Proceedings of the 68th Western International Forest Disease Work Conference

DoubleTree Hotel

Rohnert Park, California

June 5-9, 2023

Proceedings of the 68th Western International Forest Disease Work Conference

DoubleTree Hotel

Rohnert Park, California

June 5-9, 2023

Compiled by:

Rachel K. Brooks
Washington State Department of Natural Resources
Forest Resilience Division
Olympia, Washington

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.

Citation:

Brooks, R.K. (comps.) 2024. Proceedings of the 68th Western International Forest Disease Work Conference, Rohnert Park, California, 5-9 June 2023. https://www.wifdwc.org/

Conference photo contributors:
Scott Baker
Rachel Brooks
Sam Brown
Kristen Chadwick
Kim Corella
John Dobbs (cover photo)
Betsy Goodrich
Jorge Ibarra
Alan Kanaskie
Holly Kearns
Blakey Lockman
Mike McWilliams
Robin Mulvey
Greg Reynolds
Kerry Wininger

Contents

WIFDWC Members

Appendix

Conference Agenda

68th Western International Forest Disease Work Conference DoubleTree Hotel -- Rohnert Park, California

June 5-9, 2023

Monday, June 5

1300 – 1700: **Nature hike** (optional) Organizers: Chris Lee & Tom Smith CalFire

Fairfield Osborne Preserve. Much sudden oak death (SOD) research has occurred here, and there will be native tree pest and invasive plant issues to see as well. This is a great hiking area.

- Transportation not provided. The preserve is a 23-minute drive from the hotel; carpooling is suggested and details on coordination will follow.
- Water and snacks not provided; bring your own!
- Poison oak is present in the preserve, and although the hike will stick to trails, those who are susceptible should come prepared to protect yourselves.

1700 – 2100: **Registration**

Non-host social

Tuesday, June 6

0700 – 0830:	**Registration** (continued from Monday evening)		
0700 – 0825:	**Dwarf Mistletoe Committee** (breakfast)	Chair:	Dave Shaw Oregon State University
0830 – 0840:	**Welcome, introductions, & logistics**	Meeting Chair:	Jane Stewart Colorado State University
0840 – 0910:	**California ecosystems**		Chris Lee & Tom Smith CalFire
0910 – 0925:	**Outstanding Achievement Award – 2023**	Presenters:	OAA
Committee 0925 – 1030:		**Graduate Student Flash-n-**	
Dash	Moderator:	Brad Lalande	USFS Forest Health Protection
1030 – 1045:	Break		
1045 – 1200:	**Panel: New (or Relatively New) Disease Issues**	Moderator:	Betsy Goodrich USFS Forest Health Protection

1045 – 1105: **Lori Winton** – Forest Pathologist, U.S. Forest Service, Alaska Region, Forest Health Protection; Fairbanks, AK
Aspen running canker in Alaska: A widespread new disease and new fungus.

1105 – 1125: **Rachel Brooks** – Forest Pathologist, Forest Health Division, Washington Dept of Natural Resources; Olympia, WA
Sooty bark disease of maple in Washington State.

1125 – 1140: **Kelsey Sondreli** – Research Associate, Dept of Botany & Plant Pathology, Oregon State University; Corvallis, OR
Outbreak of Septoria canker caused by Sphaerulina musiva *on* Populus trichocarpa *in Oregon.*

1140 – 1200: **Curtis Ewing** – Senior Environmental Scientist Specialist - Forest Entomologist, CalFire, Cascade & Northern Sierra Region, Forest Entomology & Pathology; Vallejo, CA
*The Mediterranean Oak Borer (*Xyleborus monographus*) and associated wilt fungi: An emerging invasive ambrosia beetle in Northern California and Oregon.*

1200 – 1325: **Root Disease Committee** (lunch) Chair: Blakey Lockman
USFS Forest Health Protection

1330 – 1500: **Panel: Climate & Tree Diseases – I** Moderator: Alex Woods
British Columbia Public Service

1330 – 1400: **Dave Shaw** – Professor; Dept of Forest Engineering, Resources, & Management; Oregon State University; Corvallis, OR
Complexity of biological disturbance agents, fuels heterogeneity, and fire in coniferous forests of the western United States.

1400 – 1420: **Mike Cruickshank** – Research Scientist, Natural Resources Canada, Canadian Wood Fibre Centre; Victoria, B.C.
Genetic analysis of Douglas-fir and western redcedar family tolerance to soil moisture extremes in greenhouse studies: Survival, growth, and phenotypic adaptation.

