forest Health Protection - Special Technology Development Program (STDP-R5-2023-01), Rocky Mountain Research Station – Forest Woodland Ecosystems Program, and Pacific Northwest Research Station – Fire, Fuel, and Smoke Program. The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy.

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Armillaria collection methods: tips and tricks

John W. Hanna[1], Aaron L. Smith[2,3], Mee-Sook Kim[4], Patrick I. Bennett[1], Ned B. Klopfenstein[1]

Introduction

This report is aimed toward improving general awareness of various types of *Armillaria* samples and recommended survey practices to obtain collections for isolation/culture, DNA-based identification, and/or future studies. High-quality samples yield a higher success rate for DNA-based identification and allow isolation in the laboratory to obtain pure, living *Armillaria* cultures that can be archived for long-term storage for use in future research projects. In root disease surveys, samples of pathogenic *Armillaria* are frequently obtained from trees showing symptoms of disease, such as yellowing needles (Fig. 1A), thinning crown, basal resinosis (Fig. 1B), upturned root balls/wads (Fig. 1C), or recently "red dead" needles (Fig. 1D). However, above-ground symptoms likely only represent the "tip of the iceberg" as it relates to *Armillaria* in both a pathogenic and non-pathogenic state. In most cases, *Armillaria* can cause reduced growth and root disease in trees that show no obvious above-ground symptoms (Cruickshank 2011). Alternatively, *Armillaria* exhibiting little, or no signs of pathogenicity is also of interest for surveys and research studies. **Armillaria is most often present as rhizomorphs on trees that appear to be perfectly healthy.** For example, rhizomorph-producing *A. altimontana* that exhibited little/no sign of pathogenicity has been associated with improved health of western white pine (*Pinus monticola*) in northern Idaho, USA (Warwell 2019). In contrast, studies and empirical observation suggest that various disturbances, such as stress from other pathogens, insects, fire, soil compaction, tree thinning/harvesting, fertilization, extreme weather, climate change, etc., may "trigger" Armillaria root disease (McDonald 1987a, Woods 1994, Lundquist 2000, Kim et al. 2010, Glaeser and Smith 2013, Kubiak et al. 2017). This interaction can be evident with insect attack, where stress due to insect damage may induce pathogenicity from pre-existing *Armillaria* rhizomorphs on the roots. A reciprocal relationship is also common in which bark beetles may be more attracted to stressed trees predisposed by Armillaria root disease (Tkacz and Schmitz 1986, Lalande et al. 2020, Sierota and Gradzki 2020). Studies in northern Idaho, USA found that 92-96% of trees attacked by bark beetles also had root disease (Hertert et al.1975, Kulhavy et al 1984).

A general *Armillaria* survey method is to make collections from trees within random, 0.04-hectare plots (a circular plot with a ca. 11.3-m or 37-ft radius) (McDonald et al 1987b, 2011). Typically, three trees of different size classes for each species are surveyed/sampled for all *Armillaria* collection types (rhizomorph, mycelial fan, colonized wood, fruiting body), with rhizomorphs being the most frequent collection type. Samples from different shrub species are also surveyed/sampled. With this sampling strategy, habitat type and plant association information are also recorded to determine relationships with *Armillaria* species. This random-plot survey strategy is time consuming and may require a crew of three to five people to sufficiently survey three to four plots a day. Recently, survey studies have shifted towards using bioclimatic modeling of *Armillaria* species distribution using algorithms, such as MaxEnt (Klopfenstein et al. 2009, Kim et al. 2021, 2023). For these bioclimatic modeling

[1] USDA Forest Service, RMRS, Moscow, ID, USA;
[2]USDA Forest Service, FHP Region 6, Bend, OR, USA;
[3]Norwegian Institute of Bioeconomy Research, Ås, Norway;
[4]USDA Forest Service, PNWRS, Corvallis, OR, USA

studies, single-point collections can be used, which require fewer people and less time to collect sufficient data. An important consideration for bioclimatic modeling studies is to include diverse samples of each *Armillaria* species across its potential geographic range, which represent variable climates. A major advantage of using MaxEnt over other algorithms is that it excels at using presence-only data, because it is impractical and cost prohibitive to confirm absence data for *Armillaria*.

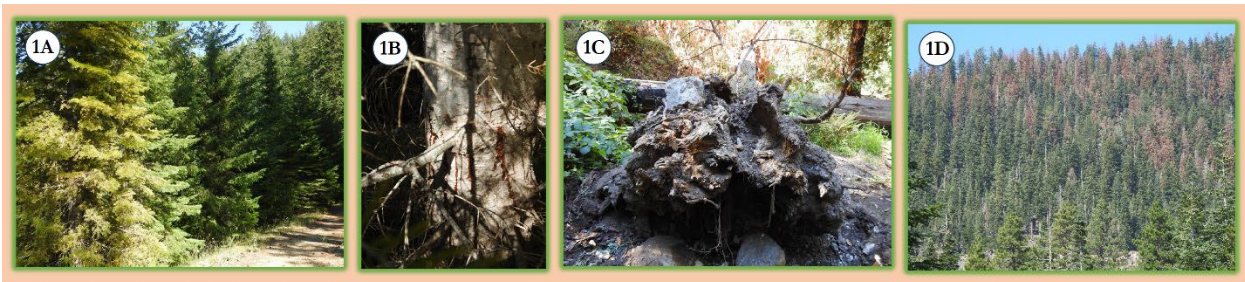

Fig. 1. 1A: Douglas-fir (*Pseudotsuga menziesii*) with yellowing needles adjacent to healthy, green-needled trees. 1B: Tree shown in 1A displaying signs of basal resinosis. 1C: Root ball/wad of a "red dead" bigleaf maple (*Acer macrophyllum*). 1D: Forest with high percentage of "red dead" conifers. Photo credits 1A, 1B: J.W. Hanna, Chicago Peak, Rogue River – Siskiyou National Forest (NF), California, USA; 1C: J.W. Hanna, Ventana Wilderness, Los Padres NF, California, USA; 1D: J.W. Hanna, The Whaleback, Klamath NF, California, USA

Safety

When collecting *Armillaria* samples, safety must be considered at all times. Approach hazard trees or any tree that may be compromised with root disease with caution and when in doubt error on the side of caution. Only collect samples if it is safe to do so and consider skipping the collection or finding an alternative collection site if necessary. See Fig. 2A, 2B, 2C, and 2D for additional safety tips to consider when working in the field.

Fig. 2. 2A: Poison oak rash and leaflets (inset) 2B: Black bear. 2C: Northern Pacific rattlesnake. 2D: Weathered road signs. Photo credits: 2A: J.W. Hanna, Clarkston, Washington, USA 2A (inset): David Cappaert, Bugwood.org 2B: J.W. Hanna, Latour State Forest, California, USA 2C: J.W. Hanna, Barlow Flat, Ventana Wilderness, Los Padres National Forest (NF), California, USA; 2D: J.W. Hanna, Rouge River – Siskiyou NF, California, USA

Sample labeling

In general, sample labeling of *Armillaria* should reflect collector name, site name, sample number, and letter for collection type: R=rhizomorph, B=basidiocarp, F=mycelial fan, and W=wood including zone lines or decay. For example, a collection from Sykes Campground may be labeled Sykes Camp 1R for a rhizomorph and Sykes Camp 1F for a mycelial fan from the same tree. A rhizomorph sample from a second tree or shrub from this general area would be labeled Sykes Camp 2R. Other information that should be collected include date of collection, GPS coordinates (preferably in decimal degrees); host species and status (e.g., live and healthy, red dead, old snag, etc.), and photos; AK = thought to be *Armillaria* killed, DBH, other notes, such as yellowing needles/leaves, thinning crown, resinosis, etc.; and any special notes about the site in general.

Fig. 3. 3A: *Armillaria solidipes* basidiocarps on an alder (*Alnus* sp.) snag. 3B: *A. sinapina* basidiocarps. 3C: *A. gallica* basidiocarps. Photo credits 3A: J.W. Hanna, La Poel, Washington, USA; 3B: J.W. Hanna, Birch Bay, Washington, USA; 3C: J.W. Hanna, Heaps Peak, San Bernadino National Forest, California, USA

Basidocarps

Armillaria basidiocarps (aka "honey mushrooms") are the collection type most frequently encountered and recognized by mycologists and naturalists (amateur and professional). Keys are available to assist identification of *Armillaria* species based on basidiocarp morphology (most notably Volk, https://botit.botany.wisc.edu/toms_fungi/armkey.html). However, morphological keys typically do not include species, such as *A. altimontana*, which can be difficult to distinguish from species with similar morphology (Brazee et al. 2012). Furthermore, morphological keys may not account for intraspecies variation that occurs across North America. For example, despite the fact that basidiocarps sometimes appear to contrast greatly (Fig. 3A and 3B), experienced mycologists were unable to find consistent morphological differences among basidiocarps of *A. solidipes* and *A. sinapina* in western North America (McKenny et al. 1987). DNA sequencing of the translation elongation factor-1 alpha (*tef1*) gene is currently the easiest and most reliable way to identify all ten *Armillaria* species and one *Desarmillaria* species that are currently recognized in North America (Ross-Davis et al. 2012, Elías-Román, et al. 2018, Antonín et al. 2021). Fresh basidiocarps, preferably small caps that are collected just before the basidiocarp gills start to show (Fig. 3C), are ideal for isolation, culturing, and DNA-based identification techniques. Alternatively, basidiocarps can be gently dried in a dehydrator, but these samples only have potential for DNA- and/or morphology-based identification because they cannot be cultured and/or stored as living archives. Generally, basidiocarps are most abundant in North America during the fall/winter months from October to February with a later occurrence in southern and/or lower elevation areas.

Fig. 4. 4A) *Armillaria* rhizomorph size compared with knife for reference at various magnifications. Note: missing parts of the outer rhizomorph sheath reveal white mycelial cords on the inside. 4B) Example of roots (top) vs rhizomorphs (bottom). 4C) Rhizomorphs extending above the soil line. 4D) Rhizomorphs revealed under bark of dead big leaf maple (*Acer macrophyllum*). 4E) The rhizomorph stretch test. 4F) Rhizomorph collection tools. 4G) J.W. Hanna savoring the "mushroomy" scent of a freshly dug "rhizo". Photo credits 4A, 4B: J.W. Hanna, Brushy Creek, Rouge River – Siskiyou National Forest (NF), California, USA; 4C, 4E: J.W. Hanna, Ventana Wilderness, Los Padres NF, California, USA; 4D: J.W. Hanna, The Whaleback, Klamath NF, California, USA 4G: P.I. Bennett, Yuki Wilderness borderlands, Mendocino NF, California, USA 4F: J.W. Hanna

Rhizomorphs

Armillaria rhizomorphs are fungal structures with the appearance of roots to the untrained eye (Fig. 4A, 4B, 4C, 4D, 4E, and 4G). *Armillaria* rhizomorphs are frequently present across many forest types in association with diverse woody hosts, whether or not they are exhibiting symptoms of Armillaria root disease. After practice digging for and collecting *Armillaria* rhizomorphs, surveyors will likely find that *Armillaria* is extremely prolific across many forest habitats. For scientific study, it is important to obtain fresh, viable rhizomorphs. Often, above-ground rhizomorphs are dried, dead, and/or contaminated with other fungi, which prevents or impedes the success of isolation and culturing (Fig. 4C and 4D). Fresh living rhizomorphs can be collected by careful root excavation. It is recommended that at least two main roots be carefully excavated using the grubbing end of a Pulaski (Fig. 4F) to a depth of up to 0.5 m (1.6 ft) and distance of 0.6 m (2 ft) from the basal bole; however, rhizomorphs are frequently found at deeper depths and sometimes on roots >2 m (several ft) from the host's bole. While excavating the roots, it is very important that extra care is taken to not disturb the upper (2-3 cm or 0.8-1.2 in) soil/litter layer surrounding the root. Excavation of this upper layer is best performed carefully by hand and/or with a knife, stick, rock, or similar digging tool. As the remaining soil is swept away (a kitchen vegetable brush may be useful), visual inspections are made for the root-like structures and determinations are made to identify these structures as roots or rhizomorphs (Fig. 4B). Below is a practical guide with some tips and tricks to train your eyes and other senses for distinguishing rhizomorphs from roots.

Rhizomorph field-identification guidance:

1) The exterior of mature rhizomorphs is usually jet black in color, but younger rhizomorphs can be shades of red/brown/tan.

2) The interior of a fresh rhizomorph is almost always white, but sometimes the interior can be stained with shades of tan/brown/purple/red.

3) The bleach test: place suspected rhizomorphs in a ~20% bleach solution and set aside for a couple minutes. After the bleach treatment, the exterior of fresh rhizomorphs will remain jet black with white mycelium through the center. If rhizomorphs are left in the bleach solution for too long, their outer black sheath will eventually disintegrate leaving only the white mycelium. After bleach treatment, roots become brownish, reddish, or bleached-out tan in color with no bright-white interior. Rhizomorphs that have undergone the bleach test in the field are typically not saved for culturing, but the bleach test is useful for training in rhizomorph identification (Fig. 4B). Note: Use safety precautions when using the bleach solution, which is also damaging to clothing.

4) The pull test (Fig. 4E): compared to roots, rhizomorphs will have a bit more stretch/elasticity and the outer sheath will start to crack to reveal the lighter colored mycelia that will continue to stretch until breakage. For this stretch test, start with a gentle pull and slowly increase the tension.

5) The end test: The ends of the outer covering of both rhizomorphs and roots can be gently pulled off. The mycelial tuft at the broken end of a rhizomorph will bend very easily, while broken roots with their outer covering removed will typically remain firm when touched.

6) The light test: Blow off the soil as well and possible from suspected rhizomorph or rinse it with water. Hold the sample in direct sunlight close enough to your eyes that allows focus on the fine detail of the black outer sheath. While slowly rotating the sample between your thumb and index finger, a rhizomorph will “glisten” from many reflective surfaces in prismatic colors as it is rotated, somewhat similar to a kaleidoscope effect (A.L. Smith, personal observation). Geral McDonald described this phenomenon as “many little diamonds shining in the light.” This effect can also be observed through a 10x hand lens under bright sunlight.

7) The smell test (Fig. 4G): For some, the smell test is perhaps the easiest test. Rhizomorphs have a distinct “mushroomy” aroma with some having a very strong scent. Investigations to understand species-specific scents and the associated variation are ongoing, but some *Armillaria* species have been distinguished using an electric nose (Baietto et al. 2010). It would be interesting to determine if dogs or pigs could be trained to hunt *Armillaria* and possibly even distinguish species.

Some evidence suggests that *Armillaria* species can be identified by rhizomorph size and branching patterns, but this method has not been investigated among all known *Armillaria* species within their associated geographic ranges (Morrison 2004).

Fig. 5. 5A, 5B: *Armillaria solidipes* mycelial fan and zone lines on fir (*Abies* sp.). 5C: *A. altimontana* zone lines on aspen (*Populus* sp.). Photos 5A, 5B: J.W. Hanna, Abajo Mountains, Manti-La Sal National Forest (NF), Utah, USA; 5C: J.W. Hanna, Jarbidge Wilderness, Humboldt NF, Nevada, USA.

Mycelial fans and zone lines

Mycelial fans and colonized wood with zone lines are two other collection types that can be used to isolate and establish pure *Armillaria* cultures in the laboratory (Fig. 5A, 5B, and 5C). Mycelial fans from trees that still show signs of life are a definitive sign of pathogenicity. Other signs of pathogenicity in relation to mycelial fans include a host response from the tree, such as resin-soaked mycelial fans or defensive growth reactions (Kim et al. 2023). *Armillaria* zone lines are areas of melanin synthesis and accumulation in fungal hyphae that are apparently formed when *Armillaria* competes with other decay fungi, different *Armillaria* species, or individuals of the same species (Morris et al. 2021). Compared to other collection types, success rates are lower for obtaining pure *Armillaria* cultures from colonized wood.

Sample storage and transport

Collected rhizomorph samples are typically placed into 15-ml screw-top tubes, but samples can also be placed in zip-lock bags. It is best to keep samples cool and dry during transport and shipment. Typically, ice packs in coolers are used for transport and shipping, while using extra barriers, such as zip-lock bags or paper bags inside an outer zip-lock or trash bag, to keep samples (e.g., basidiocarps, mycelial fans, and colonized wood samples with zone lines) separated. Elevated bottoms made to fit inside the coolers can help keep samples suspended above melted ice during collection trips. Fresh basidiocarps can be wrapped in several layers of paper towel, then placed in a small box or paper bag within a zip-lock bag. An exception to shipping samples overnight with ice packs is when basidiocarps are over-mature or could not be shipped in a timely manner. For this exception, the basidiocarp sample can be dehydrated before shipment. Dehydrated samples are often sufficient for use in DNA-based identification and are sometimes useful for morphological studies and/or species descriptions.

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Changes in intensity of white pine blister rust on western white pine across time, space, and changing climate in the interior northwestern USA

Mee-Sook Kim[1], Jane E. Stewart[2], Marcus V. Warwell[3], John W. Hanna[4], Paul J. Zambino[5], Geral I. McDonald[4], Bryce A. Richardson[4], and Ned B. Klopfenstein[4]

Introduction

Western white pine (WWP; *Pinus monticola*) is a keystone species in temperate, moist forests of western North America, where it displays adaptation to a range of climates and resilience to native root diseases (e.g., Harvey et al. 2008). Since *Cronartium ribicola*, the cause of white pine blister rust (WPBR), was introduced to North America in the early 1900s, WPBR has become well established and caused a dramatic reduction of WWP across its range (e.g., Neuenschwander et al. 1999; Harvey et al. 2008). Over recent decades, casual observations have indicated that WPBR incidence rates may be lower in some naturally regenerated WWP stands than was historically reported in the decades following the introduction of *C. ribicola* into WWP stands of northern Idaho, USA and adjacent regions (G.I. McDonald and others, person observations). In general, WPBR incidence historically increased on average by ca. 3% per year on WWP between the ages of 2-40 years (e.g., Carlson and Toko, 1968; Ketcham et al. 1968). Analyses of recent WPBR incidence rates in regenerated WWP sites may be useful to identify sites with reduced WPBR intensity where natural regeneration of WWP should be encouraged by forest managers to foster forest resilience. Although WWP is considered a generalist with populations that exhibit relatively broad climatic adaptation, ongoing climate change will likely alter its geographic range (e.g., Rehfeldt et al. 2020). For future forests, increased reliance on WWP might offer some resilience to climate change, provided that the concomitant WPBR intensity allows for sufficient WWP growth and survival to maturity.

Objectives

The objective of this study was to revisit a subset of WWP stand sites examined by Carlson and Toko (1968) and determine WPBR disease progress curves on naturally regenerated WWP for a contemporary time period of 15 years (2006-2020) for comparison with historical disease progress curves. The overall goal of this project is to determine if WPBR intensity has ameliorated over the last 60 years, while also identifying areas where WWP regeneration should be encouraged to increase forest resilience to climate change and other abiotic/biotic disturbances.

Materials and Methods

The WPBR survey notes and data from Carlson and Toko (1968) are housed at the USDA Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory in Moscow, ID, USA. During summer of 2021, a subset representing 19 of the 106 historical sites examined by Carlson and Toko (1968) were selected to determine contemporary disease progress for WPBR within naturally regenerated WWP stands in the inland, northwestern USA (northeastern Washington, northern Idaho, northwestern Montana) (Fig. 1). Contemporary survey sites are representative of the geographic range of the survey sites reported by Carlson and Toko (1968) (Fig. 1). At each survey site, a curvilinear transect was followed, with a goal of surveying 30 naturally regenerated WWP of at least

[1]USDA Forest Service – Pacific Northwest Research Station, Corvallis, OR 97331, USA
[2]Colorado State University, Department of Agricultural Biology, Fort Collins, CO 80523, USA
[3]USDA Forest Service – Southern Region, Atlanta, GA 30309, USA
[4]USDA Forest Service – Rocky Mountain Research Station, Moscow, ID 83843, USA
[5]USDA Forest Service – FHP-Region 1, Coeur d'Alene, ID 83815, USA

15 years of age, as available. Branch whorls were counted to determine the age of each tree, and counting whorls from the branch tip determined the approximate age of each WPBR canker, with the assumption that cankers were the result of *C. ribicola* infection of first-year needles (Fracker 1936). Characteristic sign and symptoms (e.g., aeciospore production, orange coloration of canker, branch swelling, branch flagging, rough bark, and/or resinosis) were used for identifying WPBR cankers (Fig. 2). Historical WPBR disease progress curves were constructed using historical WPBR incidence (% of trees infected) data that were collected at the same 19 sites in 1967, including all WPBR cankers on a tree and their approximate ages (year of infection) on felled WWP trees that had been growing since ca. 1940. The 15-year WPBR increase rates (1946-1960) from the historical records were used for comparison with contemporary 15-year (2006-2020) WPBR disease progress curves (Fig. 3). Area under the disease progress curve (AUDPC) was calculated to quantify disease progress curves for both time periods at each site using IdeTo (Simko 2021). Associated tree data, such as DBH, height, GPS location, photographs, and other health issues, were also collected. In addition, perfunctory observational surveys were also conducted to record any alternate hosts of *C. ribicola*, such as *Ribes*, *Castilleja*, and/or *Pedicularis*, at each site.

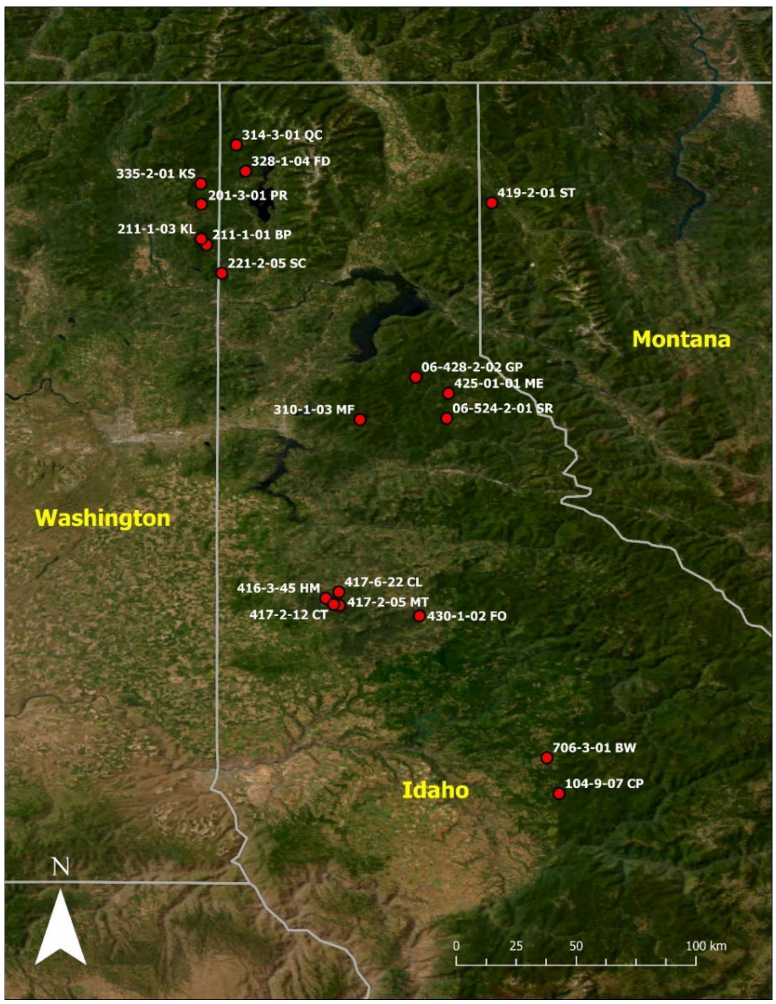

Figure 1. White pine blister rust (caused by *Cronartium ribicola*) survey sites in northern Idaho, northeastern Washington, and northwestern Montana, USA. 335-2-01 KS (Kalispell); 201-3-01 PR (UWB Priest River); 211-1-01 BP (Bear Paw); 211-1-03 KL (Kings Lake); 328-1-04 FD (Fedar); 221-2-05 SC (Snow Creek); 425-01-01 ME (Miners); 310-1-03 MF (Montford); 419-2-01 ST (Star); 417-2-05 MT (PD Masutake); 417-6-22 CL (Charlie); 430-1-02 FO (Fossil Dig); 706-3-01 BW (Browns); 104-9-07 CP (Lolo Polkadot); 416-3-45 HM (Humes); 417-2-12 CT (PD Chanterelle); 06-524-2-01 SR (Saint Regis); 314-3-01 QC (Quartz Crystals); 06-428-2-02 GP (Griffith Peak)

Figure 2. White pine blister rust (caused by *Cronartium ribicola*) canker on western white pine (*Pinus monticola*) with aeciospores present in orange pustules.

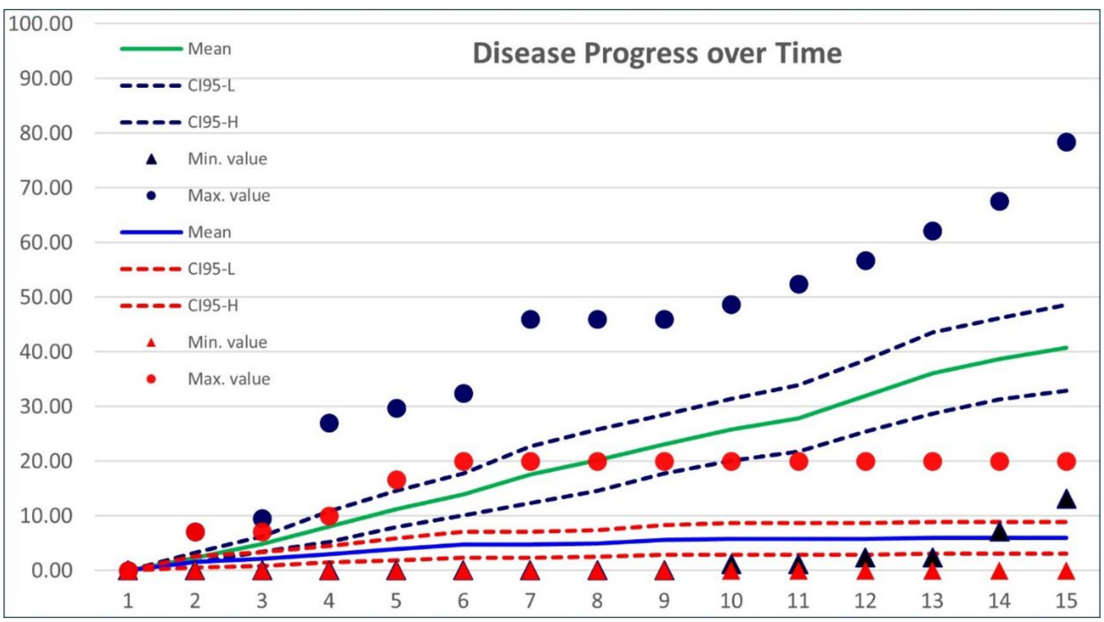

Figure 3. Comparisons of white pine blister rust (caused by *Cronartium ribicola*) canker incidence (Y axis: % of trees infected:) rates on western white pine (*Pinus monticola*) over a 15-year period (X axis) for contemporary (2006-2020: bright blue and red colors) and historical (1940-1954: green and dark-blue colors) time periods at 19 sites. Site locations and abbreviations are described in Fig. 1. Red-colored circles and triangles are WPBR determined from the recent (2020) surveys and dark-blue-colored circles and triangles are the historical WPBR incidence rates that were determined from data collected ca. 60 years before for the 1946-1960 time period. The green line depicts the mean of the historical disease progress curves, and the bright-blue line depicts the mean of the contemporary disease progress curves.

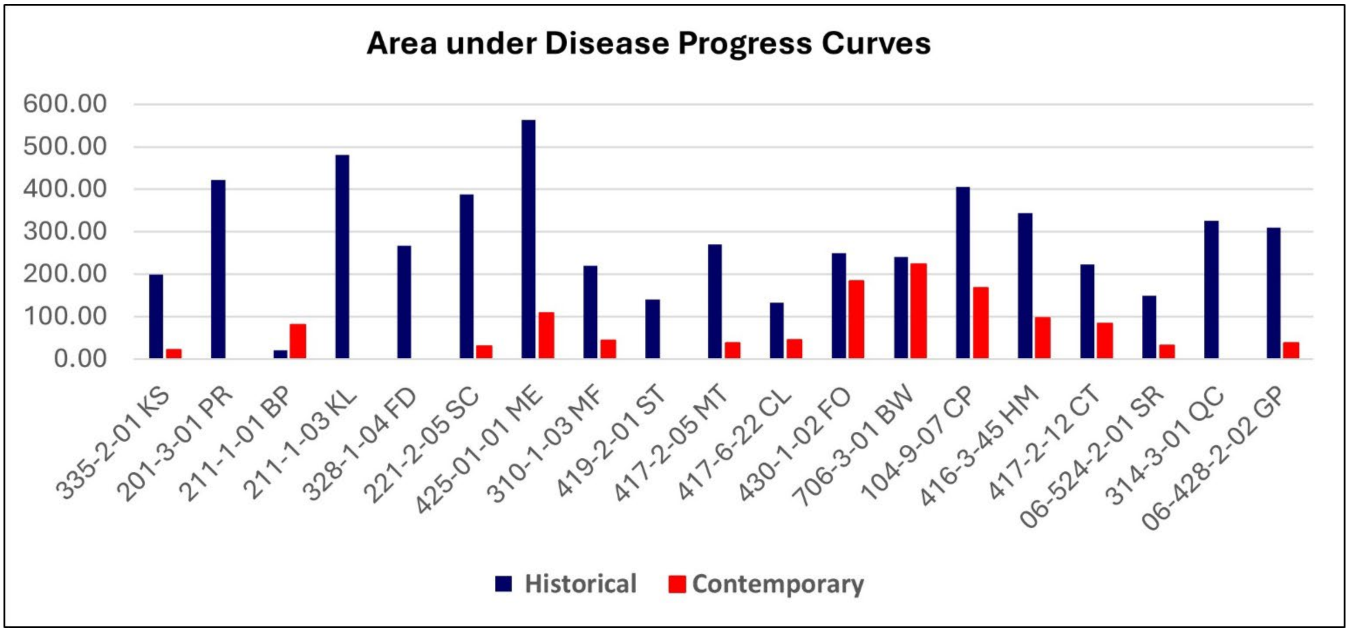

Figure 4. Comparisons of area under disease progress curves between contemporary (2006-2020) and historical (1940-1954) rates of white pine blister rust (caused by *Cronartium ribicola*) on western white pine (*Pinus monticola*). Site locations and abbreviations are described in Fig. 1.

Preliminary Results

- Across most sites, the contemporary WPBR disease progress rates and AUDPCs have decreased compared to the historical WPBR disease progress rates and AUDPCs at the site (Figs. 3 and 4).
- WPBR disease progress rates appear to vary among sites (Figs. 3 and 4)
- For most sites, WPBR intensities appear to be low enough that WWP regeneration should be encouraged, with continued stand monitoring for WPBR.
- The influence of climate on WPBR disease incidence rates does not appear to be significant within the limited area of study; however, further analyses are needed to verify the influence of climate on WPBR.

On-going Analyses

Areas where naturally regenerated WWP is exhibiting low or sustainable WPBR intensity will be identified along with geographic areas where WWP is predicted to remain climatically adapted.

Management Implication

It is unknown if lower WPBR disease progress rates and AUDPCs at most sites is due to increased WPBR resistance in WWP and/or *Ribes*, decreased *C. ribicola* virulence, interaction with other biotic components (e.g., endophytes or other biocontrol agents), interactions with *Ribes*, direct and indirect effects of changes in microenvironment and light conditions (e.g., contemporary denser canopies vs. historical open canopies), or changes in general environmental conditions (e.g., climate or weather). On most sites, rates of WPBR are sufficiently low (≤ 20% after 15 years), and WWP regeneration should be encouraged, especially if future climate is predicted as suitable for WWP. This information may assist resource managers to prioritize areas that appear suitable for WWP restoration through natural regeneration, which will help to counteract anticipated losses in forest productivity and ecological diversity.

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Bioclimatic model-based predictions of potential distributions for four forest root disease pathogens under changing climates in western North America

Duncan R. Kroese[1], Daram Choi[1, 2], David C. Shaw[2], Patrick I. Bennett[3], Ned B. Klopfenstein[3], and Mee-Sook Kim[1]

Introduction:

Root diseases are a major cause of conifer damage in forests of western North America. Two major root diseases in the region, which are caused by native pathogens, are laminated root rot (LRR) disease of Douglas-fir (*Pseudotsuga menziesii*) caused by *Coniferiporia sulphurascens* (Agne et al. 2018; Lockman and Kearns 2016; Thies and Sturrock, 1995), and black stain root disease (BSRD) caused by three fungal pathogens: *Leptographium wageneri* on single-leaf pinyon pine (*Pinus monophylla*) and pinyon pine (*P. edulis*), *L. ponderosum* on ponderosa pine (*P. ponderosa*) and Jeffrey pine (*P. jeffreyi*), and *L. pseudotsugae* on Douglas-fir (Choi et al. 2023).

As the climate changes, suitable climate spaces (potential distribution) for both hosts and pathogens will likely shift (e.g., Kim et al. 2021). Changes in climate that result in increased frequency/intensity of drought and severe heat are also likely to increase forest host stress and damage from root disease (Chmura et al. 2011; Murray and Leslie 2021; Kim et al. 2021). Management options are limited for forest root diseases; however, forest managers can use information about potential distributions of LRR and BSRD pathogens to address these root diseases. This information can be obtained by identifying geographic areas where hosts and pathogens are likely to co-occur based on climatic variables under contemporary and projected future climate scenarios. Establishing and monitoring potential LRR and BSRD risk maps that show potential distributions of pathogens and hosts under contemporary and projected future climates provides critical information to forest managers for minimizing future damage from both root diseases.

Materials and Methods:

Maximum entropy modeling (Maxent version 3.4.4) was performed using presence-only occurrence points (Phillips et al. 2006) for pathogens and hosts. DNA sequence-confirmed, georeferenced location data were used for pathogens: *C. sulphurascens* (N = 50), *L. wageneri* (N=12), *L. ponderosum* (N=10), and *L. pseudotsugae* (N=38). Host location data were obtained from USDA Forest Service, Forest Inventory and Analysis: single-leaf pinyon pine (N=5,219), ponderosa pine and Jeffrey pine (N=29,067), and Douglas-fir (N=45,005). Models were run using 19 bioclimatic variables from WorldClim v2.1 (Fick and Hijmans 2017) at 30-second (ca. 1 km) spatial resolution.

Contemporary (1970-2000) modeling was performed for BSRD (*L. wageneri* – single-leaf pinyon pine; *L. pseudotsugae* – Douglas-fir; *L. ponderosum* – ponderosa pine/Jeffrey pine) and LRR (*C. sulphurascens* – Douglas-fir) (Figs. 1 and 2). Projected future scenarios for *C. sulphurascens* and Douglas-fir (2041-2060 and 2081-2100) modeling was also performed, using Goddard Institute for Space Studies (GISS-E2.1) global climate model (Kelley et al. 2020) under two different shared socioeconomic pathways (SSPs): SSP2-4.5 (a "middle of the road" scenario were trends follow historic patterns in development, energy use, and greenhouse gas emissions) and SSP5-8.5 (a world of rapid, unconstrained growth in economic output, energy use, and greenhouse gas emissions) (Fig. 2).

[1]USDA Forest Service – Pacific Northwest Research Station, Corvallis, OR 97331, USA
[2]Oregon State University, Department of Forest Engineering, Resources & Management, Corvallis, OR 97331, USA
[3]USDA Forest Service – Rocky Mountain Research Station, Moscow, ID 83843, USA

Conclusions:

For all contemporary models, considerable overlap is evident for the predicted suitable climate spaces of each root disease pathogen and their corresponding hosts (Figs. 1 and 2). However, predicted suitable climate spaces for each host are typically larger than that of their pathogens. Geographic areas with predicted climate suitability for the host but not pathogen represent areas where forest managers should expect fewer root disease outbreaks caused by the respective pathogen.

The future scenarios show a significant reduction in suitable climate spaces for both the LRR pathogen and host (Douglas-fir), with a loss of suitable climate spaces in lower elevation, inland areas. While the areas with suitable climate space were diminished, some predicted suitable climate areas overlap for LRR pathogen and host, and these areas appear suitable for LRR development (Fig. 2).

Maxent modeling has demonstrated potential as a valuable tool for guiding forest disease management (Kim et al. 2021). However, Maxent modeling is not without limitations, such as overfitting of models with relatively few occurrence points (Phillips et al. 2006), as could be reflected in the limited availability of presence data for the LRR and BSRD pathogens. And, while a large amount of information on climatic conditions are encompassed in the bioclimate variables used, other environmental conditions, such as water drainage, soil characteristics, slope, elevation, etc., may also influence the distribution of root disease pathogens, hosts, and resulting diseases.

For better informed management decisions, more DNA sequence-verified occurrence points of the LRR and BSRD pathogens would increase the predictive power of these bioclimatic models, and predictive modeling of other host species of *C. sulphurascens*, such as mountain hemlock (*Tsuga mertensiana*), grand fir (*Abies grandis*), and white fir (*A*. *concolor* and *A*. *concolor* x *grandis*), would also benefit from more verified occurrence points for each host species.

Though disease management options are limited, predicted overlapping distributions of the hosts and pathogens represent areas for targeting present and future forest management actions, such as reducing site disturbances, planting or favoring of less susceptible tree species, or other silvicultural treatments to reduce pathogen spread.

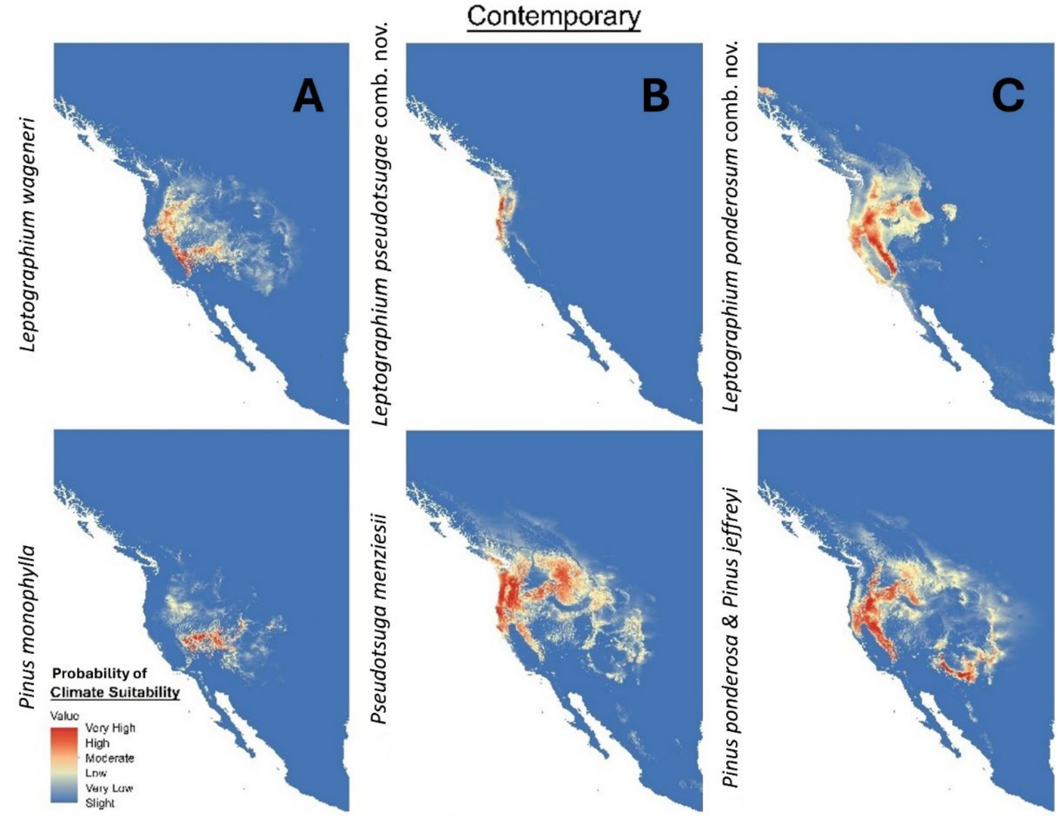

Fig. 1: Maxent bioclimatic predictive models under a contemporary scenario (1970-2000) for black-stain root disease: Leptographium wageneri and single-leaf pinyon pine (Pinus monophylla) (A), L. pseudotsugae and Douglas-fir (Pseudotsuga menziesii) (B); and L. ponderosum and ponderosa pine/Jeffrey pine (P. ponderosa/P. jeffreyi) (C).

Fig. 2: Maxent bioclimatic predictive models under five climate scenarios [Left to right: Contemporary (1971-2000), 2041-2060 SSP2-4.5, 2081-2100 SSP2-4.5, 2041-2060 SSP5-8.5, and 2081-2100 SSP5-8.5] for laminated root rot disease: host Douglas-fir (*Pseudotsuga menziesii*) (A) and pathogen (*Coniferiporia sulphurascens*) (B).

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Development of a rapid field-based detection assay for North American *Onnia Spp*.

Noah Lindeman[1], Patrick Bennett[2], I. Blakey Lockman[3], Brytten Steed[4], Bradley Lalande[5], Maria Newcomb[4], Katherine Minnix [4], Jane E. Stewart[1]

Onnia spp. cause a disease known as tomentosus root rot or red root rot, resulting in volume loss, compromised structural integrity, and mortality of coniferous hosts. *Onnia* spp. can persist on sites for decades and infected trees may show few symptoms prior to mechanical failure. Although several species of *Onnia* are known to exist in North America, their geographic distributions and host ranges are not well understood, creating challenges for proper long-term management. Identification of *Onnia* spp. often requires evaluation of morphological and molecular characteristics. Accurate diagnosis and effective management are particularly important in established recreation areas where infected trees may become hazardous. For this study, we aim to: 1) characterize the phylogenetic relationships between North American *Onnia* spp. and describe their host ranges; and 2) develop a loop mediated isothermal amplification (LAMP) assay for rapid molecular detection of North American *Onnia* spp.

Samples, including wood cores and basidiocarps, were obtained from 15 U.S states and four Canadian provinces. Fresh specimens were plated on selective media for isolation. Isolates were identified via DNA sequencing of the ITS region. To date, *O. tomentosa, O. subtriquetra*, and *O. leporina* have been detected from samples representing four host genera. For samples identified as *Onnia*, the *EF1A*, *RPB2*, and *LSU* loci were amplified and sequenced. The *EF1A* locus was most suitable for the development of the LAMP assay, and a set of primers was developed to identify North American *Onnia* spp. The sensitivity and specificity of the LAMP assay were assessed. Sensitivity was measured by testing the assay on a series of two-fold dilutions until the concentration of the DNA solution was less than or equal to 10pg/µL. Specificity was assessed by testing the assay against 28 geographically distinct North American isolates of *Onnia* spp. and by testing against 12 non-target fungal isolates. Non-target isolates were chosen for their morphological and/or ecological similarities to *Onnia* spp. as well as close phylogenetic relationship. Applicability of the LAMP assay was assessed by testing in the field Wood samples were collected and approximately 0.01g of the wood tissue (approx. 5 mm length of wood core) was subjected to a crude DNA extraction using 5% Chelex and 2% polyvinylpyrrolidone (PVP). This mixture was then incubated at 98°C for 30 minutes. Two microliters of this crude DNA extract was then added to the premixed LAMP reagents and the colorimetric reaction was observed after incubating for 35 minutes at 65°C. DNA extractions were then performed on the same samples with a modified CTAB protocol and confirmed to be *Onnia* spp. through amplification with genus specific primers developed by Gonthier et al. (2015).

We confirmed that the LAMP assay can detect DNA of North American *Onnia* spp. present in wood cores extracted from live standing trees, with reliable detection down to 170 pg/µL for *O. tomentosa*, 80 pg/µL for *O. subtriquetra*, and 121pg/µL *for O. leporina*. The specificity of the LAMP primers allows for detection of *Onnia* DNA exclusively, with no amplification of DNA from non-target fungi that can co-occur with *Onnia*. The LAMP assay is a reliable tool to use in the field, though care must be taken to ensure reagents remain cold (4 °C) at all times to avoid false positives and other spurious results. This rapid field-based molecular assay will allow land managers to more accurately diagnose trees infected with *Onnia* spp. Funding was provided by the USDA Forest Service Special Technology Development Program (STDP-R1-2022-01) through the Western Wildland Environmental Threat

[1]Colorado State University, Dept of Agricultural Biology, Fort Collins, CO
[2]USDA Forest Service, Rocky Mountain Research Station, Moscow, ID
[3] USDA Forest Service, Pacific Northwest Region, State and Private Forestry, Portland, OR
[4]USDA Forest Service, State, Private & Tribal Forestry, Forest Health Protection, Northern Region, Missoula, MT
[5] USDA Forest Service, State, Private, and Tribal Forestry, Rocky Mountain Region, Forest Health Protection, Gunnison, CO

Assessment Center (WWETAC) and was supported by the Rocky Mountain Research Station Forest and Woodland Ecosystems program.

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Assessing the drivers of ponderosa pine (*Pinus Ponderosa*) dieback and mortality

Michael McKee[1], Kelly Burns[2], Mee-Sook Kim[3], Ned B. Klopfenstein[4], Christine McTavish[5], Maria Newcomb[6], Jill Hautaniemi[6], Ashley Hawkins[7], Seth Davis[8], Jane E. Stewart[1]

Ponderosa pine (*Pinus ponderosa*) is among the most important trees species across the western USA landscape. As the most widely distributed conifer in North America, it has immense environmental, economic, and recreational value. Recently, increased dieback and mortality of ponderosa pine has been observed across its native range. The causes of this current landscape-scale dieback and mortality are yet to be identified, but it is hypothesized that contributors are a combination of abiotic and biotic factors. Abiotic factors, such as drought, heat, and other stressors, can weaken trees and affect the progression and severity of biotic factors associated with disease. Since little is known about the drivers of ponderosa dieback and mortality, more research is needed to identify causal agents and their role of declining tree health. The overall goal of this project is to quantify dieback and mortality of ponderosa pine across western states of the USA and assess the associations among biotic and abiotic factors. Our research questions are: 1) What are the biotic and abiotic agents contributing to dieback and mortality of ponderosa pine?; 2) Is the prevalence and severity of observed disease causing/contributing to significant dieback and/or mortality of ponderosa pine?; and 3) Do pathogen drivers of dieback and/or mortality in ponderosa pine differ throughout the western USA? An overarching goal of this study is to determine if ponderosa pine dieback and mortality is associated with the same diseases in multiple locations or if associated diseases vary by geographical region. Areas experiencing less annual precipitation, higher annual temperatures, and damage reported by aerial surveys were selected for field surveys and sampling of potential biotic agents associated with diseases, such as Diplodia tip blight, elytroderma needle cast, black stain root disease, Cytospora canker, and pine wilt disease. In the summer of 2024, we surveyed 21 field sites across five states (Colorado, Wyoming, Montana, Idaho, and California) in the western USA and identified 16 pathogens from various samples of ponderosa pine. Our results will provide valuable baseline data on the causal agents that are contributing to ponderosa dieback and mortality.

[1] Colorado State University, Department of Agricultural Biology
[2]USDA Forest Service, Forest Health Protection – Region 2
[3]USDA Forest Service, Pacific Northwest Research Station
[4]USDA Forest Service, Rocky Mountain Research Station
[5]USDA Forest Service, Forest Health Protection – Region 4
[6]USDA Forest Service, Forest Health Protection – Region 1
[7]USDA Forest Service, Forest Health Protection – Region 5
[8]Colorado State University, Department of Forest and Rangeland Stewardship

Predicting and reframing hemlock dwarf mistletoe in variable retention silviculture

Hanno Southam[1*], Richard Hamelin[1]

Research Problem and Gap

Hemlock dwarf mistletoe (HDM; *Arceuthobium tsugense* (Rosend.) G.N. Jones subsp. *tsugense*) is a common, endemic forest pathogen that infects western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) throughout the pacific northwest. It has dual associations that are common in endemic forest pathogens – it causes negative silviculture impacts (reduced growth, deformities, drought susceptibility) and it plays key ecological roles (canopy structure, nesting habitat, gap disturbance) (Muir and Hennon, 2007). HDM is a common feature of mature forests and as a result, it is favoured by emerging variable retention harvesting systems that aim to emulate natural disturbance patterns and increase the amount of managed regenerating forest growing at an interface with mature forests (Muir and Hennon, 2007; Beese *et al.*, 2019). This management conundrum – a silviculture system that promotes multiple values but increases levels of an endemic forest disease – has been flagged as a research priority. The effect of alternative silviculture systems, like variable retention, on forest disease is an understudied area (Roberts *et al.*, 2020). Specific to HDM, data on rates of spread are conflicting and there are no studies comparing HDM levels under different harvesting systems (Muir and Hennon, 2007).

Framing

There are two distinct and contradictory approaches to framing this research. The first is centred on the increased timber impacts that will arise with the use of variable retention and asserts research is needed to model the extent of this impact so that it can be incorporated into forest management planning. The second is focused on natural disturbance regimes and asserts this research is needed to understand how HDM levels in variable retention replicate those in unmanaged stands subject to a natural disturbance regime. These two framings lead to different management recommendations and research approaches. We support the second, and because of the extent to which framing has shaped this work, it has become a one of the research questions in this project.

Research Questions

(1) How do group variable retention harvesting scenarios impact HDM infection and severity in secondary managed stands in coastal BC?
(2) How do we define forest health for endemic pathogens in multivalued contexts?

Methods

We measured the pattern of HDM spread from interfaces of mature forest (the infection source) and managed 20 to 45-year-old regenerating forest at 11 sites in coastal British Columbia. This field data was used to build an ordinal regression model predicting dwarf mistletoe severity (DMR on an adapted version of Hawksworth's six-point scale) from distance from the infection source, tree size and seed load (a proxy metric for the infection pressure a tree is under). We are currently working on a model that scales these results to stand level.

Expected Results

Expected results include (1) a description of HDM edge spread across a range of representative stands and site conditions in coastal BC; and (2) inferred or modeled scenarios comparing HDM infection under different variable retention scenarios. These results only apply to the time window captured in our study sites (20-45 years), but the

[1]Department of Forest and Conservation Sciences, University of British Columbia, Vancouver Canada
*hsouth11@student.ubc.ca

sites were established as permanent plots and remeasurements will capture longer timeframes. This quantitative work will be paired with a discussion-based article, where we advocate for reframing of endemic pathogens, including HDM, relative to naturally occurring baselines and not against traditional, timber focused, scenarios. This reframing is better aligned with a robust definition of forest health (Carrol, 2023) and removes barriers to the uptake of multivalued forest management systems like variable retention.

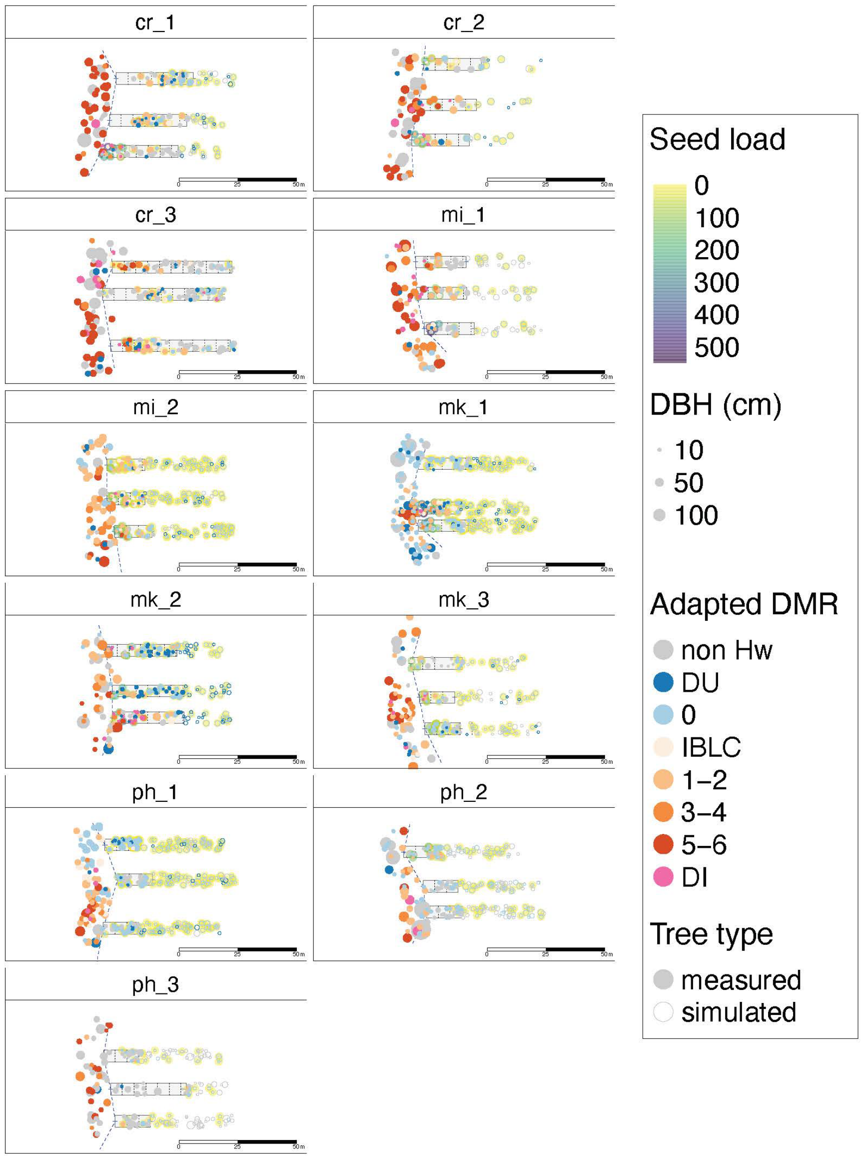

Figure 1. Stem maps showing HDM infection at each of our eleven study sites. A 10m x 55m section of mature forest (>100 years old) with considerable HDM infection is on left side in each panel. A regenerating stand between 20-45 years old is on the right. Live hemlock trees in regenerating stand are overlayed on a background of seed load – a proxy for the seed pressure on each tree from the mature component. DBH = diameter at breast height, DMR = dwarf mistletoe rating, DU = dead uninfected, IBLC = infected below live crown, DI = dead infected. Numbers refer to ratings on the Hawksworth, six class dwarf mistletoe rating scale.