1420 – 1450: **Igor Lacan** – Cooperative Extension Advisor, Division of Agriculture & Natural Resources, University of California; San Francisco, CA
Urban tree disorders and climate change: A view from the field (Bay Area cities), and a view of the trade-offs in city tree management.

1450 – 1500: **Susan Frankel** – Forest Pathologist, U.S. Forest Service, Pacific Southwest Research Station; Albany, CA
Managing intense drought and monarch butterfly habitat in an urban jungle: Albany Hill Park.

1500 – 1530: Break

1530 – 1630: **Panel: Climate & Tree Diseases – II** Moderator: Danny Norlander
Oregon Department of Forestry

1530 – 1545: **Brent Oblinger** – Forest Pathologist, U.S. Forest Service, Pacific Northwest Region, Forest Health Protection; Bend, OR
Accelerated true fir mortality in central and northeast Oregon.

1545 – 1600: **Chris Lee** – Forest Pathologist, CalFire, North Coast Region, Forest Entomology & Pathology; Fortuna, CA
Characteristics of winter 2023 storm-down trees: A rapid assessment.

1600 – 1630: **Discussion** Moderator: Janice Alexander
UC Cooperative Extension

Climate, climate change, and tree diseases: Okay, Boomers!?

Robert Scharpf – Forest Pathologist (retired), U.S. Forest Service, Pacific Southwest Research Station; Berkeley, CA

Millennials' viewpoints of climate change and forest health.

Robin Mulvey – Forest Pathologist, U.S. Forest Service, Alaska Region, Forest Health Protection; Juneau, AK

Gen Z's viewpoints of climate change and forest health.

Alexander Flores – Graduate student, Dept of Biology, Sonoma State University; Rohnert Park, CA

1630 – 1830: Dinner (on your own)

1830 – 2100:	**Poster session**	Organizer:	Patrick Bennett USFS RMRS Research
	Ice cream social	Organizer:	Local arrangements
	Silent auction	Organizer:	Betsy Goodrich Forest Health Protection

Wednesday, June 7

0700 – 0830: **Rust Committee** (breakfast) — Chair: Jane Stewart, Colorado State University

0845 – 1700: **Field trip** (lunch & snacks provided) — Organizers: Chris Lee & Tom Smith, CalFire

0845 – 0900: Buses **load**

0900 Buses **leave**

1700 Buses **return**

1800 – 2045: **Banquet & Program**

1800 – 1830: No-host social

1830 – 1930: Banquet

1930 – 2030: "*Outstanding Achievement Award*" acceptance presentations.

1930 – 1950: **Greg Filip** (2019)

1950 – 2010: **Ned Klopfenstein** (2020)

2010 – 2030: **Phil Cannon**

(2020) 2030 – 2045: "*What year was your*

first WIFDWC?"

Thursday, June 8

0700 – 0825: **Foliage & Twig Committee** (breakfast) Chairs: Kelsey Sondreli
Adam Carson
(for Jared LeBoldus)
Oregon State University

0830 – 0945: **Special papers - I** Moderator: Tom Smith
CalFire

0830 – 0854: **Robert Andrus** – Post-doc, School of the Environment, Washington State University; Pullman, WA
Western redcedar dieback linked to drier and warmer summer conditions: An analysis of tree rings. (virtual)

0854 – 0918: **Sebastian Fajardo** – Graduate student, Dept of Plant Pathology, University of California - Davis; Davis, CA
Phytophthora *species and their associations with chaparral vegetation in southern California landscapes.*

0918 – 0942: **Jane Stewart** – Associate Professor, Dept of Agricultural Biology, Colorado State University; Fort Collins, CO
Cronartium ribicola *and* Cronartium commandrae *hybrids in Wyoming and Colorado.*

0945 – 1000: Break

1000 – 1200: **Panel: Root Diseases** Moderator: Dave Shaw
Oregon State University

1000 – 1024: **Yung-Hsiang (Sky) Lan** – Research Associate, Dept of Botany & Plant Pathology, Oregon State University; Corvallis, OR
Coniferiporia sulphurascens *(a root rot) alters community composition but not forest productivity, Pacific Northwest, USA.*

1024 – 1048: **Shawn McMurtrey** – Technician, USDA Agricultural Research Service; Corvallis, OR *Whole-genome sequencing of* Coniferiporia sulphurascens *reveals evidence of long- distance gene flow and migration.*