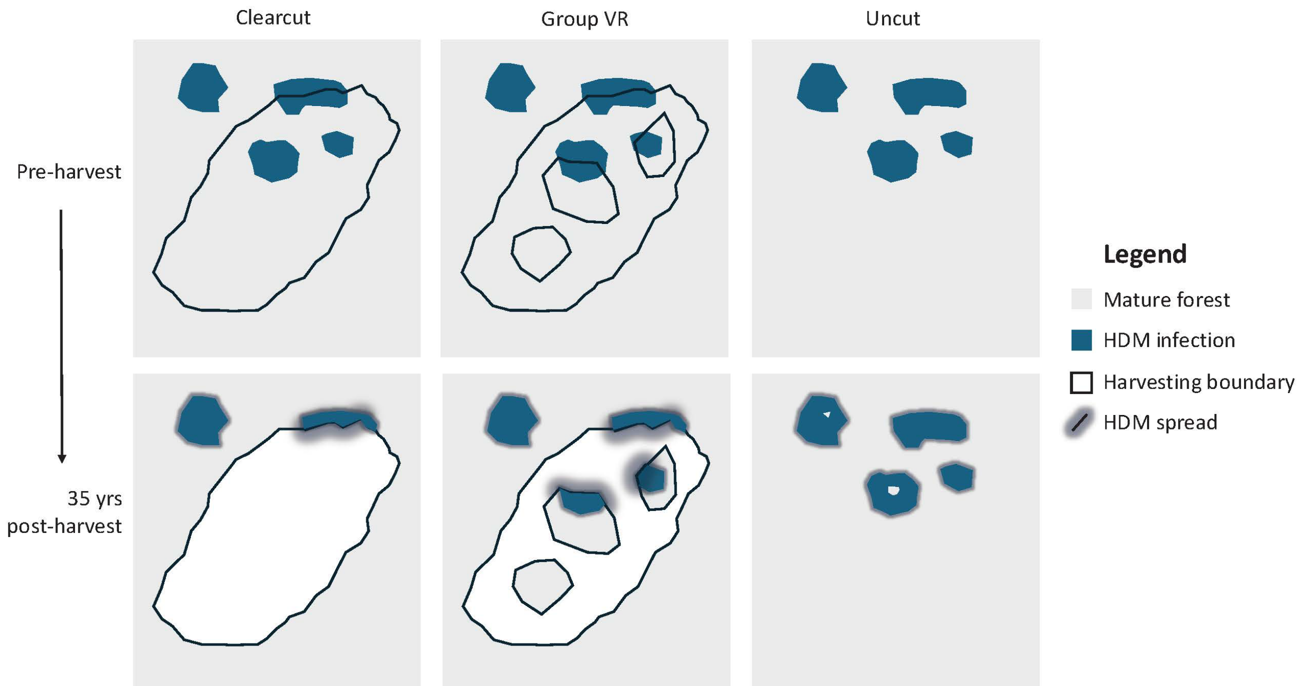

Figure 2. Representative scenarios of HDM spread under different management decisions. Uncut scenario (right panels) subject to a naturally occurring disturbance regime (small scale gap disturbance and infrequent mixed severity wildfire) is what we interpret to be the appropriate baseline to measure HDM infection against in contemporary, multivalued silviculture. In this framing, HDM does not limit the use of variable retention. Instead, variable retention outperforms a clearcut scenario because it generates levels of HDM infection closer to those in the uncut baseline. NOT REAL DATA, FOR DEMONSTRATION ONLY.

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Washington Office Presentation and Q&A

USDA Forest Service – Programmatic Update

Forest Health Protection – Washington, DC

Bruce Moltzan[1], PhD – September 12, 2024

Abstract

Forest Pathology is a distinct program area within Forest Health Protection (FHP) in the Washington DC office. In addition, the WO also carries on work in Entomology, Invasive Plants, Biological Control, Pesticide-Use, Forest Health Monitoring (FHM), and Urban Forest Health. The WO has several Special Project Funding opportunities in STDP, BCIP, Evaluation Monitoring, Genetic Resistance, Emerging Pest and FSPIAP that are evaluated to improve forest pest management. The Pathology Program spans the full suite of pathogens such as, Chestnut Blight, White Pine Blister Rust, Dutch Elm Disease, Sudden Oak Death, Laurel Wilt, Rapid Ohia Death, Beech Leaf Disease and a newly emerging disease caused by *Phytophthora austrocedri* on cedar. The primary function of the pathology work is to direct, provide resources, and assistance to the field pathologists across the US. Coordination across multiple federal, state, tribal, international, and private partners is key to our success. In 2024, approximately $3.2 million was committed accounting for 15% of annual FHP treatments. FHP pathology focuses on the principles of prevention, treatment, monitoring, methods to improve treatment and monitoring and provide technical network of pathologists to build capacity through trainings and workshops in pathogen management. In 2024 an initiative working with Foreign Agriculture Service (FAO) was begun to implement and improve sustainable forest management through biosecurity measures to respond to or manage pathogens through slowing the spread, long-term eradication or forest asset protection. The results of increased phytosanitary requirements will help facilitate international cooperation and open new possible markets.

[1]USDA Forest Service, Washington Office, Forest Health Protection; Washington DC, USA
*bruce.moltzan@usda.gov

Panel: Economics of Forest Pathology

Moderator: Danny Norlander

Attendees congregating in the main room (photo: Greg Reynolds)

Examining biological and financial effectiveness of stump removal for Controlling *Armillaria* root disease

Michael P. Murray[1], David Huggard[2]

Introduction

A common cause of natural disturbance in the forests of the northern hemisphere is a tree root disease linked to *Armillaria ostoyae* (proposed *A. solidipes*). Tree species composition, age, and size structure are frequently influenced by the presence of *Armillaria* in forest stands (Shaw and Kile 1991). Reduced growth brought on by infections is common and often followed by death (Murray and Leslie 2021; Morrison 2011). This disease affects harvest yields in areas where conifer plantations are maintained for the production of wood fiber. The majority of natural tree species in western Canada act as hosts for *Armillaria*. This fungus is found more frequently than all other root pathogens combined in managed plantations in southeast British Columbia (BC) (Merler and others 1993; Nevill and others 1996).

In southern BC, plantations that support *Armillaria* root disease frequently have stumps extracted from the soil shortly after harvest (Figure 1). In preparation for planting, stump removal may drastically lower the volume of the inoculum, or root rot food source (Morrison and Mallett 1996). Because the mechanical removal of stumps incurs financial and potential environmental costs, better understanding of effectiveness can improve land management decisions. We are examining multiple research plantations to estimate and summarize the effects of mechanical stump removal on the development of conifer plantations in southeastern BC.

Further, we are estimating the cost effectiveness of stump removal practices. The Province currently spends more than $2 million per year removing stumps. However, there is a dearth of literature (Bogdanski and others 2017) and much uncertainty regarding the overall financial benefit that stumping may provide once plantations are harvested for revenue.

Figure 1. Removing a stump (post-harvest) before planting new seedlings is commonly practiced in Southern British Columbia to reduce the incidence of *Armillaria* root disease in young plantations.

[1]British Columbia Ministry of Forests, Nelson, BC
[2]Apophenia Consulting, Vancouver, BC

Methods

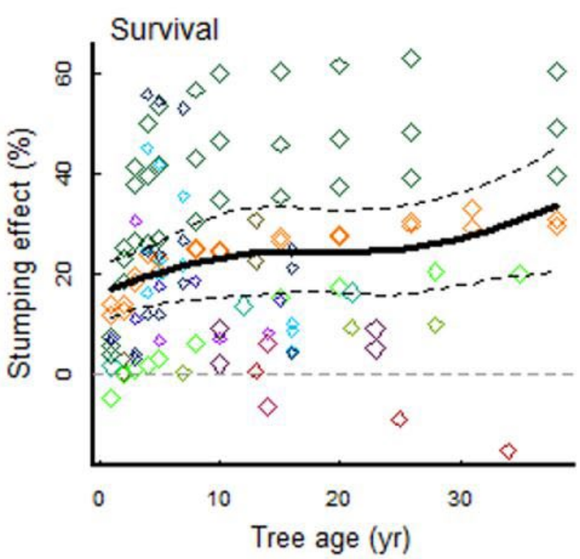
We are analyzing long-term measurements from thirteen silvicultural research trials in the interior cedar-hemlock (ICH) and mountain spruce (MS) zones of southeast British Columbia. Every site was inspected to ensure that *Armillaria* root disease was present prior to harvest and re-planting. For each site, at least one comparison is made between one or more units with mechanically removed stumps and one or more control units without stump removal. Lodgepole pine (*Pinus contorta*), western larch (*Larix occidentalis*), western white pine (*P. monticola*), Engelmann spruce (*Picea engelmannii*), ponderosa pine (*P. ponderosa*), and Douglas-fir (*Pseudotsuga menziesii*) were sampled. Every study tree was tagged, and its growth (diameter and height) and forest health agents were checked about every five years. Plantation ages range 20-38 years. *Armillaria* infection was indicated by mycelial fans, or their imprints. Only dead trees were determined to have *Armillaria* because finding mycelia on living trees would require removing bark, endangering the survival of the tagged tree. Live trees displaying signs of root disease above ground were noted. We recorded tree diameters, heights, vigor, and other forest health agents.

For this stumping analysis, AIC model selection was used. Response variables are summarized for each treatment unit at each site in each measurement year. These include survivorship and *Armillaria* occurrence (the percentage of trees showing signs of *Armillaria* infection in that remeasurement year or previous years). Each study provided one to several comparison units for the synthesis dataset, and all studies had data for more than one measurement year.

A separate analysis is aimed at understanding the costs and benefits of stump removal in a financial scope. To accomplish this, we are inputting our tree data to generate harvest volume forecasts from treatments and controls. Two models are used: forest vegetation simulator (FVS) and the tree and stand simulator (TASS). We then apply a soil expectation calculation (SEV). This represents the sum of all revenues and costs, from stand establishment on bare ground until the end of time, discounted using a given interest rate, to their value at the time of stand establishment.

Preliminary Results and Discussion

We have found Armillaria in all research trials except two. Overall survivorship in the controls averaged 62.3% for tree ages ≤10 years old and 43.6% for tree ages >10 years old. In stump removal treatments, survivorship of planted trees was 20.3% higher for trees ≤10 years old than controls, rising to 33.3% greater by age 38 (Figure 2). Visible signs of Armillaria occurred in 2.6% of trees older than 10 years old and 3.3% of trees older than 20 years in controls. Stumping treatments reduced Armillaria by an average of 1.3 to 1.8 percentage points across the range of older plantations.



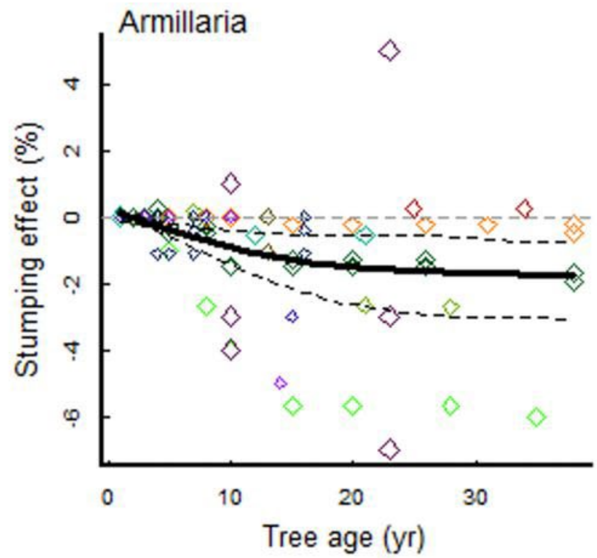


Figure 2. Stumping effects on survival (left) and percent *Armillaria* infection (right) across all studies, for all species combined. The effect is the treatment/control (T/C) value for difference in percent survival or percent *Armillaria* infection. Each study has its own color. Symbol size indicates weighting based on number of replicates. Solid line is average regression line; dotted lines are 5% and 95% percentiles.

Survivorship benefits of stumping were moderate for lodgepole pine, greatest for larch, and intermediate for Douglas-fir. The greater benefits for larch corresponded to lower overall survivorship in the control for this species: 21.1% average after age 10yr, versus 45.4% for Douglas-fir and 60.5% for lodgepole pine. *Armillaria* reduction was greater in Douglas-fir and larch than pine. Pine had the lowest overall occurrence of *Armillaria*: 1.0% average after age 10yr, versus 4.2% for Douglas-fir and 2.3% for larch.

When we examine site productivity, we find that stump removal has the greatest positive effects at moister ICH sites. These tend to be the most productive sites for timber production in Southern BC. While stumping reduced overall infection 1.3% to 1.8%, where stumping did not occur the overall infection was 2.6% to 3.3%. This represents a reduction of *Armillaria* by about half.

Results from our cost-benefit analysis are indicating that the overall financial benefit is strongly related to the productivity of the harvest site. Preliminary findings indicate that removing stumps may only be financially justified at the most productive sites.

Acknowledgements

Adrian Leslie (White Bark Consulting), Levi Robson, Hugh Scorah, Harry Nelson (UBC), the Research Branch of Ministry of Forests (funding), and Katy Fraser (Ministry of Forests), Don Norris and Duncan Morrison.

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Economic analysis of sudden oak death and the impacts to local forestry

Sarah Navarro[1] and Brandon Kaetzel[2]

Sudden Oak Death (SOD), caused by *Phytophthora ramorum,* is lethal to tanoak (*Notholithocarpus densiflorus*) and threatens this species throughout its range in Oregon. In July 2001, the disease was first discovered in coastal southwest Oregon forests. Since 2001, an interagency team has attempted to eradicate and slow the spread of disease through a program of a state quarantine, early detection, survey and monitoring, and destruction of infected and nearby host plants. Eradication treatments, totaling approximately 9,200 acres, eliminated disease from most infested sites, but the disease continued to spread slowly, mostly in a northward direction. Since its initial emergence in Oregon in 2001, four distinct clonal variants of *P. ramorum* have been recognized worldwide. Three of the clonal variants are present in Oregon's forests, the first North American variant (NA1) discovered in 2001, the first European variant (EU1) discovered in 2015, and lastly the second North American variant (NA2) discovered in 2021.

In 2016, the SOD Task Force was established, which convened local, state and federal government agencies, tribes, industry, and local residents and environmental groups. The mission of the Task Force was to develop a collaborative based strategic action plan. Following the strategic action plan developed by the task force, ODF commissioned an economic impact assessment of SOD, completed in 2019. This study relied on empirical special regression based on SOD program treatment and mortality data from 2012-2017. Rate of spread was calculated using a decay function of tanoak percent expressed in years per mile (ypm) under different conditions/dispersal sub-models, which included:

- Alternative A: Treated rate of NA1 dispersal, based on SOD treatment polygons in the quarantine zone but outside the generally infested area (GIA, where no treatments occur), with both NA1 and EU1 variants, northward and eastward.
- Alternative B: Discontinue all SOD treatments from January 1st 2019. Untreated rate of either NA1 or EU1 dispersal, based on mortality monitored via aerial photography within the GIA.
- Alternative C: Treated rate of EU1 dispersal, reflecting prioritized EU1 treatment, based on selected events near Pistol River in 2014.

Under current disease management, the SOD infestation will expand through Curry County between 0.5 and 4.5 miles per year. The SOD program's treatment regime should control the rate of expansion, while halting treatment would most likely accelerate infestation. Continued treatment may constrain SOD south of the Rogue River to 2028 and within Curry County to 2038 (Alternative A). Without treatment, SOD could move north of the Rogue River by 2023 and to Coos County by 2028 (Alternative B). Other disease models under development could provide alternative estimates of SOD expansion, including explicit climate change effects.

The assessment concluded that there would be a 19:1 cost benefit to the southern Oregon economy to continue to slow the spread of SOD under the current management strategy (Alternative A). These savings are largely due to delaying the effects of potential timber export sanctions and the loss of associated jobs, which include:

- Sanctions on southwest Oregon timber exports by China, Japan, and/or Korea
- Loss of 1,200 jobs related to timber export; $57.9 million in annual wages
- Reduction of timber harvest by 15%, with proportional loss of forest products harvest tax revenue, and forest sector jobs and wages

[1]USDA Forest Service, Forest Health Protection, Portland, OR
[2]Oregon Department of Forestry, Salem, OR, USA

- Collapse of rural residential property value; loss of real estate transaction revenues
- Decline in recreation and tourism income if an unfavorable public perception of the region takes hold due to SOD infestation

Potential impacts of SOD strike at core values that elude economic quantification, particularly tribal cultural values and the merits of tanoak-dominated forests. Cultural practices with great historic and traditional meaning—acorn gathering, materials for basket weaving, hunting—are already compromised by SOD but lack a consensus value in market terms. SOD may be an existential threat to tanoak and species that depend on tanoaks; these forests have inherent non-monetary value and may contribute to unrecognized ecosystem or biodiversity values.

Assessing and mitigating the effects of pests and diseases on forest carbon stocks in U.S.

Meg Dudley[1], Kurt Krapfl[1]

Climate change presents a threat to the health and wellbeing of the world's forests. The abundance of many forest pests and diseases has been shown to be exacerbated by a warming climate, and when this occurs the carbon storage within these systems often declines as well.

Meanwhile, forest carbon offset projects have become vital in meeting the goals outlined in the Paris Climate Accord, as some emissions sources are difficult or impossible to abate. The carbon market and forest carbon projects have become prevalent throughout the U.S. and provide important finance needed to fund forest resilience and restoration work, as well as provide a path to meet emission reduction goals.

Mapping and predicting mortality and loss of forest carbon stocks due to pests and diseases has become critical to the forest carbon market, as developing projects in risk prone areas presents a liability that must be appropriately mitigated.

ACR is a leading carbon crediting program operating in global compliance and voluntary carbon markets. Risk assessment of forest mortality resulting from natural disturbances, including insect and disease outbreaks, is a key focus for our program.

Recently, ACR has developed a systematic, geospatial tool that leverages the USFS National Insect & Disease Risk Mapping (NIDRM) pixelated raster dataset to assess pest and disease risk to forest carbon stocks. This presentation demonstrates the application of the NIDRM on a variety of forested ecosystems and a translation of pest and disease risk to a "risk percentage" for a given site. We encourage those interested in learning more about ACR's risk tool or about carbon markets in general to visit our website.

ACR continues to refine our risk tool based on implementation. We welcome engagement from the forest health community on this important aspect of risk management for forest carbon projects.

[1]ACR at Winrock International; Little Rock AR

Panel: Special Papers

Moderator: Danny Norlander

Regis Armijo of Santa Ana Native Plants discussing nursery practices to field tour attendees (photo: Greg Reynolds)

Post-harvest survivorship of endangered whitebark pine

Michael P. Murray[1]

Whitebark pine (*Pinus albicaulis*) is widely distributed in the high-elevation forests of central and southern British Columbia (BC). This is the first tree in western Canada to become federally listed as endangered under the Species at Risk Act. It's also classified as endangered by the International Union for Conservation of Nature and designated as a species of special concern (blue-list) in BC.

In BC, this long-lived tree is often found in forests suitable for harvesting (Figure 1). A study recently examined five historical harvests – all variable retention prescriptions. We analyzed survivorship and growth of retained whitebark pine. We found a strong increase in survivorship with greater tree crown length accompanied by decreasing tree height. Thus, the probability of post-harvest mortality was higher for taller trees with shorter crowns and lower for shorter trees with long crowns. Trees with blister rust cankers had less than 50% chance of survival post-harvest. In examining the importance of neighbor trees, a survivorship probability greater than 50% required a minimum of 7.5 retained neighbor trees within tree height radial distance. For trees that did not survive, we found the vast majority of downed stems oriented in a north-easterly direction from root collar to crown indicating the significant influence of wind from southwesterly directions.

Figure 1. Whitebark pine retention harvest near Elkford, BC.

[1]British Columbia Ministry of Forests, Nelson, BC

Recommendations

Pre-Harvest

- Ensure whitebark pine are accurately classified in surveys and inventories.
- Use Forest Stewardship Plans (FSPs), forest landscape-level planning, wildlife tree reserves, and Old Growth Management Areas as tools to retain.

During Harvest

- Retain healthy trees and avoid damage
- Retain a minimum of eight neighbour trees (neighbours are counted within a radius that equals the target tree's height)
- Retain trees with greater vertical crown lengths as measured along the stem from ground to tip of crown.
- Retain trees of average height. The tallest trees are more prone to wind tipping.
- Orient retention patches according to predominant wind direction

Post-Harvest

- Remove logging slash from beneath retention crowns. Surface fires can readily scorch and kill retained trees.
- Promote regeneration. Based on Provincial stocking standards, whitebark pine is classified as an acceptable or preferred species in many biogeoclimatic units.
- Carefully site seedlings. Although whitebark pine are hardy trees, they are slow-growing and compete poorly with brush and other tree species.

Panel: Genetics Talks

Moderator: Danny Norlander

Attendees search for signs and symptoms during Wedneday’s field trip (photo: Greg Reynolds)

USDA Forest Service National Genetics Program

Arnaldo Ferreira[1]

In coordination with all Forest Service Regions, the National Genetic Resources Program provide ***leadership***, ***training***, ***expertise, and develop policies*** to incorporate genetic principles into the conservation and restoration of forest resources. We provide genetic guidance to decision makers to sustain ecosystem health and conserve biodiversity. We support reforestation and restoration, support healthy forests using geneticially appropriate vegetation, perform tree conservation collections and work with partners.

1. **Provide emergency fire recovery assistance to National Forests. This includes:** seed inventory on-hand, seed procurement, seed collection, seed deployment/transfer analysis, seed increase for future emergencies.

2. **Provide training to National Forests for seed management in:** forecasting seed needs**,** seed procurement planning**,** contract preparation for seed collection increase seed inventory**,** seed biology.

3. **Provide understanding of the level and patterns of genetic variation toward conservation and restoration of species of concern. This includes:** the National Forest Genetics Laboratory (NFGEL) developing molecular genetics tools and interpretation of genetic data for land managers, conservation assessments and conservation strategies based on genetic understanding of the species of concern.

4. **Provide durable genetic resistance to endemic and introduced diseases and pests of forest trees. Steps in this process includes:** selection of potentially disease/pest-resistant forest trees**,** development of screening methods to identify disease/pest-resistant trees**,** breeding to amplify disease/pest resistance among families of forest trees**,** field validation plantings to verify levels of disease/pest resistance under operational conditions.

5. **Provide management guidelines addressing climate change challenges and proper deployment of plant materials for reforestation/restoration developing:** Seed transfer guidelines, Assisted Migration strategies, Seed and Breeding Zone maps.

6. **Provide support for genetic conservation efforts to threatened and endangered plant species, including:** the implementation of *In Situ* and *Ex Situ* Gene conservation strategies, identification of threatened populations and seed collections from at-risk tree species. This includes non-commercial conifer and hardwood tree species, native grasses and forbs.

7. **Provide conduits into research, academic, and private industry arenas. This can take the form of:** plant material exchange**,** presentations and publications**,** participation in Cooperatives**,** team member on administrative reviews**,** collaborate on projects.

8. **Regional Geneticists**: **R1** Andy Bower, **R5** Scott Kopak, **R6** Vicky Erickson, **R8** Marcus Warwell, **R9** Nicholas Labonte, WO Arnaldo Ferreira (Also, overseeing **R2/R3/R4/R10**)

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[1] USDA Forest Service, Washington Office; Washington DC, USA

USFS NFS R6 Dorena Genetic Resources Center

USFS NFS R5 Klamath NF Happy Camp

Lessons learned from successful conifer disease resistance breeding programs in the western United States

Richard A. Sniezko[1], Angelia Kegley[1]

Non-native pathogens and pests can cause high levels of mortality in native tree species. For many of these deadly biotic agents, traditional management activities or biocontrol are of limited assistance in retaining the affected tree species in our native forests or for using in plantation forestry or restoration. Fortunately, tree species usually have some level of genetic resistance to the non-native pathogens and pests. Using seedling inoculation trials and field trials enables forest geneticists and tree breeders to evaluate the level, type and frequency of resistance and its potential for use in the restoration of affected tree species (Sniezko and Nelson 2022). There are now several successful operational resistance programs in forest trees, and among the most notable are those in western North America (Sniezko and Koch 2017; Sniezko et al. 2024).

In the Pacific Northwest, the USDA Forest Service has implemented applied disease resistance programs for both white pine blister rust (caused by the fungal pathogen *Cronartium ribicola*) and for Port-Orford-cedar root disease (caused by *Phytophthora lateralis*). These programs, based at Dorena Genetic Resource Center, have been ongoing for decades, have documented genetic resistance, have begun selective breeding, and resistant seed is now available and being used for reforestation and restoration (Sniezko et al. 2012, 2020a, 2024; Sniezko and Koch 2017; Sniezko and Nelson 2022; Johnson and Sniezko 2021).

The success of a resistance program involves coupling initial research with applied development from tree breeding and tree improvement groups, along with management and public support, assistance from cooperators and a sustained effort over several decades. The objective is generally to develop populations of trees that can produce resistant seed for reforestation or restoration, while retaining adaptability for facing future forest health challenges. Although research is an important component, most of the work will utilize traditional tree improvement facilities, methods, and techniques, including seedling screening assays, field trials and seed orchard development. A full understanding of the number of genes responsible for resistance or the underlying mechanisms is not necessary to implement a successful applied resistance program.

Genetic resistance to non-native pathogens and pests is rare, and thus usually requires testing of a very large number of parent trees or their progeny. Seedling screening assays are an important component of most programs; in the early stages they can be vital for the extensive testing needed and can help determine if there is genetic resistance and the type of genetic resistance, as well as what the level, frequency and geographic distribution of resistance might be (Johnson and Sniezko 2021; Sniezko et al. 2008, 2014, 2020a, 2020b, 2024). Durability and stability of genetic resistance is crucial for forest trees, and field trials established to verify results of screening assays must be monitored over time and a variety of environments to evaluate this (Sniezko and Nelson 2022; Sniezko and Liu 2023; Sniezko et al. 2020b). At this stage, biotechnology may provide some insights but requires well documented phenotypes, and an overreliance on biotechnology may divert essential resources and slow the progress of a resistance program (Sniezko et al. 2023; Sniezko and Liu 2022).

There are now a number of forest tree resistance programs that have been underway for several decades or more, and they can share insights to help newer programs be more efficient. In July 2023, a national workshop convened at Dorena Genetic Resource Center brought together nearly all the applied forest tree resistance programs in the U.S. with the objectives of increasing networking and enhancing the efficiency of all programs; sharing of program successes and failures provided opportunities for enrichment of both newer and well-established programs. There is continuing high international interest in resistance programs, and the 8th IUFRO

[1]USDA Forest Service, Dorena Genetic Resource Center, Cottage Grove, OR

International Workshop on Resistance Mechanisms and Breeding in Forest Trees is scheduled for June 2025 in British Columbia. Continued networking among programs will help maximize the further development of resistant populations of tree species for deployment in restoration and reforestation efforts, helping to ensure healthy future forests.

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Committee Reports

Nick Wilhelmi and Greg Reynolds during the field trip. (Photo: Adam Carson)

Dwarf Mistletoe Committee Meeting Notes

Chair: Brent Oblinger[1]*

The meeting was well attended and facilitated by the new chair, Brent Oblinger, Pathologist in the USDA Forest Service's FHP Central Oregon Service Center. David C. Shaw retired as Professor at Oregon State University this year and was acknowledged for serving as chair for the last ten years, his numerous contributions and contagious enthusiasm for mistletoes and forest pathology throughout this career. See below for some recent examples of Dave's publications involving mistletoes. He was a great mentor in addition to having at least five graduate students work on mistletoe-related projects. A special issue in the journal Botany came out in March 2024, Vol. 102, No. 3 with eight papers from the IUFRO Div. 7 session (7.02.11) in Portugal and was mentioned to the group. Dave Shaw, along with Simon Shamoun and others, provided an introduction to the special issue in *Botany*. Some examples of ongoing mistletoe survey and plot work was also shared from Oregon, Wyoming and Mexico. A call for long-term plot data (at least ten years with a minimum of two measurements) involving dwarf mistletoe was made earlier this year to compare to the USDA Forest Service's FVS Dwarf Mistletoe Model predictions in hopes of revisiting the model. A FS FVS subcommittee working group for the insect and disease models was supportive. Seven or eight datasets were shown as possibilities for this future effort from the western U.S. in Oregon, Montana, Arizona and New Mexico. Limited time was available for a round robin, but Christine McTavish mentioned a remote sensing project that was of interest in Idaho involving drones and aerial imagery to try to detect Douglas-fir infected with dwarf mistletoe. Jim Blodgett provided an update below on recent surveys in Wyoming. Robin Mulvey was interested in effects of dwarf mistletoe severity on growth and survival of trees that were defoliated by insects for future discussion with an example from Alaska involving western hemlock. Charlie Barnes suggested more discussion on management planning for mistletoes and fire interactions for future meetings. Brad Lalande suggested perhaps management of dwarf mistletoes in the context of thinning to reduce the risk of high severity fire or bark beetle-related mortality could be revisited. Betsy Goodrich suggested management of dwarf mistletoes in the context of old-growth and large, old trees be a potential future topic for discussion.

There were three speakers that presented during the meeting. The first presenter was Hanno Southam, a Master's student at University of British Columbia working with Richard Hamelin at UBC and David Rusch with BC Ministry of Forests. He provided an update on his project, "Predicting and Reframing Western Hemlock Dwarf Mistletoe in Variable Retention Harvesting". Some of his research questions include, "How does variable retention influence dwarf mistletoe levels in the regenerating stand of hemlock? & How do we define forest health for endemic pathogens in multivalued contexts?" Hanno shared some background on variable retention harvesting currently and BC policy and management guidelines. He provided thoughts on dwarf mistletoe in the context of forest health and suggested that when dwarf mistletoe occurs in hemlock in BC, its ecological value can contribute to some objectives.

Nick Wilhelmi, Pathologist with the USDA Forest Service, then provided background on some mistletoes unique to Arizona and some that occur throughout the Southwest. He talked about the host range and distribution of multiple *Phoradendron* species including *californicum*, *macrophyllum*, *coryae*, *pauciflorum*, and *densum*. Nick mentioned several dwarf mistletoes and some examples of management of southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum*) in Arizona.

Greg Reynolds, Pathologist with the USDA Forest Service, then gave an overview of dwarf mistletoes in the Land of Enchantment / New Mexico. He discussed the following dwarf mistletoes: pinyon pine, southwestern, Douglas-fir, Apache, western spruce and Chihuahua pine. Examples of mistletoe suppression projects were highlighted on

[1]USDA Forest Service, Pacific Northwest Region, Forest Health Protection; Bend, OR, USA
*brent.oblinger@usda.gov

National Forest system and tribal lands. Applying FVS Dwarf Mistletoe Model predictions was mentioned and identifying issues related to data quality and control from inventory data where mistletoe infections have been confused with other disease infections.

Jim Blodgett provided an update on recent dwarf mistletoe surveys completed in Wyoming. Surveys of lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) were conducted in the Bighorn (93 plots) and Shoshone (59 plots) National Forests (NFs) in 2023. Previous surveys were conducted in the Bighorn NF in 1958, 1979, 1999, 2013, and 2018; and in the Shoshone NF in 2018. Results indicate an increase in dwarf mistletoe disease incidence since 1979 in the Bighorn NF and a slight increase in dwarf mistletoe disease incidence in the Shoshone NF since 2018. For more details, Jim shared two reports listed below that document survey findings.

Blodgett, J. T., Allen, K. K., Schotzko, K., and Wilson, M. 2024. Plot Survey of Dwarf Mistletoe and Comandra Blister Rust Diseases in Lodgepole Pine on the Bighorn National Forest: 2023. USDA For. Serv., Rocky Mountain Region, For. Health Protection Rpt. RCSC-24-09.

Blodgett, J. T., Allen, K. K., Schotzko, K., and Wilson, M. 2024. Plot Survey of Dwarf Mistletoe and Comandra Blister Rust Diseases in Lodgepole Pine on the Shoshone National Forest: 2023. USDA For. Serv., Rocky Mountain Region, For. Health Protection Rpt. RCSC-24-10.

Examples of more recent publications involving mistletoes contributed by Dave Shaw and others are below.

Shaw, D.C., P.A. Beedlow, E.H. Lee, D.R. Woodruff, G.W. Meigs, S.J. Calkins, M.J. Reilly, A.G. Merschel, S.P. Cline, R.L. Comeleo. 2022. Tamm Review: The complexity of biological disturbance agents, fuels heterogeneity, and fire in coniferous forests of the western United States. Forest Ecology and Management. Vol. 525. https://doi.org/10.1016/j.foreco.2022.120572

Hennon, P.E., S.J. Frankel, A.J. Woods, J.J. Worrall, T.D. Ramsfield, P.J. Zambino, D. C. Shaw, G. Ritokova, M.V. Warwell, D. Norlander, R.L. Mulvey, and C.G. Shaw III. 2021. Applications of a conceptual framework to assess climate controls of forest tree diseases. Forest Pathology: https://doi.org/10.1111/efp.12719

Calkins, S.J., D.C. Shaw, and Y-H Lan. 2021. Transformation of western hemlock (*Tsuga heterophylla*) tree crowns by dwarf mistletoe (*Arceuthobium tsug*ense, Viscaceae). Forest Pathology: https://doi.org/10.1111/efp.12664

Shaw, D.C., and C.A. Lee. 2020. Expansion of the invasive European mistletoe in California, USA. Botany 98: 517-524. https://doi.org/10.1139/cjb-2019-0215

Bell, D.M., R.J. Pabst, D.C. Shaw. 2019. Tree growth declines and mortality associated with a parasitic plant increase during warm and dry climatic conditions in a temperate coniferous forest ecosystem. Global Change Biology: https://doi.org/10.1111/gcb.14834

Oester, P.T., D.C. Shaw, G.M. Filip. 2018. Managing Insects and Diseases of Oregon Conifers. Oregon State University Extension, Corvallis, OR. 133 p. Managing Insects and Diseases of Oregon Conifers | OSU Extension Service

Shaw, D., R. Mathiasen, J. Oliva. 2018. *Parasitic Plants*. pp. 138-146 in *Part I. Biotic Diseases* in Compendium of Conifer Diseases, Second Edition. The American Phytopathological Society, APS Press, St. Paul, MN. https://doi.org/10.1094/9780890545980

Shaw, D.C. and M.C. Agne. 2017. Fire and Dwarf Mistletoe (Viscaceae: *Arceuthobium* species) in Western North America: Contrasting *Arceuthobium tsugense* and *Arceuthobium americanum*. Botany 95(3): 231-246. https://doi.org/10.1139/cjb-2016-0245

Pritchard, K.R., J.C. Hagar, and D.C. Shaw. 2017. Avian Abundance and Diversity are Associated with Oak Mistletoe (*Phoradendron villousm*) in Willamette Valley Quercus Woodlands. Botany 95(3): 283-294. https://doi.org/10.1139/cjb-2016-0249

Figure 1. Southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum*) on ponderosa pine at San Diego Canyon Overlook, New Mexico.

Foliar and Twig Committee Meeting Notes

Chair: Adam Carson[1]* (for Jared LeBoldus)

The 2024 foliar and twig committee meeting began with three presentations followed by a round robin discussion.

Presentations

1. Adam Carson gave a presentation on the progress of the second five-year remeasurement (ten-years post establishment) of the Swiss Needle Cast Cooperative research and monitoring plot network. Preliminary data was shared for the first 1/3 of plots measured thus far. Data comparison from the first 5-year period (2013-2018) to the second 5-year period (2019-2023) showed a 23% increase in growth loss during the second 5-year period. This increase in growth loss was estimated assuming the first 1/3 of the plots are representative of the entire plot network, however, Adam pointed out that many of these initial plots are geographically clustered in areas where Swiss needle cast severity is generally high and there are many plots located in areas with historically lower severity levels that are yet to be measured. From this, Adam postulated that the restricted geographic range of the first 1/3 of plots in the network may not accurately reflect actual growth impacts to the entire range of the plot network. Adam also overviewed the results from the 2024 aerial detection surveys for Swiss needle cast in Oregon, Washington, and British Columbia. While the 2024 SNC ADS survey resulted in an all-time record number of symptomatic acres mapped in Oregon (950,000 acres), Washington observed a reduction in symptomatic acres (49,000). The pilot flight in BC was problematic due to weather, terrain, and leaf out.

2. Nick Wilhelmi gave a presentation ongoing canker work being conducted in Arizona. This was in response to calls his office began receiving in 2017 & 2018 regarding observations of cankers on oaks. Upon site visits, large *Biscogniauxia* cankers were found on oaks. Nick showed images of the cankers and described their morphology. Nick reported that the infected trees seemed to die quickly and that a variety of tree sizes were impacted. One casusal species was identified as *Biscogniauxia mediterranea* and there was a second species that was undescribed and the culture was lost. Nick has been collaborating with multiple individuals, including a PhD student, who established a plot network in Arizona to determine disease distribution and environmental correlations. Nick also described observations of Arizona alder dieback associated with cankers and significant insect activity. From these infected alders, samples were collected and *Cytospora umbrina* was identified. Alders are being artificially inoculated and monitored to complete a formal first report. Nick also reported that Gamble oaks in his region are experiencing top dieback associated with *Cytospora ceratosperma*.

3. Robin presented an overview of a common garden yellow cedar shoot dieback trial located north of Juno, Alaska. A brief background of the trial was given, and Robin explained that three additional trials were installed at the same time as the site near Juno. However, all three trials failed due to high tree mortality rates leaving only the Juno site remaining. Images of the disease were shown displaying shoot death that is distinct from freezing injury. The pathogen was identified as *Kabatine thujae*. Robin described the survey123 layout and information that was collected. Information recorded in the study included severity of total percent of shoots impacted, color and ranked of discoloration to inform time of infection, as well as top kill and new leader development. Robin noted that the disease was very common in the study area and that infection levels varied. It was also mentioned that tree sized varied from 1.5-17 feet tall and that

[1] Oregon State University, Swiss Needle Cast Cooperative, Corvallis, OR, USA
*adam.carson@oregonstate.edu

this variation will make it difficult to assess growth impacts. Robin concluded the presentation by pointing out that the variation in disease level offers a unique opportunity to assess the heritability of disease tolerance within these trees.

Round Robin

- Jim Blodget gave an update on South Dakota/Nebraska Diplodia Foresty Health Survey. During early fall a hail event was suspected of causing tree damage (browning shoots), but the damage was too extensive to be caused by hail. Investigations in the fall did not reveal any fruiting bodies, but they were discovered in the spring.
- Mike McWilliams shared that northeast Oregon was seeing extensive Rhabdocline needle cast in naturally regenerating Douglas-fir, but this year the disease has disappeared. Mike suggested that stressed trees, due to climate change or heat domes, we may see more or less disease as a result.
- Robin Mulvey discussed hemlock needle rust on western hemlock and *Vaccinium spp*., Both host species are present in southeast Alaska but extensive disease is not observed. This year, Robin noticed that infected needles seem to drop from the tree and suggested that this may be a natural mechanism of control.
- Adam shared that multiple *Phytophthora pluvialis* flare ups were observed in Douglas-fir plantations in western Oregon in the spring.

Nursery Committee Meeting Notes

Chair: Anna Leon[1]*

The nursery committee meeting centered on recent activities and addressing issues within the nursery community.

The group discussed resources available to help new growers develop given recent retirements, attrition, and new hiring. We discussed Paul Rhoades' new role as the Nursery Pest Specialist with the forest service and his availability to help growers in need. Nabil Khadduri, the new Forest Service Western Nursery Specialist, is also an excellent resource for growers with a broad range of questions. Marianne Elliott shared that Washington State University provides some education services and there is some WSDA money available for those in Washington.

Gary Chastagner, Washington State University, shared several projects that WSU has been working on.

- There has been a shift in popular Christmas tree species, to Turkish, Trojan, and Nordmann fir. Some of these species have phytophthora and balsam woolley adelgid resistance and they have good needle retention.
- Seed issues have been a problem with these new species
    - Metastigmus has been found by APHIS. Their larvae are an issue in transit and there is significant seed loss observed at inspection.
        - A 45°C seed treatment for 48 hours results in 100% metastigmus eradication without effects on germination.
        - Metastigmus issues are a problem in Denmark as well
    - There have been issues with seed viability in storage
        - There is a large range of viability within a single seed processor
        - Most batches of domestic and international seed sources reduced in viability within the 36 months. Only 1 family maintained >50% viability at 36 months and 4 more families maintained >50% viability at 13 months.
        - Temperature differences of -10°C and 18°C had no effect on viability.
        - Drying seed to 4-5% improved seed viability.
- Phytophthoras are an issue on several Christmas tree species, sometimes starting at the nursery. A current question is whether warmer and wetter conditions will impact Phytophthora on Christmas tree species. Testing for susceptibility in Turkish, Trojan, and Nordmann fir is ongoing.
- Australia is currently concerned about the "Douglas-fir conifer plant bug" on incoming shipments. Little is known about the insect, and it is believed to be a hitchhiker on other crops, not on the trees being shipped. More information is needed, but this may result in regulation of imports to Australia.

Ebba Peterson, Oregon State University, shared information about a new North American Phytophthora has been found in Oregon nurseries. It causes an aggressive cyprus root and collar disease and has been found on ornamental conifers, including Jupiner communis and Thuja sp.. There are concerns that it may cause issues on Port Orford cedar. The Phytophthora has been verified by APHIS and Nik Grunwald is looking into how local isolates relate to those in Argentina and the UK. Chris Benemann of the Oregon Department of Agriculture is a good resource to learn more about this disease.

Danny Norlander, Oregon Department of Forestry, told the group about a $750,000 effort to expand the Oregon seed orchard for climate adaptive species and families. Mike McWilliams, USFS, mentioned that forest service

[1]Weyerhaeuser, Strategy and Technology, Centralia, WA, USA
*anna.leon@weyerhaeuser.com

seed orchards are in need of upkeep. There has been renewed interest in using them to help with reforestation, primarily with Ponderosa pine and Douglas-fir. The forest service is also interested in larch but does not have the resources in the seed orchards. The Oregon orchard may be able to fill this gap. Armillaria is occasionally an issue in the orchards.

Kymi Draeger, USFS, discussed spruce beetle kill in Alaska, as well as needle rust on cones collected by the silviculturist. The cones were still closed at the time of collection and the seed was unaffected. Growers in Alaska are concerned about the quality of seedlings being shipped from the lower 48.

Lydia Tymon discussed Mast Reforestation's involvement in a larger effort to figure out what to do with old styro blocks. They also have been testing the use of Ellepot paper containers in the nursery that can be kept on the trees at outplant. They promote air pruning through increased air gaps and the trees have shown less j-rooting. There have been some issues with consistent dry down throughout the bench. Differences are found within the same tray and growers have responded by watering conservatively. It is still unknown if any diseases are an issue under this system. Trees used in this system have been planted in dry areas but have not been planted in coastal regions. It has been useful for sowing automation.

Nursery Committee Meeting Attenndees:

Anna Leon
Paul Rhoades
Diana Tomback
Ebba Peterson
Gary Chastagner
Charlie Barnes
Lydia Tymon
Ned Klopfenstein
Mee-sook Kim
Duncan Kroese
Bradley Lalande
Grace Ganter
Ada Fitz-Axen
Ashley Miller
Sean Wright
Noah Lindeman
Greg Reynolds
Kymberly Draeger
James T. Blodgett
Mike McWilliams
Marianne Elliott
Danny Norlander

Root Disease Committee Meeting Notes

Chair: Patrick Bennett[1]

The breakfast meeting took place Thursday morning, September 12, 2024 at the Hotel Santa Fe in Santa Fe, New Mexico.

Patrick Bennett (Research Plant Pathologist, USFS Rocky Mountain Research Station, Moscow, ID) provided updates on his studies of the diversity of ophiostomatoid fungi associated with pinyon (*Pinus monophylla* and *P. edulis*) mortality across the western U.S. including California, Colorado, Idaho, Nevada, New Mexico, and Utah. Historically, most black staining at the roots and root crown of pinyons has been diagnosed as black stain root disease (BSRD) caused by *Leptographium wageneri* based on signs and symptoms. However, it now appears that other ophiostomatoid fungi are often present and may be contributing to pinyon mortality. *Leptographium terebrantis* has been isolated several times from pinyons exhibiting symptoms of BSRD, and those attacked by red turpentine beetle (*Dendroctonus valens*), in Colorado, Idaho, and Utah. *Leptographium terebrantis* has recently been shown to be pathogenic on loblolly pine (*P. teada*) in the southeastern U.S. Other species recovered from symptomatic pinyons included *Ophiostoma minus*, *O. ips*, *O. montium*, *Grosmannia aurea*, and other *Leptographium* spp. that have yet to be identified. Whether these agents are causing or contributing to pinyon mortality is unclear, but it is likely that some are weak secondary pathogens, while others (e.g., *L. terebrantis*) may be more aggressive.

Mee-Sook Kim (Research Plant Pathologist, USFS Pacific Northwest Research Station, Corvallis, OR) provided a brief update on recent advancements in the taxonomic classifications of *Leptographium* species previously recognized as varieties of *L. wageneri* (Choi et al., 2023). The former *L. wageneri* var. *wageneri,* which affects pinyons, is now *L. wageneri*. The variety formerly referred to as *L. wageneri* var. *pseudotsugae*, which causes BSRD of Douglas-fir (*Pseudotsuga menziesii*), is now *L. pseudotsugae*. The pathogen that causes BSRD on ponderosa (*P. ponderosa*) and Jeffrey (*P. jeffreyi*) pines, formerly known as *L. wageneri* var. *ponderosum*, is now *L. ponderosum*.

Choi, D., Harrington, T.C., Shaw, D.C., Kroese, D.R., Stewart, J.E., Klopfenstein, N.B., & Kim, M.-S. 2023. Phylogenetic analyses allow species-level recognition of *Leptographium wageneri* varieties that cause black stain root disease of conifers in western North America. *Frontiers in Plant Science,* 14, 1286157. https://doi.org/10.3389/fpls.2023.1286157

Charlie Barnes (Plant Pathologist, USFS SP&TF, Forest Health Protection, Region 5, San Bernardino, CA) asked about the effects of fire on BSRD and the survival of *L. wageneri* in stumps, which led to a lively discussion on the lack of evidence and suggestions of future research avenues to investigate these interactions.

Noah Lindeman (MS student, Colorado State University, Fort Collins, CO) presented slides showing the defining characteristics of the three known species of *Onnia* affecting conifer tree health in North America. These were previously known as *O. tomentosa* and *O. circinata*. It is now recognized that *O. circinata* is actually two separate species now known as *O. subtriquetra* and *O. leporina*. *Onnia tomentosa* and *O. leporina* share similar hosts (*Picea, Peudotsuga*, *Tsuga*, etc.), but differ in that *O. tomentosa* has straight hymenial setae while *O. leporina* has curved or “hooked” hymenial setae. *Onnia leporina* also grows directly from host substrate (wood) rather than on the ground like *O. tomentosa*. *Onnia subtriquetra* is similar to *O. leporina* in that it has curved hymenial setae and grows on wood. However, *O. subtriquetra* has only been observed on shore pine (*P. contorta* var. *contorta*),

[1]USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA

lodgepole pine (*P. contorta* var. *latifolia*), and other *Pinus* spp. Further research will be required to determine its geographic distribution, host range, impacts, and management implications of *O. subtriquetra*.

Brad Lalande (Plant Pathologist, USFS SP&TF, Forest Health Protection, Region 2, Gunnison, CO) provided an update on efforts to develop rapid field-based detection assays for important forest pathogens including *Armillaria* spp. (e.g., *A. solidipes*, *A. sinapina*, and others). These assays will employ the loop-mediated isothermal amplification (LAMP) methodology to develop species-specific detection assays that can be utilized in the field on a variety of sample types. This led to further discussion regarding the distinction between *A. solidipes* and *A. ostoyae*. Historically, the aggressive conifer pathogen that is associated with Armillaria root disease of conifers across western North America has been considered to be *A. ostoyae*, a species that exists in Europe and Asia. *Armillaria solidipes* and *A. ostoyae* are very similar morphologically, and **Mike McWilliams** reminded the group that these species are interfertile, suggesting that they are the same species as defined by the biological species concept. A previous publication called for the name of all *A. ostoyae* globally to be changed to *A. solidipes*, since this name had precedence due to it being an older taxonomic name for the fungus (Burdsall & Volk, 2008). This name change raised considerable controversy (Hunt et al., 2011; Klopfenstein et al., 2017), which led to a proposal to conserve the name *A. ostoyae* for the species throughout its range (Redhead et al., 2011). This proposal was accepted by the International Botanical Congress Nomenclature Committee for Fungi. However, at that time, taxonomists did not recognize that the North American "*A. ostoyae*" was phylogenetically distinct from the *A. ostoyae* occurring in Europe and Asia. Burdsall and Volk (2008) suggested that if genetic evidence were found to support the separation of the North American and Eurasian species as distinct, then the North American species should be called *A. solidipes*. Current evidence demonstrates that the species that had been referred to as *A. ostoyae* in North America (i.e., *A. solidipes*) is a distinct species from Eurasian *A. ostoyae* based on the phylogenetic species concept (Guo et al., 2016; Klopfenstein et al., 2017). North American *A. solidipes* is sister species to *A. gemina* (Guo et al., 2016; Klopfenstein et al., 2017). Based on this evidence, Guo et al. (2016) provisionally assigned their North American isolates to *A. solidipes* and Eurasian isolates to *A. ostoyae*. During the committee meeting, **Ned Klopfenstein** (Research Plant Pathologist, USFS Rocky Mountain Research Station, Moscow, ID) provided further context for this, referring to current efforts by Jane Stewart, Ada Fitz Axen, Mee-Sook Kim, and others, to publish an "epitypification" paper to designate a new type specimen of *A. solidipes* from North America, complete with complementary phylogenetic and morphological evidence that demonstrates that *A. solidipes* is distinct from *A. ostoyae*. Following the publication that establishes a new epitype for *A. solidipes*, which will serve as the type specimen (holotype) for *A. solidipes*, use of the name "*A. ostoyae*" for an *Armillaria* specimen collected in North America will no longer be appropriate, unless it is an invasive species.

Ada Fitz-Axen (PhD student, Colorado State University, Fort Collins, CO) presented some preliminary evidence that serves as the basis for the phylogenetic species concept, showing phylogenetic trees produced using DNA sequence data from the translation elongation factor 1-alpha (*tef1*) and other genes, which are currently the most reliable methods to distinguish *Armillaria* species. The phylogenetic trees she presented clearly showed that DNA sequences from *A. solidipes* samples collected in North America are distinct from those of *A. ostoyae* collected in Europe and Asia.

Katie Minnix (USFS R1 FHP, Missoula, MT) asked for clarification on which *Armillaria* species name(s) to use for FHP trip reports. Patrick Bennett and others suggested that using "*Armillaria* sp." is most appropriate unless DNA-based identification is available for species-level designation.

Further reading**:**

Burdsall, H., & Volk, T. J. (2008). *Armillaria solidipes*, an older name for the fungus called *Armillaria ostoyae*. *North American Fungi*, 261–267. https://doi.org/10.2509/naf2008.003.00717

Guo, T., Wang, H. C., Xue, W. Q., Zhao, J., & Yang, Z. L. (2016). Phylogenetic analyses of *Armillaria* reveal at least 15 Phylogenetic lineages in China, seven of which are associated with cultivated *Gastrodia elata*. *PLOS ONE*, *11*(5), e0154794. https://doi.org/10.1371/journal.pone.0154794

Hunt, R. S., Morrison, D. J., & Bérubé, J. (2011). *Armillaria solidipes* is not a replacement name for *A. ostoyae*. *Forest Pathology*, *41*(4), 253–254. https://doi.org/10.1111/j.1439-0329.2011.00730.x

Klopfenstein, N. B., Stewart, J. E., Ota, Y., Hanna, J. W., Richardson, B. A., Ross-Davis, A. L., Elías-Román, R. D., Korhonen, K., Keča, N., Iturritxa, E., Alvarado-Rosales, D., Solheim, H., Brazee, N. J., Łakomy, P., Cleary, M. R., Hasegawa, E., Kikuchi, T., Garza-Ocañas, F., Tsopelas, P., … Kim, M.-S. (2017). Insights into the phylogeny of Northern Hemisphere *Armillaria*: Neighbor-net and Bayesian analyses of translation elongation factor 1-α gene sequences. *Mycologia*, *109*(1), 75–91. https://doi.org/10.1080/00275514.2017.1286572

Redhead, S. A., Bérubé, J., Cleary, M. R., Holdenrieder, O., Hunt, R. S., Korhonen, K., Marxmüller, H., & Morrison, D. J. (2011). (2033) Proposal to conserve *Armillariella ostoyae* (*Armillaria ostoyae*) against *Agaricus obscurus*, *Agaricus occultans*, and *Armillaria solidipes* (*Basidiomycota*). *Taxon*, *60*(6), 1770–1771. https://doi.org/10.1002/tax.606023

Betsy Goodrich (USFS R6 FHP, Wenatchee, WA) showed photos of ponderosa pine stumps recently harvested in north-central Washington that had been “masticated” upon harvesting. She asked the group for ideas about whether they should recommend that stump treatments, such as CELLU-TREAT, should be applied to prevent colonization by *Heterobasidion irregulare*. Some in the audience suggested that they should be treated due to greater surface area exposed to inoculum. Others suggested that they would not recommend treatment because the masticated stumps will dry out more quickly and may be colonized more rapidly by competing fungi. This discussion concluded with a suggestion that further research be conducted to determine whether stump mastication may be a viable alternative to chemical stump treatments for the prevention of *H. irregulare*.

Borys Tkacz gave an update on the Terrestrial Conditions Assessment (TCA) efforts, which used data from Forest Health Assessment and Applied Sciences Team (FHAAST), National Insect and Disease Risk Map (NIDRM), Forest Activities Tracking System (FACTS), Aerial Detection Surveys (ADS), and other sources. This assessment depicts health status and ecological conditions in U.S. forests. Borys suggested that agents such as root diseases were major drivers of many forest health issues across the nation. He also suggested that NIDRM should be updated following development of new root disease models. He requested that volunteers interested in working on revisions of the root disease models in NIDRM contact FHAAST directly.

Rust Committee Meeting Notes

Chair: Kelly Burns[1]* (for Jane Stewart)

Presentations

1. **Overview of rust work in the Southwest Region, Nick Wilhelmi (R3-FHP-Flagstaff, AZ)**

Nick gave a brief overview of work with white pine blister rust, highlighting resistance testing at Dorena Genetic Resource Center; seed orchards in Mora, NM and at Tyrrell in Oregon; and long-term resistance durability test sites located in New Mexico and Arizona. Efforts to monitor disease progression, including spore trapping in collaboration with Colorado State University and a region wide monitoring plot network in collaboration with Northern Arizona University, were also highlighted. A brief overview of common rust diseases of the Southwest was also presented with emphasis on those endemic to the Southwest, including cone rust (*Cronartium conigenum*) and limb rust (*C. arizonicum*).

2. **Assessing differences in *Cronartium ribicola* colonization by needle age class in limber pine, Ashley Miller (Colorado State University, Fort Collins, CO)**

White pine blister rust is a disease on five-needle white pines caused by the non-native invasive fungal pathogen *Cronartium ribicola*. This pathogen is causing widespread tree decline and mortality of limber pine (*Pinus flexilis*) in high elevation forests. Elucidating the infection process is essential for developing solutions for managing the disease. As an obligate biotroph, *C. ribicola* infects pine needles through stomatal pores and parasitizes needle tissue before growing into the stem, causing stem cankers. Limber pine retains 8 to 9 years of needles on shoots, and it is unclear if *C. ribicola* infects and colonizes all needle age classes equally. It is also unknown if there are differences in needle colonization from trees with and without the major resistance gene *Cr4*. To assess these knowledge gaps, limber pine shoots from mature resistant and susceptible field trees were artificially inoculated with *C. ribicola* to assess fungal colonization. Former studies inferred the resistance status (*Cr4* or *cr4*) of the source trees (Schoettle et al., 2014). The shoots were cut underwater in the field at collection and inserted into water-filled vials to retain an intact xylem water column. Inoculation was conducted in a dew chamber with shoots oriented to expose all age classes of needles to the inoculum evenly. The inoculated shoots (and uninoculated controls) were kept watered and under high humidity and grow lights for three weeks after inoculation to allow *C. ribicola* to colonize the needle tissue. At this time, all needles per age class per shoot were harvested, Fv/Fm was measured to assess needle stress, and DNA was extracted. Quantitative PCR was carried out with two species-specific assays, one that targets *C. ribicola* (CRIB190, Bergeron et al. 2019) and one that targets the pine host (AGP6, Krutovsky et al. 2004), and standardized *C. ribicola* DNA quantity (*C. ribicola:P. flexilis*) was calculated (Bertram 2021) for each needle age class per shoot.

To test the impact of needle age class and tree resistance status on needle stress (Fv/Fm), we fit a mixed-effects model with Fv/Fm as the outcome predicted by age class and resistance status, accounting for *C. ribicola* incidence as fixed effects, and tree branch number as a random effect. Using ANOVA, we found that needle stress levels were significantly influenced by the interaction between needle age class and tree resistance status ($F = 2.04$, $p = 0.049$). Stress was lower in youngest needles from shoots from the resistant tree compared to the susceptible tree, but this trend reversed in the oldest needles, where stress was higher in resistant needles. To assess variance in needle colonization, we fit a linear regression model with standardized *C. ribicola* DNA quantity as the outcome predicted by needle age class and tree resistance status. Using ANOVA, we found strong evidence of a linear relationship between standardized *C. ribicola* DNA levels and needle age class when accounting for tree

[1]USDA Forest Service, Forest Health Protection, Lakewood, CO
*kelly.burns@usda.gov

resistance status (F = 3.79, $p < 0.001$). Quantity of *C. ribicola* DNA in the inoculated needle tissue of trees susceptible and resistant to white pine blister rust was not significantly different (F = 1.57, $p = 0.21$).

We will continue to analyze these and complimentary data to further explore these relationships. These preliminary analyses suggest that needles of all ages can support *C. ribicola* colonization. The lack of differences in colonization by tree resistance status provides evidence to support the hypothesis that this resistance mechanism (major gene resistance inferred by *Cr4*) occurs after fungal establishment within the needle.

References:

Bergeron, M-J, Feau N, Stewart D, Tanguay P, Hamelin RC. 2019. Genome-enhanced detection and identification of fungal pathogens responsible for pine and poplar rust diseases. *PLOS ONE* 14 (2): e0210952.

Bertram JH. 2021. Effects of Drought Stress on Early White Pine Blister Rust Development in Limber Pine. Thesis, Colorado State University.

Krutovsky KV, Troggio M, Brown GR, Jermstad KD, Neale DB. 2004. Comparative mapping in the Pinaceae. *Genetics* 168 (1): 447–61.

Schoettle AW, Sniezko RA, Angeli K, and Burns KS. 2014. White pine blister rust resistance in limber pine: Evidence for a major gene. Phytopathology 104:163-173.

Round Robin

1. **Anna Schoettle (RMRS-Fort Collins, CO)**

This winter, we will begin a WPBR quantitative resistance trial with 120 limber pine families, funded by R1 FHP and WO NFS Genetics, at Dorena Genetic Resource Center. Previously, only 74 US limber pine families have been tested for this type of resistance (Schoettle et al., 2022, https://www.fs.usda.gov/research/treesearch/64863). We've awaited both screening capacity and funding for years, so this is great news. Seed sources from across the western US will be included.

We are also continuing the International Limber Pine Provenance Study (ILPPS), which includes seedlings from 30 populations (145 families total) across the Rockies from NM to Alberta/BC. Established in 2016 in northern Colorado and Alberta, this study aims to assess growth and stress tolerance traits to inform seed transfer guidelines and climate change sensitivity. If WPBR becomes common around these plantings, they may serve as *in situ* rust resistance trials or seed sources for future restoration projects.

Additionally, we are maintaining the Southern Rockies Rust Resistance Trial (SRRRT) east of Laramie, WY, where WPBR incidence is high. This trial includes limber and RM bristlecone pine families previously shown to have or lack WPBR resistance. Seed from a subset of these families was used to grow new seedlings for outplanting at SRRRT in 2013-2014. The objective is to assess if resistance that was observed under artificial conditions is expressed under natural conditions (Schoettle et al., 2018, https://research.fs.usda.gov/treesearch/56727).

In FY24, our team at RMRS received BIL funding to establish the Whitebark Pine Resilience Network. This network brings together engaged managers and researchers to co-produce knowledge on the effects of various management actions on whitebark pine resilience within WCS priority landscapes. We aim to develop monitoring methods to assess the effectiveness and trade-offs of operational daylighting, thinning, and fuels treatments on WPBR, mountain pine beetle, and the growth and regeneration of whitebark pine. The project is led by Jason Reinhardt, with team members Stephanie Yelenik, Sharon Hood, and Anna Schoettle. (https://research.fs.usda.gov/rmrs/projects/bil-whitebark-pine-resilience-network)

2. Brad Lalande (R2-FHP-Gunnison, CO)

In southern Colorado, R2 pathologists confirmed the identification of WPBR in Archuleta and La Plata counties in 2024. In coordination with CSU and Mountain Studies Institute, three spores trap were deployed along the East Fork of the San Juan River and collected weekly from Mid-May through Mid-October. A second phenology plot was assess, along the confluence of Flagler fork and Junction Creek on the Colorado trail, north of Durango. Limber pine cone collections were conducted on the East Fork and other locations within the Pagosa Springs RD and sent to Bessey for sowing in January 2025. Two-thousand limber pine seedlings will be delivered and planted in Spring 2027. An invasives grant proposal was submitted to fund five years of WPBR outreach events, cone collections, plantings, and monitoring for the Pagosa Springs RD-San Juan NF.

3. Jim Blodgett (R2-FHP-Rapid City, SC)

In spring 2017, 2018, and 2021, 440 total 2-year-old limber pine (*Pinus flexilis*) seedlings were planted at seven areas in the Norbeck Wildlife Preserve of the Black Hills National Forest (NF), South Dakota. A mortality check in May 2022 indicated seedling mortality was 3.6%. However, a mortality check in May 2023 revealed fire killed all seedlings in area 2. This resulted in an overall mortality of 29.7% (all areas).

In spring 2025, limber pine seedling will be planted at area 2 to replace the ones killed by fire and at three additional areas in the fire-burn. The expectation is areas recently burned are less likely to burn in the near future. The Black Hills NF is also reconsidering establishing new planting areas in the Black Elk Wilderness and is consulting with the Washington Office.

Surveys of comandra blister rust disease (*Cronartium comandrae*) were conducted in the Bighorn (93 plots) and Shoshone (59 plots) NFs in 2023. Previous surveys were conducted in the Bighorn NF in 1979, 1999, 2013, and 2018; and in the Shoshone NF in 2018. Results indicate an increase in comandra blister rust disease incidence since 2013 in the Bighorn NF and a slight decrease in comandra blister rust disease incidence in the Shoshone NF from 2018.

References:

Blodgett JT. 2023. Limber Pine Planting in the Black Hills National Forest (2023 Update). USDA For. Serv., Rocky Mountain Region, For. Health Protection Rpt. RCSC-24-06.

Blodgett JT, Allen K, Schotzko, K, Wilson M. 2024. Plot Survey of Dwarf Mistletoe and Comandra Blister Rust Diseases in Lodgepole Pine on the Bighorn National Forest: 2023. USDA For. Serv., Rocky Mountain Region, For. Health Protection Rpt. RCSC-24-09.

Blodgett JT, Allen K, Schotzko, K, Wilson M. 2024. Plot Survey of Dwarf Mistletoe and Comandra Blister Rust Diseases in Lodgepole Pine on the Shoshone National Forest: 2023. USDA For. Serv., Rocky Mountain Region, For. Health Protection Rpt. RCSC-24-10.

4. Charlie Barnes (R5-FHP-San Bernardino, CA)

Charlie mentioned that White Pine Blister Rust is not a good or descriptive common name for *Cronartium ribicola*. Something like Ribes White Pine Rust would be better. The uredinia and urediniospores on *Ribes* are the source of infection for pine, various *Ribes* species and other plants like paint brush. The urediniospores are responsible for most of the spread of the disease and are what makes it an infectious disease. The rust aeciospores present on white pine are not infectious between white pine trees and can only infect susceptible *Ribes* species. The rust can persist only as urediniospores from *Ribes*, without the need to infect pine and produce aeciospores on pine. This has a significant impact on the white pines because there is no negative feedback on the rust fungal population when the white pines are dying off. There are other examples of rust with these reproductive types (macrocyclic, heteroecious) like leaf rust of wheat. That rust has existed as uredinia in North America without going to the aecial host as long as wheat has been in North America. This rust still adapts to new wheat rust resistance genes bred into wheat because of the genetic variation that exists in its enormous asexual population. Fungi are not like animals and don't rely on sexual recombination of haploids to make new individuals to increase their populations. *Cronartium ribicola*, as its name implies, is firstly a *Ribes* rust.

In southern California, *Ribes aureum* (golden current) produces the largest number of uredinia and likely contributes the most to disease dispersal over distance and to other hosts. Other *Ribes* species, like *R. roezlii*, *R. malvaceum*, and *R. nevadense*, produce less total uredina overall, but at times produce more telia and basidia and therefore may contribute more to infection of local sugar pine.

5. Isabella Valdez (Idaho Department of Lands)

In north Idaho, Isabella observed either absent or very early spore stages of white pine blister rust on western white pine during site visits in late spring/early summer at multiple sites and trees with cankers that fruited last year. The host trees were still alive, however, the cankers appeared to have already fruited with the aeciospores having been dispersed long before she saw the cankers this year. Some of the cankers she had confirmed in previous years also seemed to have had no spermatia or aecia at all this year. She hypothesized this may be due to poor snowpack during winter 2023/2024, since Kelly Burns mentioned incredible amounts of fruiting bodies in Colorado after their impressive snow year.

6. Brent Oblinger (R6-FHP-Bend, OR)

A willow rust epidemic was observed in south central Oregon and northeast California in summer of 2023. On portions of the Fremont and Modoc National Forests, the Melampsora rust outbreak was found in riparian areas across hundreds of acres. The rust was severe along creeks in the Warner Mountains covering the foliage of multiple willow species, such as coyote and Scouler's willows. Although rust on willows has been observed in the past here, the severity of the outbreak had not been documented before at this location. Rust on willows was particularly severe surrounding the Dismal Creek drainage and Dismal Swamp area near the Oregon/California border. Above average precipitation in May, June, and August likely contributed to an increase in incidence and severity of rust on willows in 2023. Early defoliation resulted from severe infection levels at multiple sites. In willows, reduced growth, stress, and increased susceptibility to secondary agents also occurred. A single *Melampsora* species was found on willows at four different sites based on molecular identification and appears to be in the *epitea* complex matching an undescribed species that is closely related to *M. laricis-epitea* (Bennett et al. 2011). After performing PCR and sequencing, the Oregon State University Plant Clinic found the *Melampsora* species closely matched phylotype 'B' in the study by Bennett et al. 2011.

References

Bennett C, Aime MC, Newcombe G. 2011. Molecular and pathogenic variation within Melampsora on Salix in western North America reveals numerous cryptic species, Mycologia, 103:5, 1004-1018, https://doi.org/10.3852/10-289

7. Holly Kearns (R6-FHP-Sandy, OR)

Forest managers in western Oregon are planting large numbers of both sugar and western white pine following recent wildfires, which has given us the opportunity to initiate a pruning study. The study aims to evaluate the effectiveness of five different pruning treatments in reducing infection and mortality by white pine blister rust. To date, two study sites have been established; we plan to establish more study sites in the coming year.

Climate Change Committee Meeting Notes

Chairs: Danny Norlander[1], Michael Murray[2], Susan Frankel[3], Alex Woods[4]

Betsy Goodrich notes:

Had excellent presentation on "How do trees die" by Sanna Sevanto, Los Alamos Labs

Goal of presentation (according to author): overview of how we predict plant response to climate change

Older model: tree vigor matters most, while newer models incorporating physiological approaches to try find bottlenecks in structure and function to build theories

Discussed hydraulic failures vs. carbon starvation in trees:

Sevanto et al. 2014 How do trees die? A test of the hydraulic failure and carbon starvation hypotheses. S Sevanto, NG Mcdowell, LT Dickman, R Pangle, WT Pockman. Plant, cell & environment 37 (1), 153-161

Discussion on roles of ectomycorrhizal fungi and plant water relations:

Benefits of symbiotic ectomycorrhizal fungi to plant water relations depend on plant genotype in pinyon pine. S Sevanto, CA Gehring, MG Ryan, A Patterson, AS Losko, SC Vogel, ...Scientific Reports 13 (1), 14424

Group had good discussion and questions with Dr. Sevanto

Climate Change Round Robin

McWilliams: brought discussion back to presentation and seedlings – are nursery managers priming seedlings for drought impacts?

Group brought up Jeremy Pinto with SPTF (RNGR, USFS National Center for Reforestation, Nurseries and Genetic Resources) and New Mexico State University on that exact work with pinon seedlings – are having discussions in the regeneration programs about this and implementing.

Gary Chastagner: North American species tend to have higher mortality due to drought (plantations, Christmas trees) – all seedlings much smaller than Eurasian species with hot, dry conditions

Conversations on extreme temp/precip variability: Brent Oblinger – central Oregon SC has observed winter injury / red belt at multiple locations recently. Affected by inversion in central Oregon

Kelly Burns – have had similar issues on Front Range, a lot of inversions happening in winter causing winter damage.

Kristen Chadwick – high east winds and extreme wind events in Willamette Valley, have seen a lot of ice storm damage in Cascades

Betsy G – read through extension articles that winter burn is worse on trees in dry soils – have seen winter damage around central Washington after very quick, dry transition from hot October to winter/snow

[1]Oregon Dept of Forestry, Forest Health; Salem, OR
[2]British Columbia Ministry of Lands and Natural Resource Operations; Nelson, BC, Canada
[3]USDA Forest Service, Pacific Southwest Research Station, Albany, CA, USA
[4]British Columbia Public Service, Smithers, BC, USA

Discussion on 'telling our story': Kristen commented on the classic Douglas-fir beetle story possibly changing, Danny Norlander discussed how fire regime in changing in western Oregon and how do pathologists continue to tell the disease story in relation to fire and insect disturbances

Mike McWilliams: thinks that Douglas-fir dwarf mistletoe causing more top dieback and mortality in eastern Oregon (suggested also in eastern WA but not sure if its more than historical) – discussion from group on DM effects on stomatal closure. Excellent publication from Bell, Shaw et al. on hemlock DM and trees with higher DMs associated with mortality.

Robin Mulvey discussed yellow cedar decline projects and shared slides and photos of dying yellow cedar on Zaremno Island = signs and symptoms of YC decline from aerial imagery, and then ground truthed. Unique because she had not seen YC decline in young growth sites. Starting a database on decline across young growth stands (not necessarily modeled to have YC decline). Also saw some trees turn bright red (had Phleosinus spp) and some dying slowly (yellowing, etc). Found some weaker Armillaria species (sinapina?).

Michael Murray – seeing western redcedar dieback consistently with Armillaria root disease in Kootenays of BC. Betsy G. also seeing a lot of WRC dieback across the Metaline Falls to Kettle Falls area in NE WA (not necessarily mortality) – not always associated with ARD but is in some cases because there is so much ARD across that forest type in those area (but are we sampling low enough on roots because having to dig far past root collar in many cases!).

Danny Norlander – ODF used FIA data to quantify recent WRC mortality (10 year?) and found that it is not higher than background levels across various ecotypes of Oregon (paper in works). Discussion amongst groups whether FIA data are appropriate for that type of analysis (are there enough plots in areas of low elevation/private land where WRC dieback is prevalent to represent? Is WRC dieback functionally the same as just recent mortality? FIA probably not picking up crown thinning). Robin M. brought up the misinterpretation of FIA data in various publications on yellow cedar decline (Hennon, Barrett publications). Betsy G. would like to see the FIA analysis to be done across Washington as well and thinks that Washington might have more locations with mortality than Oregon, but there is lack of dieback/mortality at higher elevations across north Washington cascades.

Discussion on the WRC dieback publication (Andrus et al. 2023) that found differences in timing of WRC mortality between westside (western WA/OR) and intermountain populations – 70-80% of mortality occurred in 2017/18 in westside pops but much less mortality, a lack of a 'pulse' of mortality, and more 'dieback only' observed in the intermountain pops in northeastern WA. Seems like between these differences and differences noticed in Alaska that there are strong regional differences in WRC dieback – how do we capture differences but also bring data together and tell the story? What is needed in a case like WRC dieback?

How do trees die? -The physiological mechanisms of tree mortality and their implications to forest ecosystem services. (Session: Climate Change)

Sanna Sevanto[1]

Wide-spread tree mortality events related to drought have increased in frequency and severity over the last 20 years (*e.g.* Allen, Breshears, McDowell 2015; Hammond *et al.* 2022). Therefore, understanding mechanisms leading to tree mortality under drought is becoming increasingly important for predicting changes in forest cover and structure. Predicting tree mortality under drought is challenging because there can be multiple factors that contribute to tree well-being and survival. The old forester's approach for predicting tree survival is based on that

[1] Earth and Environmental Sciences Division, Los Alamos National Laboratory

the trees growing better than their peers are the most resilient. This, however, is difficult to include in large-scale forest models because it requires computationally expensive tracking of growth of individual trees.

To overcome this challenge, based on observations of tree hydraulics and the coupling between water use and carbon uptake, theories on drought effects on tree function and survival have been developed (McDowell *et al.* 2008). The most commonly used tree mortality mechanism framework hypothesizes that desiccation tolerant trees that allow their minimum leaf water potential to decline with increasing drought severity (anisohydric behavior) survive droughts by doing some photosynthesis throughout the drought but risk high water tensions in the xylem and embolism possibly leading to hydraulic failure. Desiccation avoidant trees that maintain a constant minimum leaf water potential under drought (isohydric behavior), close their stomata at relatively low drought severity to preserve water, but if the drought lasts long enough might die of carbon starvation because of absent photosynthetic productivity. These two strategies are linked to survival under different drought scenarios where anisohydric plants are more susceptible to short by severe droughts while isohydric plants succumb to long droughts (Fig. 1). Since their publication, these theories have inspired a large number of studies on forest mortality and mortality mechanisms, and they are used in global-scale dynamic vegetation models to predict tree mortality under drought (Fisher *et al.* 2018).

Figure 1: Tree mortality at the Pajarito Plateau, NM during 2002 drought when most of the isohydric piñon pine trees died while anisohydric junipers survived. This event was used as the basis for the theories on differences in mortality mechanisms between iso- and anisohydric plants. Photo courtesy Craig Allen.

The main challenge in using these theories is that the mortality thresholds of loss of hydraulic conductivity or carbohydrate reserves are poorly known. While most models use a threshold of 50 or 80% loss of hydraulic conductivity for triggering hydraulic failure and tree mortality, there is evidence that some trees can revive from even 90% loss of hydraulic conductivity when rewatered (Hammond *et al*. 2019). Similarly, even if leaf and twig total non-structural carbohydrate (NSC) reserves are the best predictor for timing of tree mortality (Sevanto *et al.* 2014; Dickman *et al.* 2014), some trees die at higher NSC content than others (Sevanto et al.), and the reason for this is currently unknown. There is also evidence that the isohydric species experience higher to loss of hydraulic than anisohydric species even if they close stomata at lower drought severity (Garcia-Forner *et al*. 2016), questioning the plausibility of hydraulic failure as a mortality mechanism related specifically to anisohydric behavior. Generally, use of these theories to predict tree mortality in models results in a population collapse when the hydraulic failure or carbon starvation thresholds are reached. This is different from what is often observed in nature where tree mortality, in the absence of biotic drivers or fires tends to be very patchy.

To capture this patchiness, and predict tree mortality realistically, more research is needed to understand possible alternative mortality mechanisms, phenotypic plasticity and acclimation capacity of trees to new climates (Grossiord *et al.* 2017), as well as resource redistribution in tree communities. An alternative tree mortality mechanism that represents the coupling between the carbon and water transport and their vulnerability under drought is related to the failure of the carbohydrate transport system, the phloem. This tissue relies on the transpiration stream for its water. Under severe drought, it is possible that phloem transport is impaired because of lack of water (Sevanto 2018). This could induce stomatal closure via increasing sugar content in the leaves. While measuring phloem transport and its failure is difficult because of the small size and sensitivity of the phloem tissue (Savage *et al.* 2016) shrinkage of the inner bark and phloem tissue under drought predicts timing of tree mortality relatively well (Sevanto *et al*. 2014).

At ecosystem scale, the desiccation tolerant and avoidant drought response strategies of trees determine the drought severity at which the ecosystem turns from a carbon sink to a carbon source. They also influence the water cycle and availability of newly produced photosynthates to the rhizosphere microbiome. It can be hypothesized that keeping the stomata open during drought could allow the anisohydric trees to maintain their rhizosphere microbiome and connection to the soil resources so that they can revive faster after drought. The isohydric trees, on the other hand, have been observed to become disconnected form the soil during drought and not reconnecting back when precipitation resumes leading to these trees slowly dying after drought once their water with-holding capacity is used (Sevanto *et al*. 2014 Plaut *et al.* 2012). An interesting observation from ^{13}C labeling experiments suggests that trees might exchange carbon via the fungal networks in the soil even between species boundaries (Klein *et al.* 2016). Therefore, especially for the isohydric trees that disconnect from the soil under drought, survival might depend on their underground connections to other trees more than their intrinsic traits.

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Hazard Tree Committee Meeting Notes

Chair: Kristen Chadwick[1]

Attendees:

Kristen Chadwick, James Blodget, Charlie Barnes, Katie Minnix, Noah, Brad Lalande, Chrissy McTavish, Kymi Daeger, Betsy Goodrich, Kelly Burns, Adda, Nick Wilhelmi, Greg Reynolds, Sean Wright, Holly Kearns, Jill Hautaniemi, Robin Mulvey, Mee-Sook Kim, Ned Klopfenstein, Lori Winton, Mike McWilliams, Adam Carson

Kristen opened the meeting with an update about the recent western hazard tree workshop. It was reported that the meeting was very successful with good attendance. The 2026 workshop was discussed and Kristen mentioned the need for a secretary since the 2023 workshop went without and this is a critical role to ensure workshop proceedings and compiled. For the 2026 workshop, a written proposal prepared by James Jacobs was read in which James proposed moving the upcoming meeting out of the west to make it more nationwide. James proposed hosting the meeting in Minneapolis / St. Paul. Interest has been expressed from the eastern colleagues. Kristen opened the floor for discussion.

Discussion around moving the meeting out of the west commenced with a bit of discussion on how eastern pathologists have attended and supported the meeting in the past, including preparation of the proceedings. Concerns included removing the western emphasis may run a risk of prohibiting the attendance of some forest service pathologists due to leadership pushback in certain regions. Concern around pushback could be due to these supervisors questioning the value of the meeting (not monetary). Kelly Burns suggested keeping the west-focused but occasionally move the meeting eastward. Holly voiced concern that there could be too many people if the meeting was nationwide which would run into meetings management issues for FS attendance. Robin suggested that a full day of travel on either end could result in an even shorter meeting and requested that some of the presentations be available virtually. This was discussed. One difference with the Western Hazard Tree Workshop compared to WIFDWC is that it is only three full days (Tuesday-Thursday) allowing participants to travel on Monday and Friday, which has more flexibility for travel than the 3.5 days of WIFDWC. Additionally, there is typically 1.5 days of field trips. The difficulties with a combined virtual attendance and physical attendance were discussed which included attendance fees and complications associated with the private sector and having presentations recorded. It was agreed that this could be resolved or worked around in the future.

A possible name of the workshop should it be moved out of the west was discussed. Holly suggested a "North American Hazard Tree Workshop" hosted by this wifdwc committee could be used.

Charlie, as supported by Martin McKenzie, presented a proposal from Martin (not present) to host the next meeting in Sequioa National Park to see unique pathology and fire-related issues. A discussion about what city/town the workshop would be hosted in with questions about the cost of travel and local per diem rates might drive attendance (and meetings management for the FS) at for the Minneapolis/St. Paul or Sequoia NPS. Kristen proposed putting together a group to discuss the potential meeting locations with Martin and James Jacobs. Kymi, Charlie, and Holly agreed to assist with this. Brad offered to assist with putting together a cost benefit analysis. A vote was held for both locations and the California location won more votes, but it was agreed that both options should be considered and explored within the confines of feasibility of travel and potential budgets.

From the FS side, Robin asked how frequently the FS handbook is revised? She also stated that there is no mention of hazard trees in the development section. Kristen said the recreation version was updated in 2021 and the roads fairly recently as well, and that the concessionaire handbook is currently being updated. Robin clarified

[1]USDA Forest Service, Forest Health Protection, Sandy, OR, USA
*kristen.chadwick@usda.gov

that she is referring to FS handbook direction on creation of potential new recreational sites and that hazard tree and vegetation management concerns are not mentioned. Kristen suggested talking to Bruce about this matter.

A lot of discussion about FS pathologists working with, training, or accessing concessionaire operated campgrounds ensued. Each region seems to have taken direction from the WO differently depending on the support of those at the regional level. Kelly Burns mentioned that there was push back regarding the inclusion of concessionaires and having trainings at concessionaire campgrounds. Brad mentioned that the Hazard tree road show scared off the inclusion of concessionaires. Concerned was voiced about the lack of recreation folks attending trainings by multiple people. Robin asked, how can we increase our communication effectively as a group? Kristen reassured the group that the policy is not the responsibility of this group, only training is. Charlie shared their training occurs around the same time every year, in May, and that this is helpful with recruiting attendance. Kristen proposed discussing this with Bruce and asking him to provide better guidance. Kristen asked if the group would like to set up an additional meetings with FS pathologists about hazard tree programs and specifically working with Forest staff and concessionaires Kristen suggested having virtual meetings and to make an effort to stay in touch more frequently regarding this and other related issues. Betsy offered to host these meetings on a semi-regular basis and invite Bruce to attend.

Round Robin:

Additional discussion of the complexities of the HT program in the FS were discussed as part of the round robin including what to name training sessions etc.

Kristen mentioned that the updated region 6 guide will be printed soon. This will include a two-tiered training and survey approach designed so that people with little to no tree knowledge can do the most basic surveys looking for dead trees and obvious tree defects, this would include concessionaires and engineers for road systems. A draft will be sent out once it is prepared.

Danny shared that Oregon state parks closed Beverly Beach campground, but it is now re-open, and all the prior hazard trees have been dealt with!

Mike McWilliams shared that he keeps his own list of rec personnel and would keep the rangers out of it when hazard tree work was needed. He recommends communicating directly with them.

Submitted for the proceedings from Jim Blodgett for R2:

Rocky Mountain Region: *Hazard Tree Evaluation Using Survey123* was updated in December 2023 (Blodgett et. al. 2023). The associated *Survey123* form was also updated. Among other improvements the form now has a single-tree report template and two summary report templates for all trees selected. The ability to enter host genus and species was added if it was not in the original species list and a management/mitigation field was added. *Tree Failure Evaluation Using Survey123* was updated in January 2024 (Blodgett et. al. 2024). This *Survey123* form was also updated. Among other improvements, the form now has a single-tree report template and the ability to enter host genus and species was improved. Region 2 also has a *Survey123* version of the *International Tree Failure Database* (ITFD)*.* Data from this version is compatible with the previous online ITFD and with the Region 2 *Tree Failure Evaluation Survey123 form.* However, Region 2 has not updated the ITFD guide since it is not currently being used in the Region. Brad Lalande has recently taken the lead for the Region 2 hazard tree *Survey123* products.

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Kymi Draeger investigating possible pathogen activity during the field trip (photo: Adam Carson).

Other Reports

Landscape view from Wednesday's field trip (photo: Adam Carson)

2024 Student Awards Committee Report

Betsy Goodrich[1], Kelly Burns[2], Joey Hulbert[3]

The Student Travel Award Committee reviewed excellent applications and awarded seven students (three PhD students and four MS students from three Universities) travel awards totaling **$2,850**.

Congratulations once again to the following students: Ashley Miller, Ada Fitz Axen, Noah Lindeman, Grace Ganter, Hanno Southam, Michael McKee, and Jorda Kovash.

Thank you again to everyone who donated items for the silent auction. Through their generous donations and the excellent participation of the attendees the silent auction raised $505. In addition, there was a donation of $1000 from Weyerhaeuser, $25.00 contributed from individual donations online, and 36 regular WIFDWC member registrations (at $30 each) which added **$2,105**, so the Student Travel Award account currently has a balance of **$4,542**.

Action shot from the silet auction (photo: Adam Carson)

[1]USDA Forest Service, Pacific Northwest Region, Wenatchee, WA, USA
[2]USDA Forest Service, Rocky Mountain Region, Forest Health Protection; Golden, CO, USA
[3]Department of Plant Pathology, Puyallup Research and Extension Center, Washington State University; Puyallup, WA, USA

Business Meeting Notes

Secretary: Adam Carson[1]*

The WIFDWC business meeting was called to order by the Meeting Chair, Lori Winton, at 15:30 on Tuesday, September 10, 2024.

NEW BUSINESS

Deceased members

A moment of silence was held for known and unknown deceased WIFDWC members.

WIFDWC 2025

Michael Murray presented information regarding the prospect of holing the meeting in Nelson, British Columbia in the late summer of 2025. The natural beauty and forest types of the surrounding area were mentioned. Transportation logistics were also discussed as there are no major airports located within the city of Nelson. A discussion was also had regarding the logistics for approving international travel for USFS personnel. A motion was made to hold the meeting Nelson BC in 2025 which was seconded and passed with all in favor.

The Railroad committee (Betsy Goodrich, Christy Cleaver) proposed the following new Planning Committee and officers: conference chair (Michael Murray), program chair (Danny Norlander), secretary (Isabella Valdez), and webmaster (Danny Norlander). A motion was made to accept these nominations which was seconded and passed with all in favor.

WIFDWC 2026+

A motion was made by Sean Wright to hold the 2026 meeting in Coeur d'Alene, Idaho which was seconded and passed with all in favor.

Treasurer's report

Holly Kearns overviewed the 2023 treasurer's report, noting that due to the high cost of the previous meeting in Rhonert Park, California, the international sponsorship fund was zeroed out, however, the Western Hazard Tree Workshop of 2023 was 'profitable'. In 2024, there were 48 meeting registrants including 2 single day registrants, 8 graduate students, and 2 retirees. Holly also mentioned that the Student Travel Award fund is in good shape due to a generation contribution from Weyerhaeuser Co., which was secured by Anna Leon.

Committee updates:

*Note: Due to the business meeting being scheduled on the second day of the conference, multiple committee meetings had not yet occurred restricting the number of meeting updates that could be given.

- Mistletoe: There was good attendance at this meeting which included short round robin discussion and three presentations. Hanno Southam gave an update on his dwarf mistletoe on western hemlock project, Nick Wilhelmi presented on mistletoes in Arizona, and Greg Reynolds gave some background on mistletoes in New Mexico.
- Foliage and twig: Adam Carson filled in for Jared LeBoldus, who will be back next year. The meeting was well attended and included three presentations followed by a round robin discussion. Adam Carson gave

[1] Oregon State University, Swiss Needle Cast Cooperative, Corvallis, OR, USA
*adam.carson@oregonstate.edu

a research update on the activities of the Swiss Needle Cast Cooperative as well as an overview of the aerial detection survey results for Swiss needle cast in Oregon, Washington and British Columbia. Following this, Nick Wilhelmi gave a presentation regarding ongoing canker work occurring in Arizona, and Robin Mulvey overviewed a common garden yellow cedar shoot dieback trial located north of Juno, Alaska.

- Hazard tree: As the committee had not yet met at the time of the business meeting, a meeting update could not be given. However, Kristen Chadwick reported on the Western Hazard Tree Workshop that occurred in the fall of 2023 in Wenatchee, WA, and stated that there was good attendance and was a highly productive.
- Student Travel Award: This year seven students were awarded and funds were not exhausted. A motion was made to reduce the application requirements from two letters of recommendations to one, which was seconded and passed with all in favor. The current committee includes Kelly Burns, Betsy Goodrich, and Joey Hulbert who are happy to continue serving.

Other business

Proposals given during the 2024 business meeting were revisited, which included giving more networking time by moving all committee meetings to the first day, reducing committee meetings to round robin discussions only, and restricting talks to 15 minutes and/or having fewer talks, as well as adding an additional day to the conference. Lori Winton encouraged attendees to note how and if the current agenda increased time for networking, without specifically adopting the aforementioned proposals, and to give feedback to the 2025 planning committee.

An update from the ad hoc social media committee was requested. The committee was formed last year and includes Joey Hulbert, Betsy Goodrich, Danny Norlander, Robin Mulvey, Ada Fitz Axen, and Yung-Hsiang (Sky) Lan. This committee was tasked with coming up with ideas to communicate with the public. The committee reported that no notable progress had been made. A motion was made to shelf the ad hoc committee for the foreseeable future, which was not officially passed. Danny Norlander suggested setting up a webpage on the WIFDWC website to be made available to members to add content. Danny will investigate if the website is suitable for this purpose and will report back to the members. Anna Leon suggested sending out a digest to members regularly to encourage activity on the website. Adam Carson proposed setting up a WIFDWC slack channel.

A discussion was had about the reduced attendance of the current meeting. Lori Winton noted the recently reduced maximum spending allowance within the Forest Service meetings management system as one cause. Lori Winton shared that scheduling the meeting earlier in the year was suggested by the Washington office as a means of reducing travel restrictions. This prompted a conversation regarding the advantages and challenges associated with scheduling the meeting during various times of the years. Concerns were raised about possible restrictions on international travel within the Forest Service prohibiting some members from attending the 2025 meeting in Nelson, BC.

The conversation regarding low attendance prompted a discussion about the prospect of expanding the 2027 meeting to include attendance beyond WIFDWC members. Holly Kearns proposed exploring the possibility of combining the 2027 WIFDWC meeting with the Western Forest Insect Work Conference (WFIWC). Danny Norlander asked if the members would like to consider hosting a national pathology meeting that would include pathologist from all regions as an alternative to combining meetings with WFIWC. Mike McWilliams commented that the WFIWC meeting is very large and that the entomologist may not have much interest in pathology portion of a combined meeting.

Lori Winton proposed drafting a justification of attendance document to be included in the attendee detailed cost analysis spreadsheet (ADCAS) package for pathologist attending pathology meetings. This suggestion was well received. Mike McWilliams mentioned that WIFDWC had previously written a letter of justification to the Washington office. Lori also proposed that the annual task of completing the ADCAS be assigned to the same individual each year. Brad Lalande volunteered to be this person and Betsey Goodrich offered to assist. Lori also suggested that all members include meeting attendance on their individual development plans as critical training as an additional means of justification for attendance.

Danny Norlander set a motion to have the meetings management position become a standing position to be voted on every 5 years. This motion was not passed, but a motion was made by Sean Wright to revisit this topic at the business meeting in 2025, which was seconded and with all in favor.

Banquest enthusiasm (photo: Adam Carson)

Treasurer's Report

Treasurer: Holly Kearns[1]*

The 69th Western International Forest Disease Work Conference in Santa Fe, New Mexico had 48 attendees including 36 regular members, 8 graduate students, 2 retirees, and 2 single-day registrants. The following is a summary of transactions for the WIFDWC accounts from 1/1/2024 through 12/31/2024.

	Income / Expense	Balance	Total Account
All WIFDWC Accounts balance 12/31/23			**$25,470.04**
WIFDWC Meeting Account balance 12/31/23		$10,057.33	
2024 WIFDWC			
Total registration	22,374.91		
Hotel meeting rooms, meals & breaks	-16,129.42		
Field trip transportation	-2,361.84		
Field trip snacks and entry fees	-297.24		
Souvenirs	-706.67		
Awards	0.00		
Office supplies	-71.29		
On-line ticketing	-141.00		
TacBoard	-159.00		
Regular member registration fees to STA Fund	-1,080.00		
WIFDWC Meeting Account balance 12/31/24		**$11,485.78**	
Hazard Tree Committee Account balance 12/31/23		$10,630.71	
No activity			
Hazard Tree Committee Account balance 12/31/24		**$10,630.71**	
Student Travel Award Fund balance 12/31/23		$4,782.00	
2024 Silent Auction Proceeds	505.00		
2024 Regular member registration fees (36 @ $30)	1,080.00		
2024 Individual Contributions	1,025.00		
2024 Student Travel Awards	-2,850.00		
Student Travel Award Fund balance 12/31/24		**$4,542.00**	
All WIFDWC Accounts balance 12/31/24			**$26,658.49**

The WIFDWC Federal Tax Identification Number is available upon request.

[1]USDA Forest Service, Forest Health Protection; Sandy, OR, USA
*holly.kearns@usda.gov

Outstanding Achievement Award Recipients

Year	Recipient	Meeting	Comments
2000	Lew Roth	Kailua-Kona, HI	For pioneering work on *Phytophthora lateralis*, Armillaria and dwarf mistletoes, and for inspiration and leadership of a generation of plant pathology students and colleagues.
2000	Duncan Morrison		For long-standing contributions to forest pathology research, especially in relation to roots diseases and tree hazards.
2001	Bob Gilbertson	Carmel, CA	For contributions to the taxonomy and identification of wood-inhabiting basidiomycete fungi.
2002	No award given		
2003	Everett Hansen	Grants Pass, OR	For strong leadership in forest pathology including research on the biology and management of tree and seedling diseases of western conifers
2004	Bob James	San Diego, CA	For strong leadership in forest pathology especially technology transfer and research on the biology and management of forest nursery diseases for growers and nursery pathologists throughout the West.
2005	Walt Thies	Jackson, WY	For sustained long-term high-quality research on laminated root rot and other root diseases of forest trees.
2006	Bart van der Kamp	Smithers, BC	In recognition of outstanding lifetime contribution to tree disease research and for inspiring a generation of students and colleagues in the field of forest pathology.
	Alan Kanaskie		For outstanding leadership, as a practicing forest pathologist, in the management of Swiss Needle Cast.
2007	Richard Hunt	Sedona, AZ	In recognition of his valuable research and extension efforts on white pine blister rust, along with many other contributions to forest pathology and biology.
2008	No award given		
2009	Bill Jacobi	Durango, CO	In recognition of his 30-plus years as an educator, researcher, organizer, advocate and practitioner of forest pathology.
	Bob Edmonds		In recognition of his 40-plus years as an educator, researcher, organizer, advocate and practitioner of forest pathology and ecology.
2010	Paul Hennon	Valemount, BC	For sustained, significant contributions to our knowledge and understanding of forest disease dynamics and ecology.
2011	Susan Frankel	Leavenworth, WA	For leadership in the science and practice of forest pathology and for critical contributions to the management of Sudden Oak Death.
	Ellen Goheen		For leadership in the science and practice of forest pathology and for critical contributions to the management of Sudden Oak Death.
2012	John Schwandt	Lake Tahoe, CA	For the energy, enthusiasm, and integrity which he has invested in the professions of forest pathology and forest management.
2013	Don Goheen	Waterton Lakes, AB	In honor of your 35 years of dedicated service to forest pathology as a researcher, leader and mentor of others.
2014	Terry Shaw III	Cedar City, UT	In recognition of broad western U.S. and international experiences, and dedicated mentoring and storytelling.
	Willis R. Littke		In recognition of a valuable industry perspective, support for WIFDWC Nursery Committee, international experience, mentoring and storytelling.

<table>
<tr><td>2015</td><td>Brian Geils</td><td>Newport, OR</td><td>In recognition of a creative scientist with a broad range of interests, a high level of enthusiasm and curiosity, and a great guy to be with in the field.</td></tr>
<tr><td>2016 - 2018</td><td colspan="3">No award given</td></tr>
<tr><td>2019</td><td>Greg Filip</td><td>Estes Park, CO</td><td>In recognition of a lifetime of strong contributions to forest pathology research both internationally and in the western U.S. on root diseases and various other important issues.</td></tr>
<tr><td rowspan="2">2020</td><td>Phil Cannon</td><td rowspan="2"></td><td>For the major impact to the U.S. Pacific SW and beyond on multiple diseases, mentoring others, being a strong collaborator, and for a high level of energy and enthusiasm.</td></tr>
<tr><td>Ned Klopfenstein</td><td>For major contributions to understand genetic relationships between forest pathogens and Armillaria, improve diagnostics, for expertise on multiple diseases, as a mentor to others, and a good-natured character.</td></tr>
<tr><td>2022</td><td colspan="3">No award given</td></tr>
<tr><td>2023</td><td>Blakey Lockman</td><td>Rohnert Park, CA</td><td>For her combined expertise in forest pathology, leadership and mentorship, and her legacy on the field of forest pathology in US western forests.</td></tr>
<tr><td>2024</td><td>Dave Shaw</td><td>Santa Fe, NM</td><td>For his dedication to promoting forest health through research, academia, and extension, his dedication to applied forest pathology research, and his unending outreach, support, and mentorship</td></tr>
</table>

Lori Winton and Greg Reynolds enjoying the local art (photo: Robin Mulvey)

Outstanding Achievement Award Committee Members

Year	Members		
2000	J. Byler	W. Littke	B. van der Kamp
2001	W. Littke	B. van der Kamp	R. Sturrock
2002	B. van der Kamp	R. Sturrock	G. Filip
2003	R. Sturrock	G. Filip	
2004	G. Filip	D. Goheen	S. Zeglen
2005	D. Goheen	S. Zeglen	D. Shaw
2006	S. Zeglen	D. Shaw	B. Ferguson
2007	D. Shaw	B. Ferguson	R. Reich
2008	B. Ferguson	R. Reich	E. Goheen
2009	R. Reich	E. Goheen	P. Angwin
2010	E. Goheen	P. Angwin	H. Kope
2011	P. Angwin	H. Kope	B. Jacobi
2012	H. Kope	B. Jacobi	P. Hennon
2013	B. Jacobi	P. Hennon	M. Cruickshank
2014	P. Hennon	M. Cruickshank	K. Lewis
2015	M. Cruickshank	K. Lewis	E. Goheen
2016	K. Lewis	E. Goheen	J. LeBoldus
2017	E. Goheen	J. LeBoldus	A. Leon
2019	A. Leon	J. Stewart	A. Woods
2020	A. Leon	J. Stewart	A. Woods
2023	A. Leon	J. Stewart	A. Woods
2024	K. Chadwick	J. Stewart	N. Feau

Katie Minnix enjoying a view of the Valles Caldera (photo: Adam Carson)

Standing Committees and Chairs, 1994 - 2023

Committee	Chairperson	Term
Hazard Trees	J. Pronos	1994—2005
	P. Angwin	2006—2015
	K. Chadwick	2016—present
Dwarf Mistletoe	R. Mathiasen	1994—2000
	K. Marshall	2001—2003
	F. Baker	2004—2013
	D. Shaw	2014—2023
	B. Oblinger	2024
Root Disease	G. Filip	1994—1995
	E. Michaels Goheen	1996—2005
	B. Ferguson	2006—2009
	M. Cleary	2010—2011
	B. Lockman	2012—2023
	P. Bennett	2024
Rust	J. Schwandt	1994, 2005
	R. Hunt	1995—2004
	H. Kearns	2006—2011
	H. Maffei	2012—2016
	P. Zambino & J. Stewart	2017—2020
	J. Stewart	2023
	K. Burns	2024
Disease Control[1]	B. James	1995—2002
Nursery Pathology	B. James	2002—2005
	K. Mallams	2007—2010
	W. Littke	2011—2014
	A. Leon	2015—present
Foliar and Twig Diseases[2]	H. Kope	2007—2020
	A. Carson & K. Sondreli	2023
	A. Carson	2024
Climate Change[3]	S. Frankel	2007—2008
	S. Frankel & D. Shaw	2009—2014
	S. Frankel, D. Shaw, & A. Woods	2015—2023
	D. Norlander, M. Murray, S. Frankel, & A. Woods	2024

[1] Disease Control committee was disbanded in 2002.
[2] Foliar and Twig Diseases committee was made full charter member in 2009.
[3] Climate Change committee was made full charter member in 2010.

Bylaws of the Western International Forest Disease Work Conference

Passed by a vote of the Membership at the Business Meeting of September 10, 2024

Article I: Objectives

The Western International Forest Disease Work Conference (WIFDWC) was formed in 1953 to provide a forum for information exchange among forest pathologists in western North America. The primary objectives of the organization are:

- To exchange information on forest pests and related matters through periodic meetings and other appropriate means,
- To promote education, research and extension activities in forest pathology, and
- To sustain and improve the health of western North America's forests.

Article 2: Membership

Membership is open to individuals who are engaged in forest pathology related endeavors in western North America. These include but are not limited to: research, survey, management, teaching or extension activities pertaining to tree diseases, forest health, or deterioration of forest products.

Western North America is defined as Canada: British Columbia, Yukon, Alberta, Manitoba, Saskatchewan; United States: Washington, Oregon, California, Idaho, Nevada, Utah, Arizona, Montana, Wyoming, Colorado, New Mexico, North Dakota, South Dakota, Nebraska, Kansas, Alaska, Hawaii, Guam, the Commonwealth of the Northern Marianna Islands and other Pacific Islands in Micronesia; and all of Mexico.

Membership is established after attending one Western International Forest Disease Work Conference. Members must attend another Western International Forest Disease Work Conference within 5 years or their membership is no longer valid.

Honorary Life membership will be automatically awarded to those members of WIFDWC (as defined above) who have attended at least 5 previous meetings of WIFDWC and have retired. Newly retired members who meet these criteria should notify the current WIFDWC Secretary of their status. Other members who have retired but do not meet the attendance criteria or other outstanding contributors to the field of Forest Pathology may request, or be proposed for, Honorary Life Membership by members present at an annual business meeting.

A list of Honorary Life Members will be published in the Proceedings of each meeting.

A 50% or more reduction in the registration fees for Honorary Life Members, to include a copy of the Proceedings, should be considered by the Executive Committee, as per Article 7.

Article 3: Officers

WIFDWC officers will include a Conference Chairperson, Secretary, Treasurer, Program Chairperson, Historian and Web Coordinator. The Conference Chairperson and Secretary will be elected by majority vote of the membership at the annual business meeting. If there is no majority, an acting Chairperson will be appointed by the current Conference Chairperson. The tenure of the Conference Chairperson and Secretary begins at the conclusion of the WIFDWC meeting where they were elected and ends when all business from the next WIFDWC is completed. The Treasurer, Historian and Webmaster will be elected every five years, to serve for the following 5 years.

Duties of the Conference Chairperson

At each WIFDWC, the Conference Chairperson will run the general and business meetings. The Conference Chairperson will appoint an interim Program Chairperson at the start of each WIFDWC to gather suggestions and opinions to guide the conference in the planning of next year's conference. The Conference Chairperson will also appoint three members to serve as the "railroad committee" to nominate candidates for next year's

Conference Chairperson and Secretary (and every fifth year, Treasurer, Historian and Web Coordinator). The Conference Chairperson may appoint members to assist in conducting the affairs of the Conference including, but not limited, to Local Arrangements representative(s) and Program Chairperson. The Conference Chairperson may also appoint ad hoc committees and their chairpersons as deemed necessary to assist in carrying out the mission of WIFDWC.

In the event that a new Conference Chairperson cannot carry out their duties, the previous Chairperson will carry them out. If another member of the Executive Committee cannot or will not carry out their duties the Conference Chairperson may appoint a replacement.

Duties of the Secretary

The Secretary shall maintain the membership and mailing lists. The Secretary shall send out meeting notices to the membership, take minutes at the business meeting, and compile and distribute the Conference proceedings.

The secretary will query all Honorary Life Members to determine if they want to receive a free copy of the proceedings and only those responding in the affirmative will receive a copy.

Duties of the Treasurer

The Treasurer shall receive all payments, be custodian of WIFDWC funds, keep an account of all moneys received and expended, and make commitments and disbursements authorized by the Conference Chairperson. At the annual business meeting the Treasurer shall make a report covering the financial affairs of WIFDWC. All funds, records and vouchers in the Treasurer's control should be subject to inspection by the Executive Committee.

Duties of the Program Chairperson

The Program Chairperson is appointed by the Conference Chairperson. The Program Chairperson is responsible for all aspects of the conference agenda including arranging the format and timing of the meeting, selecting panel chairpersons or moderators, selecting the poster session coordinator, assigning subject matter committee meeting times, and arranging keynote, contributing paper and other speakers.

Duties of the Historian

The Historian will keep a complete set of WIFDWC proceedings and answer any inquires as needed. The Historian will contact the WIFDWC Secretary and provide the address for mailing the archival copy of the proceedings.

Duties of the Web Coordinator

The Web Coordinator will create and manage the WIFDWC website. The Web Coordinator will supervise the hosting, security and access of the website. Content for the website will be provided by the Executive Committee for each meeting. The Web Coordinator will ensure that previous WIFDWC meeting websites and their proceedings are archived and linked to the current website.

Compensation

Officers will not be compensated for their services.

Non-liability of Officers

The officers shall not be personally liable for the debts, liabilities or other obligations of the WIFDWC.

Article 4: Decision Making Process

The business meeting will be run under Roberts Rules of Order. Meetings are open to the public and non-members may participate in meetings. Only members may vote.

Decisions will be made by majority, with each member granted one vote. Votes may be called for at the annual business meeting or via electronic ballot (i.e., e-mail ballot, web poll, etc.). A quorum is reached when more than 25 members are present.

Article 5: Finances

Expenditures

The Conference Chairperson may authorize expenditures of WIFDWC funds. Standing Committee Chairs may similarly authorize the expenditure of funds that are generated by their standing committees (e.g., Hazard Trees Committee). Checks, orders for payment, etc. may be signed by the Treasurer, or other person designated by the Chairperson. The Executive Committee may determine which and how many outside speakers they want to invite, and travel costs for such speakers can be paid from registration fees.

Contracts

The Conference Chairperson may authorize any officer or agent of WIFDWC to enter into a contract on behalf of WIFDWC. Standing Committee Chairs may similarly authorize any agent of their standing committee to enter into a contract on behalf of their committee. Unless so authorized, no person shall have any authority to bind WIFDWC or any standing committee to any contract.

Gifts

The Conference Chairperson or the Treasurer may accept on behalf of the WIFDWC any contribution, gift, or bequest. Commercial sponsorship of conference special events is not allowed.

Fiscal year

The WIFDWC fiscal year shall begin on the first of January and end on the last day of December.

Article 6: Bylaws

Amendments

Changes to bylaws shall be made available to all WIFDWC members for review at least one month prior to the next business meeting. A two-thirds majority is required to pass a motion to amend existing bylaws if the vote is held at a business meeting. An affirmative vote from at least 26 members is required to approve a motion voted on by electronic balloting (i.e., e-mail ballot, web poll, etc.).

Article 7: Meetings

Frequency

The WIFDWC endorses holding annual meetings but will, on vote of the membership, change the time of any particular meeting when circumstances dictate that such action be taken.

Date

WIFDWC endorses holding meetings in late summer but will change the interval between any two meetings when circumstances dictate that such an action be taken. Meeting dates will be set by the Executive Committee for each meeting.

Registration

Registration will be reduced by half, if possible, for graduate students and Honorary Life Members. It will be at the discretion of the WIFDWC Executive Committee for each meeting to offer a further reduction in fees to graduate students and Honorary Life Members and to offer further reduced fees to others such as retired professionals and visitors.

Article 8: Committees

There shall be two types of committees, namely

a) Standing Committees – as designated in the by-laws, and

b) Ad Hoc Committees – as appointed by the Conference Chairperson to serve for a term specified by the Chairperson.

The chair of each standing committee shall prepare a report of the committee activities for the membership. The report will be submitted by the publication deadline to the Secretary for inclusion in the proceedings.

The following are WIFDWC standing committees:

- Executive Committee
  - ○ Composed of the elected Conference Chairperson, Secretary, Treasurer, Historian and Web Coordinator.
  - ○ The Conference Chairperson may appoint a Program Chair, Local Arrangements representative(s) and other persons as necessary to carry out the business of the next WIFDWC meeting.
  - ○ The Executive Committee may invite non-member speakers to the annual meeting and pay their travel expenses from conference registration fees.
- Awards Committee
  - ○ Composed of three members with the longest serving member designated as chair.
  - ○ Committee will be comprised of a representative from each of the following – a university employee, a public agency employee, and one member at large. At least one member should be from Canada.
  - ○ The chair's term will be completed at the end of the annual business meeting and a new junior member will be appointed by the Conference Chairperson. The most senior serving member will assume the chair for the next year.
  - ○ The chair will provide a report of activities at the annual business meeting.
  - ○ Responsible for accepting and evaluating nominations and determining recipients of the WIFDWC Outstanding Achievement Award as outlined in Article 10.
- Student Scholarship Committee
  - ○ Composed of four members with the longest serving member designated as chair.
  - ○ The chair will provide a report of activities at the annual business meeting.
  - ○ The committee will be comprised of at least one representative from a university.
  - ○ Replacement of committee members will be by election at the annual business meeting.
  - ○ The committee is responsible for fundraising to finance any awards given by the committee.
  - ○ The committee is responsible for determining and advertising the award application criteria, receiving and evaluating applications and determining recipients of the WIFDWC Student Travel Awards as outlined in Article 10.
- Hazard Trees Committee,
- Dwarf Mistletoe Committee,
- Root Disease Committee,
- Rust Committee,
- ~~Disease Control Committee~~ [disbanded 2002],
- Nursery Pathology Committee [approved 2002],

- Foliage and Twig Diseases Committee [established 2007, approved 2009],
- Climate Change Committee [established 2007, approved 2010].

Ad hoc committees are established by the Conference Chairperson to carry out various functional needs (e.g., the annual Nominating Committee). Ad hoc committees carry out specific, normally short term, tasks required by the membership. The terms of reference for ad hoc committees will be determined by the Conference Chairperson in consultation with the membership.

Article 9: Proceedings

Papers for each year's proceedings must be submitted to the Secretary by the deadline set for each conference by the Secretary.

Distribution of proceedings is made to all paid registrants and honorary members who have indicated a desire to receive them and will be made available to others at cost.

Article 10: Awards

Outstanding Achievement Award

Members may recognize outstanding achievement in the field of forest pathology by bestowing the WIFDWC Outstanding Achievement Award. The award will recognize an individual that has, in the opinion of the membership, contributed significantly to the field of forest pathology in western North America.

The award will be presented during the conference by the chair of the Awards Committee or designate. The recipient will receive a framed certificate or plaque. The recipient will present a keynote address at the following year's WIFDWC. A list of recipients will be published in the proceedings.

Members may nominate other current or active members for the award; they may not nominate themselves. A member may only make one nomination each year. A nomination must include: a short introductory letter, a narrative of the nominees qualifications, educational background, work history, etc., letters of support from other members and organizations, and copies of a few of the nominee's published works. Nominations are due no later than three months prior to the start of next year's conference and must be sent to the Awards Committee chair.

The Awards Committee may decide to not make an award if no suitable candidates are nominated.

Student Travel Awards

Members encourage participation in the annual conference by students engaged in studies in the field of forest pathology by bestowing the WIFDWC Student Travel Awards to enable their attendance. The awards are intended for students currently enrolled in a university graduate level program with a thesis or dissertation topic relevant to the field of forest pathology. The awards are intended to assist with conference-related expenses.

Criteria for application and selection of award recipients will be determined by the committee and made public at least four months prior to the early registration date for the meeting or by the first WIFDWC mailing. Completed applications are due by the deadline set by the committee.

The awards will be presented at least four weeks prior to the early registration date for the conference by the chair of the committee or designate. The recipients will receive an award of up to US$500 depending on funding availability. Recipients will be required to make an oral or poster presentation at the meeting for which they received the award. Oral presentations are preferred.

The committee may decide to not make an award if no suitable candidates apply.

Addendums: Select Motions and Decisions

1998

Outstanding Achievement Award—established.

1999

Honorary Life Members—members added and provisions discussed (see 1996 Proceedings for historic retrospective on HLM).

Assisting Outside Speakers—amendment passed.

Website—Committee Reports and Meeting synopsis by the Chairperson would be posted; web committee (Baker, Muir, and Adams) formed.

2000

Outstanding Achievement Award—staggered committee established and recommendations made.

Joint Meetings with WFIWC—motions passed to meet in 2004, have dual program chairs, form a planning committee in 2001 for the joint meeting.

2001

Standing Committees—proposal to reorganize Disease Control Committee tabled.

2002

Standing Committees—motion passed to disband the Disease Control Committee and establish a Nursery Pathology Committee.

2004

Outstanding Achievement Award—changes to the Bylaws for this award were proposed and accepted by the membership.

Executive Committee—motion to make Webmaster an official position on the committee was approved.

2007

Standing Committees—motion passed to create both an ad hoc Foliar and Shoot Diseases Committee and a Climate Change Committee.

2008

Digital Proceedings—motion to make WIFDWC proceedings available on the website was approved.

2009

Standing Committees—motion passed to confirm the Foliage and Twig Diseases Committee as a standing committee.

2010

Standing Committees—motion passed to confirm the Climate Change Committee as a standing committee.

Fund Raising—the first WIFDWC Silent Auction was held to raise funds for graduate student travel awards.

2011

Standing Committees—motion passed to add the Student Scholarship Committee as a standing committee.

Business Meeting—motion passed outlining requirements needed to pass a motion by means of an electronic ballot.

2012

Finances—motion passed to hire a tax consultant for WIFDWC taxes.

Student Travel Award—motion passed to recommend to the program chair of each meeting to allow time in the program for each student receiving a travel award to present their work.

Deceased members – a moment of silence or tribute will be given for deceased members.

Regional Reports – motion passed for the Secretary to request regional reports in a standard format prior to the meeting and distribute reports at the meeting.

Joint Meetings with WFIWC- motion passed for the fall 2016 Executive Committee to consider having joint meeting with WFIWC.

2013

Officers- motion passed for Kristen Chadwick to maintain mailing and member list up to date, not the Secretary as specified in the bylaws.

Fund Raising- motion passed to increase regular registration rates by $15 to go to student travel award.

2014

Joint Meetings with WFIWC- conference chair will send an invitation to the WFIWC chair to hold a joint meeting in 2018 at a location in the US.

2015

No New Motions Passed

2016

WIFDWC Website - Danny Norlander will investigate in conjunction with the 2017 planning committee for hosting WIFDWC 2017 website on a non-federal option. WIFDWC will invest funds.

International Funds - funds should be used for international travelers to attend meetings in Canada or the states, but not to fund regular Canadian/American members to attend American or Canadian meetings, respectively.

2017

Fund Raising - motion passed to raise the portion of registration fees used for the student travel awards to $25.

2019

No New Motions Passed

2022

No New Motions Passed to amend Bylaws.

2023

Fund Raising - motion passed to raise the portion of registration fees used for the student travel awards to $30.

2024

Meetings Management Position – motion passed to revisit a set motion of making the meetings management position a standing postion to be voted on every 5 years during the 2025 business meeting.

Student Travel Award – motion passed to reduce the application requirements from two letters of recommendations to one.

Past Annual Meeting Locations and Officers, 1953—2024

Meeting	Year	Location	Chairperson	Secretary	Treasurer	Program Chair	Local Arrangements	Historian	Web Coordinator
1	1953	Victoria, BC	R. Foster	-	-	-	-	-	-
2	1954	Berkeley, CA	W. Wagener	P. Lightle	P. Lightle	-	-	-	-
3	1955	Spokane, WA	V. Nordin	C. Leaphart	C. Leaphart	G. Thomas	-	-	-
4	1956	El Paso, TX	L. Gill	R. Davidson	R. Davidson	V. Nordin	-	-	-
5	1957	Salem, OR	G. Thomas	T. Childs	T. Childs	R. Gilbertson	-	-	-
6	1958	Vancouver, BC	J. Kimmey	H. Offord	H. Offord	A. Parker	-	-	-
7	1959	Pullman, WA	H. Offord	R. Foster	R. Foster	C. Shaw	-	-	-
8	1960	Centralia, WA	A. Parker	F. Hawksworth	F. Hawksworth	J. Parmeter	K. Shea	-	-
9	1961	Banff, AB	F. Hawksworth	J. Parmeter	J. Parmeter	A. Molnar	G. Thomas	-	-
10	1962	Victoria, BC	J. Parmeter	C. Shaw	C. Shaw	K. Shea	R. McMinn	-	-
11	1963	Jackson, WY	C. Shaw	J. Bier	J. Bier	R. Scharpf	L. Farmer	-	-
12	1964	Berkeley, CA	K. Shea	R. Scharpf	R. Scharpf	C. Leaphart	H. Offord	-	-
13	1965	Kelowna, BC	J. Bier	H. Whitney	H. Whitney	R. Bega	A. Molnar	-	-
14	1966	Bend, OR	C. Leaphart	D. Graham	D. Graham	G. Pentland	D. Graham	-	-
15	1967	Santa Fe, NM	A. Molnar	E. Wicker	E. Wicker	L. Weir	P. Lightle	-	-
16	1968	Coeur D'Alene, ID	S. Andrews	R. McMinn	R. McMinn	J. Stewart	C. Leaphart	-	-
17	1969	Olympia, WA	G. Wallis	R. Gilbertson	R. Gilbertson	F. Hawksworth	K. Russell	-	-
18	1970	Harrison Hot Spring, BC	R. Scharpf	H. Toko	H. Toko	A. Harvey	J. Roff	-	-
19	1971	Medford, OR	J. Baranyay	D. Graham	D. Graham	R. Smith	H. Bynum	-	-
20	1972	Victoria, BC	P. Lightle	A. McCain	A. McCain	L. Weir	D. Morrison	-	-
21	1973	Estes Park, CO	E. Wicker	R. Loomis	R. Loomis	R. Gilbertson	J. Laut	-	-
22	1974	Monterey, CA	R. Bega	D. Hocking	D. Hocking	J. Parmeter		-	-
23	1975	Missoula, MT	H. Whitney	J. Byler	J. Byler	E. Wicker	O. Dooling	-	-
24	1976	Coos Bay, OR	L. Roth	K. Russell	K. Russell	L. Weir	J. Hadfield	-	-
25	1977	Victoria, BC	D. Graham	J. Laut	J. Laut	E. Nelson	W. Bloomberg	-	-
26	1978	Tucson, AZ	R. Smith	D. Drummond	D. Drummond	L. Weir	R. Gilbertson	-	-
27	1979	Salem, OR	T. Laurent	T. Hinds	T. Hinds	B. van der Kamp	L. Weir	-	-
28	1980	Pingree Park, CO	R. Gilbertson	O. Dooling	O. Dooling	J. Laut	M. Schomaker	-	-
29	1981	Vernon, BC	L. Weir	C.G. Shaw III	C.G. Shaw III	J. Schwandt	D. Morrison R. Hunt	-	-
30	1982	Fallen Leaf Lake, CA	W. Bloomberg	W. Jacobi	W. Jacobi	E. Hansen	F. Cobb J. Parmeter	-	-
31	1983	Coeur d'Alene, ID	J. Laut	S. Dubreuil	S. Dubreuil	D. Johnson	J. Schwandt J. Byler	-	-
32	1984	Taos, NM	T. Hinds	R. Hunt	R. Hunt	J. Byler	J. Beatty E. Wood	-	-
33	1985	Olympia, WA	F. Cobb	W. Thies	W. Thies	R. Edmonds	K. Russell	-	-
34	1986	Juneau, AK	K. Russell	S. Cooley	S. Cooley	J. Laut	C.G. Shaw III	-	-
35	1987	Nanaimo, BC	J. Muir	G. DeNitto	G. DeNitto	J. Beatty	J. Kumi	-	-

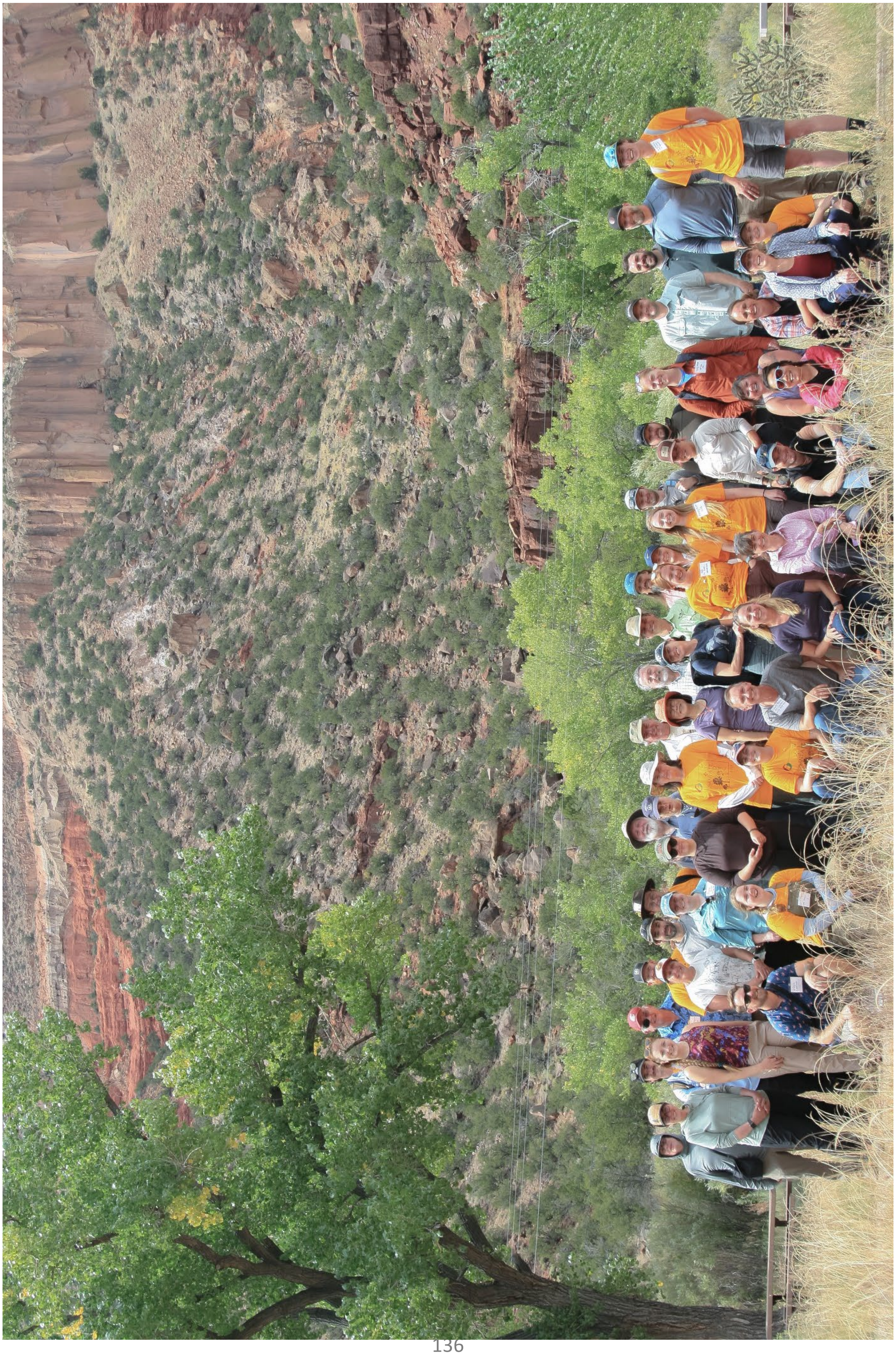
36	1988	Park City, UT	J. Byler	B. van der Kamp	B. van der Kamp	J. Pronos	F. Baker	-	-
37	1989	Bend, OR	D. Goheen	R. James	R. James	E. Hansen	A. Kanaskie	-	-
38	1990	Redding, CA	R. Hunt	J. Hoffman	K. Russell	M. Marosy	G. DeNitto	-	-
39	1991	Vernon, BC	A. McCain	J. Muir	K. Russell	R. Hunt	H. Merler	-	-
40	1992	Durango, CO	D. Morrison	S. Frankel	K. Russell	C.G. Shaw III	P. Angwin	-	-
41	1993	Boise, ID	W. Littke	J. Allison	K. Russell	F. Baker	J. Hoffman	-	-
42	1994	Albuquerque, NM	C.G. Shaw III	G. Filip	K. Russell	M. Schultz	D. Conklin T. Rodgers	-	-
43	1995	Whitefish, MT	S. Frankel	R. Mathiasen	K. Russell	R. Mathiasen	J. Taylor J. Schwandt	-	-
44	1996	Hood River, OR	J. Kliejunas	J. Beatty	J. Schwandt	S. Campbell	J. Beatty K. Russel	-	-
45	1997	Prince George, BC	W. Thies	R. Sturrock	J. Schwandt	K. Lewis	R. Reich K. Lewis	-	-
46	1998	Reno, NV	B. Edmonds	L. Trummer	J. Schwandt	G. Filip	J. Hoffman J. Guyon	D. Morrison	-
47	1999	Breckenridge, CO	F. Baker	E. Michaels Goheen	J. Schwandt	J. Taylor	D. Johnson	D. Morrison	J. Adams
48	2000	Waikoloa, HI	W. Jacobi	P. Angwin	J. Schwandt	S. Hagle	J. Beatty	D. Morrison	J. Adams
49	2001	Carmel, CA	D. Johnson	K. Marshall	J. Schwandt	A. Kanaskie	S. Frankel	D. Morrison	J. Adams
50	2002	Powell River, BC	B. van der Kamp	H. Maffei	J. Schwandt	P. Hennon	S. Zeglen R. Diprose	D. Morrison	J. Adams
51	2003	Grants Pass, OR	E. Hansen	B. Geils	J. Schwandt	H. Merler	E. Michaels Goheen	D. Morrison	J. Adams
52	2004	San Diego, CA	E. Goheen	B. Lockman	J. Schwandt	H. Merler K. Lesiw	J. Pronos J. Kliejunas S. Smith	D. Morrison	J. Adams
53	2005	Jackson, WY	M. Fairweather	H. Merler J. Guyon	J. Schwandt	K. Burns	J. Hoffman F. Baker J. Guyon	D. Morrison	J. Adams
54	2006	Smithers, BC	K. Lewis	M. Jackson	J. Schwandt	B. Lockman	A. Woods	D. Morrison	J. Adams
55	2007	Sedona, AZ	S. Zeglen	M. McWilliams	J. Schwandt	J. Worrall	M. Fairweather B. Geils B. Mathiason	D. Morrison	J. Adams
56	2008	Missoula, MT	G. DeNitto	F. Baker	J. Schwandt	W. Littke	B. Lockman M. Jackson	D. Morrison	J. Adams
57	2009	Durango, CO	G. Filip	J. Adams	J. Schwandt	D. Shaw	K. Burns B. Jacobi J. Worrall R. Mask J. Blodgett	R. Sturrock	J. Adams
58	2010	Valemount, BC	R. Sturrock	M. Fairweather	J. Schwandt	D. Goheen	M. Cleary R. Reich	R. Sturrock	J. Adams
59	2011	Leavenworth, WA	P. Angwin	S. Zeglen	H. Kearns	A. Kanaskie	G. Filip A. Saavedra A. Ramsey-Kroll D. Omdal	R. Sturrock	J. Adams
60	2012	Tahoe City, CA	A. Woods	J. Browning	H. Kearns	P Hennon	P. Cannon B. Woodruff	R. Sturrock	J. Adams
61	2013	Waterton Lakes National Park, AB	R. Reich	K. Chadwick	H. Kearns	B. Lockman	T. Ramsfield	R. Sturrock	J. Adams

62	2014	Cedar City, UT	M. McWilliams	M. Murray	H. Kearns	J. Worrall	J. Guyon	R. Sturrock	J. Adams
63	2015	Newport, OR	A. Kanaskie	A. Ramsey	H. Kearns	E. Goheen	K. Chadwick A. Kanaskie G. Filip D. Shaw	R. Sturrock	S. Romero
64	2016	Sitka, AK	P. Hennon	B. Goodrich	H. Kearns	H. Kope	R. Mulvey P. Hennon	R. Sturrock	B. Lilly
65	2017	Parksville, BC	H. Kope	C. Cleaver	H. Kearns	D. Shaw	S. Zeglen	R. Sturrock	D. Norlander
66	2019	Estes Park, CO	K. Burns	G. Reynolds N. Wilhelmi	H. Kearns	J. Stewart	J. Stewart K. Burns J. Blodgett	R. Sturrock	D. Norlander
-	2020-2021	No WIFDWC held due to Global COVID-19 Pandemic							
67	2022	Held Virtually Online due to COVID-19 Pandemic	S. Navarro	B. Oblinger	H. Kearns	M. S. Kim.	-	E. Becker	D. Norlander
68	2023	Rohnert Park, CA	J. Stewart	R. Brooks	H. Kearns	B. Ferguson	C. Lee T. Smith M. Fairweather	B. Ferguson	D. Norlander
69	2024	Santa Fe, NM	L. Winton	A. Carson	H. Kearns	D. Norlander	G. Reynolds N. Wilhelmi	B. Ferguson	D. Norlander

Note: Bylaws passed at 1998 WIFDWC Business Meeting identify officers as chairperson and secretary elected at annual business meeting and treasurer and historian, elected every five years.

Group Photos

Non-host social, poster reception, and field trip socializing. (photos: Kristen Chadwick, Adam Carson, Betsy Goodrich, Greg Reynolds)



Banquet tables. (photos: Adam Carson)

WIFDWC Members

Current WIFDWC Members

(*Due to the COVID-19 pandemic limiting recent meetings, members listed here include those that have attended an in-person meeting since 2016. No attendee list is available for the 2022 virtual session.)

Gerard Adams, University of Nebraska; Lincoln, NE; 402-472-2897 gadams3@unl.edu (Last attended 2019)
Juan Aldana, University of Victoria; Victoria, BC; 778-829-2083 jaldana@uvic.ca (Last attended 2017)
Kiah Allen, University of British Columbia; Vancouver, BC; 604-790-2586 kiahallen@hotmail.com (Last attended 2019)
Brandon Alveshere, Oregon State University; Corvallis, OR; 701-426-9115 alvesheb@onid.oregonstate.edu (Last attended 2016)
Robert Andrus, Washington State University; Pullman, WA (Last attended 2023)
Jessa Ata, Colorado State University; Fort Collins, CO; jessa.ata@colostate.edu (Last attended 2019)
David Atkins, Colorado State University; Fort Collins, CO; david.atkins@colostate.edu (Last attended 2019)
Charles Barnes, USDA Forest Service; San Bernardino, CA; 909-520-5753 charles.barnes2@usda.gov (Last attended 2024)
Elisa Becker, Canadian Forest Service; Victoria, BC; 250-298-2382 elisa.becker@nrcan-rncan.gc.ca (Last attended 2017)
Lorne Bedford, British Columbia Ministry of Forests; Victoria, BC; 250-387-1946 lorne.bedford@gov.bc.ca (Last attended 2017)
Patrick Bennett, USDA Forest Service; Moscow, ID; 208-883-2308 patrick.bennett@usda.gov (Last attended 2024)
Nathan Berner, Calaveras Tree Care; Murphys, CA; 209-404-4341 calaverastreecare@gmail.com (Last attended 2023)
Jacob Betzen, University of Washington; Shoreline, WA; 970-901-5725 betzen@uw.edu (Last attended 2017)
James T. Blodgett, USDA Forest Service; Rapid City, SD; 605-716-2783 james.blodgett@usda.gov (Last attended 2024)
Kellee Boyer, Oregon State University; Corvallis, OR; 503-880-4463 kellee.boyer@oregonstate.edu (Last attended 2024)
Josh Bronson, USDA Forest Service; Medford, OR; 541-618-2081 jjbronson@fs.fed.us (Last attended 2023)
Rachel K. Brooks, WA State Department of Natural Resources; Olympia, WA; 360-522-2030 rachel.brooks@dnr.wa.gov (Last attended 2023)
Samuel Brown, WA State Dept of Agriculture; Olympia, WA; 360-819-7714 skbrown@agr.wa.gov (Last attended 2023)
John Browning, Weyerhaeuser Forestry; Centralia, WA; 360-330-1721 john.browning@weyerhaeuser.com (Last attended 2017)
Kelly Burns, USDA Forest Service; Lakewood, CO; 303-236-8006 kelly.burns@usda.gov (Last attended 2023)
Marcelo Bustamante, University of California; Davis, CA (Last attended 2023)
Stephen Calkins, Oregon State University; Corvallis, OR; calkinss@oregonstate.edu (Last attended 2019)
Brenda Callan, Natural Resource Canada; Victoria, BC; 250-298-2356 brenda.callan@canada.ca (Last attended 2017)
Phil Cannon, USDA Forest Service; Vallejo, CA; 707-980-1665 philip.cannon@usda.gov (Last attended 2023)
Adam Carson, Oregon State University; Corvallis, OR; 541-737-3826 adam.carson@oregonstate.edu (Last attended 2024)
Kristen L. Chadwick, USDA Forest Service; Sandy, OR; 503-668-1474 kristen.chadwick@usda.gov (Last attended 2024)
Steph Chase, Oregon State University; Corvallis, OR; 518-390-3667 chasest@oregonstate.edu (Last attended 2023)
Gary Chastagner, Washington State University; Puyallup, WA; 253-445-4528 chastag@wsu.edu (Last attended 2024)
Daram Choi, Oregon State University; Corvallis, OR; 541-737-2004 daram0924@gmail.com (Last attended 2023)
Christy Cleaver, USDA Forest Service; Coeur d'Alene, ID; 303-907-8718 christy.cleaver@usda.gov (Last attended 2024)
Richard Cobb, California Polytechnic State University; San Luis Obispo, CA; 805-756-6333 rccobb@calpoly.edu (Last attended 2023)
Vanessa Comeau, University of British Columbia; Vancouver, BC; 604-505-2259 vmcomeau@gmail.com (Last attended 2017)
Kim Corella, California Department of Forestry and Fire Protection; San Luis Obispo, CA; 805-550-8583 kim.corella@fire.ca.gov (Last attended 2023)
Mike Cruickshank, Natural Resource Canada; Victoria, BC; 778-350-9116 mike.cruickshank@nrcan-rncan.gc.ca (Last attended 2023)
Angie Dale, University of British Columbia; Vancouver, BC; 778-689-3065 angela.dale@fpinnovations.ca (Last attended 2017)
Hazel Daniels, Oregon State University; Corvallis, OR; 865-896-9457 danieldi@onid.oregonstate.edu (Last attended 2019)
Sapphitah Dickerson, WA State Dept of Agriculture; Olympia, WA; 360-878-0616 sdickerson@agr.wa.gov (Last attended 2023)
John Dobbs, Colorado State University; Fort Collins, CO; 808-230-0214 john.dobbs@colostate.edu (Last attended 2023)
Erika Dort, University of British Columbia; Vancouver, BC; erika.dort@ubc.ca (Last attended 2019)

Kymi Draeger, USDA Forest Service; Anchorage, AK; 608 231-9297 kymberly.draeger@usda.gov (Last attended 2024)
Garret Dubois, USDA Forest Service; Anchorage, AK; 907-743-9469 garretddubois@fs.fed.us (Last attended 2016)
Megan Dudley, Adams State University; Alamosa, CO; 970-222-9558 mmdudley@adams.edu (Last attended 2024)
Nick Dudley, Hawaii Agriculture Research Center; Kunia, HI; 808-391-5421 ndudley@harc-hspa.com (Last attended 2016)
Tim Ebata, Resource Practices Branches; Victoria, BC; 250-658-4407 tim.ebata@gov.bc.ca (Last attended 2017)
Tom Eckberg, Idaho Department of Lands; Coeur d'Alene, ID; 208-666-8666 teckberg@idl.idaho.gov (Last attended 2019)
Marianne Elliott, Washington State University; Puyallup, WA; 253-445-4596 melliott2@wsu.edu (Last attended 2023)
Curtis Ewing, California Department of Forestry and Fire Protection; Vallejo, CA (Last attended 2023)
MaryLou Fairweather, Retired USDA Forest Service; Vallejo, CA; 707-562-8843 mary.fairweather@usda.gov (Last attended 2023)
Sebatian Fajardo, UC Davis; Davis, CA; 530-760-5489 snfajardo@ucdavis.edu (Last attended 2023)
Nicolas "Nico" Feau, University of British Columbia; Vancouver, BC; 604-317-6134 feaunico@mail.ubc.ca (Last attended 2023)
Brennan Ferguson, USDA Forest Service; Wenatchee, WA; 509-664-9215 brennan.ferguson@usda.gov (Last attended 2023)
Ada Fitz Axen, Colorado State University; Fort Collins, CO; 952-454-7857 ajfa@colostate.edu (Last attended 2024)
Alexander Flores, Sonoma State University; Rohnert Park, CA; 530-515-4294 dasflores37@gmail.com (Last attended 2023)
Susan Frankel, USDA Forest Service; Albany, CA; 510-559-6472 sfrankel@fs.fed.us (Last attended 2023)
Amy Gannon, State of Montana; Missoula, MT; 406-542-4283 agannon@mt.gov (Last attended 2016)
Grace Ganter, Colorado State University; Fort Collins, CO; gracelyn@colostate.edu (Last attended 2024)
Matteo Garbelotto, University of California; Berkeley, CA; 510-643-4282 matteog@berkeley.edu (Last attended 2024)
Andrea Garfinkel, Washington State University; Puyallup, WA; 970-412-6445 garfinka@oregonstate.edu (Last attended 2019)
Betsy Goodrich, USDA Forest Service; Wenatchee, WA; 509-664-9223 anne.goodrich@usda.gov (Last attended 2024)
Michael Gordon, Oregon State University; Corvallis, OR; 503-927-2935 michael.gordon@oregonstate.edu (Last attended 2023)
Elizabeth Graham, USDA Forest Service; Juneau, AK; 907-586-8883 eegraham@fs.fed.us (Last attended 2016)
Richard Hamelin, University of British Columbia; Vancouver, BC; 604-827-4441 richard.hamelin@ubc.ca (Last attended 2023)
John Hanna, USDA Forest Service; Moscow, ID; 208-553-2768 john.w.hanna@usda.gov (Last attended 2023)
Jill Hautaniemi, USDA Forest Service; Missoula, MT; 406-499-9732 jill.hautaniemi@usda.gov (Last attended 2024)
Ashley Hawkins, USDA Forest Service; Redding, CA; 530-410-2264 ashley.hawkins@usda.gov (Last attended 2023)
Amanda Hendrix, USDA Forest Service; Missoula, MT (Last attended 2023)
Anthony Hopkins, Natural Resource Canada; Victoria, BC; 205-298-2441 anthony.hopkin@canada.ca (Last attended 2017)
Joey Hulbert, Washington State University; Puyallup, WA; 541-908-5129 hulbe@wsu.edu (Last attended 2023)
Jorge Ibarra Caballero, Colorado State University; Fort Collins, CO; 970-619-1838 jorgeiba@colostate.edu (Last attended 2023)
James Jacobs, USDA Forest Service; Alburquerque, NM; 505-842-3288 jamesjjacobs@fs.fed.us (Last attended 2016)
Holly Kearns, USDA Forest Service; Sandy, OR; 503-668-1475 holly.kearns@usda.gov (Last attended 2024)
Susanna Kerio, Oregon State University; Corvallis, OR; 541-740-5657 kerios@oregonstate.edu (Last attended 2019)
Mee-Sook Kim, USDA Forest Service; Corvallis, OR; meesook.kim@usda.gov (Last attended 2024)
Ned Klopfenstein, USDA Forest Service; Moscow, ID; 208-883-2310 ned.klopfenstein@usda.gov (Last attended 2024)
Jennifer Klutsch, University of Alberta; Edmonton, AB; 780-802-1554 jklutsch@gmail.com (Last attended 2017)
Harry H. Kope, British Columbia Ministry of Forests; Victoria, BC; 250-387-5225 harry.kope@gov.bc.ca (Last attended 2019)
Jorda Kovash, University of Alaska; Fairbanks, AK; 506-560-1677 jkovash@alaska.edu (Last attended 2024)
Daniel Krieble, Adams State University; Alamosa, CO; 610-331-6016 kriebledj@grizzlies.adams.edu (Last attended 2019)
Ducan Kroese, USDA Forest Service; Corvallis, OR; 541-750-7167 duncan.kroese@usda.gov (Last attended 2024)
Igor Lacan, University of California; San Fransisco, CA (Last attended 2023)
Brad Lalande, USDA Forest Service; Gunnison, CO; 303-506-5389 bradley.lalande@usda.gov (Last attended 2024)
Yung-Hsiang "Sky" Lan, Oregon State University; Corvallis, OR; 541-602-4555 yung-hsiang.lan@oregonstate.edu (Last attended 2023)
Thomas Lawson, Lawson & Associates; El Cerrito, CA; 510-206-1794 drthomlawson@gmail.com (Last attended 2024)
Jared Leboldus, Oregon State University; Corvallis, OR; 541-737-1907 lebolduj@science.oregonstate.edu (Last attended 2019)
K.A. Leddy, Colorado State University; Fort Collins, CO; 505-903-9661 leddyleds@gmail.com (Last attended 2017)
Chris Lee, California Department of Forestry and Fire Protection; Fortuna, CA; 479-739-1484 christopher.lee@fire.ca.gov (Last attended 2023)
Ryan Lenz, Oregon State University; Corvallis, OR; 541-737-2905 lenzr@oregonstate.edu (Last attended 2017)
Anna Leon, Weyerhaeuser Forestry; Centralia, WA; 360-330-1754 anna.leon@weyerhaeuser.com (Last attended 2024)

Kathy Lewis, University of Northern British Columbia; Prince George, BC; 250-960-6659 kathy.lewis@unbc.ca (Last attended 2016)
Noah Lindeman, Colorado State University; Fort Collins, CO; 530-260-1235 noah.lindeman@colostate.edu (Last attended 2024)
Blakey Lockman, USDA Forest Service; Portland, OR; 503-808-2997 irene.lockman@usda.gov (Last attended 2023)
Martin MacKenzie, USDA Forest Service; Sonora, CA; 209 288 6348 martin.mackenzie@usda.gov (Last attended 2023)
Suzanne Marchetti, USDA Forest Service; Gunnison, CO; 970-642-4448 sbmarchetti@fs.fed.us (Last attended 2024)
Alex Martin, Sonoma State University; Rohnert Park, CA; 707-664-2880 martinale@sonoma.edu (Last attended 2023)
Robert Mathiasen, Retired USDA Forest Service; Flagstaff, AZ; 928-699-4365 robert.mathiasen@nau.edu (Last attended 2023)
Michael Mbenoun, University of Alberta; Edmonton, AB; 587-594-6259 mbenoun@ualberta.ca (Last attended 2016)
Michael McKee, Colorado State University; Fort Collins, CO; 765-637-3398 michael.mckee@colostate.edu (Last attended 2024)
Kathleen McKeever, USDA Forest Service; Missoula, MT; 406-329-3189 kmckeever@fs.fed.us (Last attended 2019)
Shawn McMurtrey, USDA Agricultural Research Service; Corvallis, OR; 541-918-1866 shawnmcmurtrey@gmail.com (Last attended 2023)
Christine McTavish, USDA Forest Service; Boise, ID; 208-409-9465 christine.mctavish@usda.gov (Last attended 2024)
Michael McWilliams, USDA Forest Service; La Grande, OR; 541-760-5373 michael.mcwilliams@usda.gov (Last attended 2023)
Ashley Miller, Colorado State University; Fort Collins, CO; 847-660-9772 ashley.e.miller@colostate.edu (Last attended 2024)
Katie Minnix, USDA Forest Service; Missoula, MT; 406-370-7387 katherine.minnix@usda.gov (Last attended 2024)
Bruce Moltzan, USDA Forest Service; Washington, DC; 703-595-8261 bruce.moltzan@usda.gov (Last attended 2023)
David Montwe, University of Victoria; Victoria, BC; davidmontwe@uvic.ca (Last attended 2019)
Robin Mulvey, USDA Forest Service; Juneau, AK; 907-586-7971 robin.mulvey@usda.gov (Last attended 2024)
Michael Murray, British Columbia Ministry of Forests; Nelson, BC; 778-671-9159 michael.murray@gov.bc.ca (Last attended 2023)
Sarah Navarro, Oregon Department of Forestry; Salem, OR; 503-945-7394 sarah.navarro@oregon.gov (Last attended 2023)
Maria Newcomb, USDA Forest Service; Ogden, UT; 801-721-3324 maria.newcomb2@usda.gov (Last attended 2023)
Danny Norlander, Oregon Department of Forestry; Salem, OR; 503-945-7310 danny.norlander@state.or.us (Last attended 2024)
Brent Oblinger, USDA Forest Service; Bend, OR; 541-383-5701 brent.oblinger@usda.gov (Last attended 2024)
Nai'a Odachi, University of Hawaiʻi; Hilo, HI; 808-747-1478 nodachi@hawaii.edu (Last attended 2024)
Daniel Omdal, WA State Department of Natural Resources; Olympia, WA; 360-902-1692 dan.omdal@dnr.wa.gov (Last attended 2019)
Ebba Peterson, Oregon State University; Corvallis, OR; 541-737-5242 petersoe@science.oregonstate.edu (Last attended 2024)
Adrian Poloni, California Polytechnic State University; San Luis Obispo, CA; apoloni@calpoly.edu (Last attended 2019)
Puri Priya, University of British Columbia; Vancouver, BC; 604-822-2507 ppuri@mail.ubc.ca (Last attended 2023)
Amy Ramsey, WA State Department of Natural Resources; Olympia, WA; 360-902-1309 amy.ramsey@dnr.wa.gov (Last attended 2019)
Leah Rettenbacher, University of British Columbia; Vancouver, BC; 604-822-2507 lrettenbacher@live.com (Last attended 2023)
Gregory Reynolds, USDA Forest Service; Albuquerque, NM; 612-275-6087 gregory.j.reynolds@usda.gov (Last attended 2024)
Gabriela Ritokova, Oregon Department of Forestry; Salem, OR; 503-798-2404 gabriela.ritokova@odf.oregon.gov (Last attended 2023)
Cynthia Ross Friedman, Thompson Rivers University; Kamloops, BC; 250-319-6404 cindyrossfriedman@gmail.com (Last attended 2017)
Roger Ruess, University of Alaska; Fairbanks, AK; 907-474-7153 rwruess@alaska.edu (Last attended 2016)
David Rusch, British Columbia Ministry of Forests; Williams Lake, BC; 250-392-4488 david.rusch@gov.bc.ca (Last attended 2023)
Angel Saavedra, USDA Forest Service; Boise, ID; 208-373-4221 alsaavedra@fs.fed.us (Last attended 2019)
Edoard Scali, University of California; Berkley, CA (Last attended 2023)
Merlin Schlumberger, Merlin Arborist Group; Sebastopol, CA; 707-888-7927 office@merlinarboristgroup.com (Last attended 2023)
Anna Schoettle, USDA Forest Service; Fort Collins, CO; 970-498-1333 anna.schoettle@usda.gov (Last attended 2024)
Simon Francis Shamoun, Natural Resource Canada; Victoria, BC; 250-298-2358 simon.shamoun@nrcan-rncan.gc.ca (Last attended 2023)

David C. Shaw, Oregon State University; Corvallis, OR; 541-737-2845 dave.shaw@oregonstate.edu (Last attended 2023)
Michael Simpson, USDA Forest Service; Bend, OR; 541-383-5575 mlsimpson@fs.fed.us (Last attended 2019)
Rachael Sitz, USDA Forest Service; Moscow, ID; 402-990-2133 rsitz@fs.fed.us (Last attended 2019)
Daniel Sklar, University of Northern British Columbia; Prince George, BC; 604-367-5902 (Last attended 2017)
Tom Smith, State of California; Sacramento, CA; 916-599-6882 tom.smith@fire.ca.gov (Last attended 2023)
Kelsey Sondreli, Oregon State University; Corvallis, OR; 701-361-8612 kelsey.dunnell@oregonstate.edu (Last attended 2023)
Hanno Southam, University of British Columbia; Vancouver, BC; 250-509-0413 hannosoutham@gmail.com (Last attended 2024)
Cameron Stauder, USDA Forest Service; Bend, OR; 541-383-5591 cameron.stauder@usda.gov (Last attended 2023)
Jane Stewart, Colorado State University; Fort Collins, CO; 509-338-5038 jane.stewart@colostate.edu (Last attended 2023)
Grace Sumampong, University of Laval; Victoria, BC; 250-298-2359 grace.sumampong@canada.ca (Last attended 2017)
Steve Swenson, USDA Forest Service; Anchorage, AK; 907-743-9456 sswenson@fs.fed.us (Last attended 2016)
Diana Tomback, University of Colorado Denver; Denver, CO; 303-315-7642 diana.tomback@ucdenver.edu (Last attended 2019)
Brian Tucker, University of Hawaiʻi at Mānoa; Honolulu, HI; 808-339-4842 bjtucker@hawaii.edu (Last attended 2024)
Lydia Tymon, Master Reforestation; Seattle, WA; phone 206-321-9216 lydia.t@mastreforest.com(Last attended 2024)
Isabella Valdez, Idaho Department of Lands; Coeur d'Alene, ID; 208-666-8626 ivaldez@idl.idaho.gov (Last attended 2024)
Brian Verhulst, Rocky Mountain National Park; Estes Park, CO; 970-586-1444 brian_verhulst@nps.gov (Last attended 2019)
Detlev Volger, USDA Forest Service; Placerville, CA; 530-621-6881 dvogler@fs.fed.us (Last attended 2016)
Robinson Wallis, UC Cooperative Extension Humboldt/Del Norte; Eureka, CA; 707-445-7351 wallisrobinson@gmail.com (Last attended 2023)
Kristen Waring, Northern Arizona University; Flagstaff, AZ; 928-523-4920 kristen.waring@nan.edu (Last attended 2019)
Marcus Warwell, USDA Forest Service; Moscow, ID; 208-883-2305 mwarwell@fs.fed.us (Last attended 2017)
Jerry Weiland, USDA ARS; Corvalis, OR; 541-738-4062 jerry.weiland@ars.usda.gov (Last attended 2016)
Nicholas Wilhelmi, USDA Forest Service; Flagstaff, AZ; 928-556-2075 nwilhelmi@fs.fed.us (Last attended 2024)
Lori Winton, USDA Forest Service; Fairbanks, AK; 907-717-5736 lmwinton@fs.fed.us (Last attended 2024)
Rebecca Wolff, Santa Clara Valley Water District; San Jose, CA; 408-690-0023 rwolff@valleywater.org (Last attended 2023)
Alex Woods, British Columbia Ministry of Forests; Smithers, BC; 250-847-6382 alex.woods@gov.bc.ca (Last attended 2023)
Sean Wright, USDA Forest Service; Coeur d’Alene, ID; phone 970-692-3086 sean.wright@usda.gov (Last attended 2024)
Stephen Wyka, Colorado State University; Fort Collins, CO; stephen.wyka@colostate.edu (Last attended 2019)
Mikhail Yatskov, Oregon State University; Anchorage, AK; 503-705-2755 yatskovm@yahoo.com (Last attended 2016)
Jewel Yurkewich, British Columbia Ministry of Forests; Prince George, BC; 778-349-5871 jewel.yurkewich@gov.bc.ca (Last attended 2017)
Paul Zambino, USDA Forest Service; Coeur d'Alene, ID; 208-765-7493 pzambino@fs.fed.us (Last attended 2017)
Stefan Zeglen, British Columbia Ministry of Forests; Nanaimo, BC; 250-739-8385 stefan.zeglen@gov.bc.ca (Last attended 2023)
Tom Zegler, New Mexico State Forestry; Santa Fe, NM; 505-476-3351 tomj.zegler@state.nm.us (Last attended 2023)

Honorary Members

(Awarded to members that have attended at least 5 previous meetings of WIFDWC and are retired. Contact the current WIFDWC secretary if you would like to request membership. See Bylaws for details.)

Judy Adam; Fort Collins, CO
Paul Aho; Corvallis, OR
Ed Andrews
Peter Angwin; Redding, CA
Fred Baker; Max, MN
Jerry Beatty; Portland, OR
Jim Byler; Dalton Gardens, ID
Sally Campbell; Portland, OR
David Conklin; Albuquerque, NM
Gregg DeNitto; Florence, MT
Robert L. Edmonds; Seattle, WA
Lowell Farmer; Mount Vernon, WA
Gregory Filip; West Linn, OR
Brian Geils; Flagstaff, AZ
Linnea Gillman; Denver, CO
James Ginns; Penticton, BC
Don Goheen; Jacksonville, OR
Ellen Michaels Goheen; Jacksonville, OR
Don Graham; Vancouver, WA
Jim Hadfield; East Wenatchee, WA
Susan K. Hagle; Harper, ID
Everett Hansen; Corvallis, OR
John H. Hart; Cheyenne, WY
Alan Harvey; West Richland, WA
Bob Harvey; Frenchtown Township, ME
Paul Hennon; Juneau, AK
Diane Hildebrand; Wheat Ridge, CO
Ray Hoff; Moscow, ID
John Hopkins; Victoria, BC
Richard Hunt; Victoria, BC
William Jacobi; Fort Collins, CO
Bob James; Vancouver, WA
David Johnson; Lakewood, CO
Alan Kanaskie; Salem, OR
John King; Victoria, BC
John Kliejunas; Kent, WA
John Laut; Mesa, AZ
Leon Lemadeleine; Morgan, UT
Will Littke; Federal Way, WA
Blakey Lockman, Portland, OR
Helen Maffei; Bend, OR
Katy Mallams; Central Point, OR
Otis Maloy; Moscow, ID
Walter Mark; La Pine, OR
Arthur McCain; Rancho Cucamonga, CA
Geral McDonald; Pullman, WA
Duncan Morrison; Saanichton, BC
John Muir; Victoria, BC
Earl Nelson; Redmond, OR
Thomas H. Nicholls; Fifield, WI
Vidar Nordin; Ottawa, ON
Don Norris; Trail, BC
Steve Oak; Asheville, NC
Art Partridge; Moscow, ID
Roger S. Peterson; Santa Fe, NM
John Pronos; Sonora, CA
Jerry W. Riffle; Syracuse, IN
Kenelm Russell; Olympia, WA
Robert Scharpf; Berkley, CA
Craig Schmitt; LaGrande, OR
Mike Schomaker; LaPorte, CO
John W. Schwandt; Coeur d'Alene, ID
Mike Sharon
Dave Shaw; Corvallis, OR
Terry Shaw; Prineville, OR
Wayne Sinclair; Ithica, NY
Eric L. Smith; Fort Collins, CO
Michael Srago; El Cerrito, CA
James Stewart; Fairfax, VA
Rona Sturrock; Victoria, BC
Jack Sutherland; Victoria, BC
Al Tegethoff; Tuscon, AZ
Walter Thies; Corvallis, OR
Bob Tinnin; Tigard, OR
Borys Tkacz; OR
Lori Trummer; Gustavus, AK
Bart van der Kamp; Delta, BC
Allen Van Sickle; Victoria, BC
Conrad Wessela
Stuart Whitney; Victoria, BC
Ralph Williams; Nampa, ID
Ed Wood
Jim Worrall; Vancouver, WA

Deceased Members

Norm Alexander
Stuart "Stuie" Andrews
Jesse Bedwell
Robert Bega
Warren Benedict
John Bier
Richard Bingham
Bill Bloomberg
Roy Bloomstrom
Thomas "Buck" Buchannan
Don Buckland
Hubert "Hart" Bynum
Elmer Canfield
Fields Cobb
Ross Davidson
Oscar Dooling
Charles Driver
Norm Engelhart
David Etheridge
Mike Finnis
Ray Foster
Dave French
Alvin Funk
Robert Lee Gilbertson
Lake S. Gill
Clarence "Clancy" Gordon
John Gynn
John Hansbrough
Hans Hansen
Homer Hartman
George Harvey
Frank G. Hawksworth
Dwight Hester
Tommy Hinds
Brenton Howard
John Hunt
Paul Keener
James Kimmey
Andrea Koonce
Tom Laurent
Don Leaphart
Neil E. Martin
Tom McGrath
Neil E. McGregor
Jim Mielke
D. Reed Miller
Alex Molnar
Vergil Moss
Harrold Offord
Nagy Oshima
Lee Paine
John Palmer
John "Dick" Parmeter
Fred Peet
Glenn Peterson
Clarence Quick
Jack Roff
Lew Roth
Keith Shea
Dave Schultz
Charles G. Shaw
Albert Slipp
Richard B. Smith
Willhelm Solheim
Albert Stage
Phil Thomas
Eugene Van Arsdel
Willis Wagener
Gordon Wallis
Charles "Doc" Waters
Larry Weir
Roy Davidson Whitney
Ed Wicker
John Woo
Ernest Wright
Wolf Ziller