1048 – 1112: **Daram Choi** – Graduate student, Dept of Forest Engineering, Resources, & Management; Oregon State University; Corvallis, OR
Genetic characterization and bioclimatic modeling of the three varieties of Leptographium wageneri *(cause of black stain root disease) in the western USA.*

1112 – 1136: **Noah Lindeman** – Graduate student, Dept of Agricultural Biology, Colorado State University; Fort Collins, CO

Hooked or unhooked: Characterizing the morphological and molecular species relationships in Onnia *spp. of North America.*

1136 – 1200: **Richard Cobb** – Associate Professor, Dept of Natural Resources & Environmental Science, California Polytechnic State University (Cal Poly); San Luis Obispo, CA *Heterobasidion root disease emergence and impacts over fifty years in montane California forests: A comparison of three host-pathogen systems.*

1200 – 1325: **Nursery Committee** (lunch) — Chair: Anna Leon, Weyerhaeuser Company

1330 – 1530: **Panel: Rusts** — Moderator: Jane Stewart, Colorado State University

1330 – 1354: **Jorge Ibarra Caballero** – Research Associate, Dept of Agricultural Biology, Colorado State University; Fort Collins, CO
Field ready: Development of a rapid LAMP-based colorimetric assay for the causal agent of white pine blister rust, Cronartium ribicola.

1354 – 1418: **Amanda Hendrix** – Regional Botanist, U.S. Forest Service, Northern Region; Missoula, MT
Whitebark pine and ESA (Endangered Species Act) implications. (virtual)

1418 – 1442: **Kelly Burns** – Forest Pathologist, U.S. Forest Service, Rocky Mountain Region, Forest Health Protection; Lakewood, CO
Interactions between white pine blister rust and climate indicate vulnerabilities to limber pine health.

1442 – 1506: **James Blodgett** – Forest Pathologist, U.S. Forest Service, Rocky Mountain Region, Forest Health Protection; Rapid City, SD
Limber pine restoration in the Black Hills.

1506 – 1530: **Michael Murray** – Forest Pathologist, British Columbia Ministry of Lands and Natural Resources; Nelson, BC
Blister rust distribution, trends, and resistance screening in southern British Columbia's endangered limber and whitebark pine.

1530 – 1600: Break

1600 – 1715: **Special papers - II** — Moderator: Rachel Brooks Washington DNR

1600 – 1624: **Nicolas Feau** – Research Scientist, Natural Resources Canada, Canadian Forest Service; Pacific Forestry Centre, Victoria, B.C.

Advances in Swiss needle cast work in British Columbia.

1624 – 1648: **Sarah Navarro** – Forest Pathologist, U.S. Forest Service, Pacific Northwest Region, Forest Health Protection; Portland, OR
Sudden oak death: Oregon update. (virtual)

1648 – 1712: **Bruce Moltzan** – National Program Director - Pathology, U.S. Forest Service, Washington Office, Forest Health Protection; Washington, D.C.
Hazard-rating activities.

1715 – 1900: Dinner (on your own)

1900 – 2130: **Climate Change & Disease Committee** Moderator: Alex Woods

Climate and Tree Diseases show and tell.

- We ask you bring an article on climate and tree diseases to orally share with the group.
- Each person will have about five minutes to informally talk about the paper, why they think it is important, and discuss.
- We will compile a list of these papers for the proceedings. For those planning ahead, please email susan.frankel@usda.gov with the citation of the paper you plan to share.
- You do not need to bring hardcopies of the article to the meeting.

Debate!! Will climate change significantly alter root disease behavior and impact?
David Shaw (Oregon State University) & Michael Murray (BC Ministry of Forests)

Round-robin: Climate change and forest diseases: Research and management exchange.

Friday, June 9

0700 – 0825: **Hazard Tree Committee** (breakfast) Chair: Kristen Chadwick
USFS Forest Health Protection

0830 – 1030: **Special papers – III** Moderator: Chris Lee CalFire

0830 – 0854: **Joey Hulbert** – Post-doc, Puyallup Research & Extension Center, Washington State University; Puyallup, WA
Citizen science for forest disease monitoring.

0854 – 0918: **John Dobbs –** Graduate student, College of Agricultural Sciences, Colorado State University; Fort Collins, CO
Fusarioid community structure among conifer nurseries of the contiguous U.S.A. and virulence of conifer collected Fusarium *spp.*

0918– 0942: **Edoardo Scali** – Graduate student, Dept of Environmental Science, Policy, & Management; University of California - Berkeley; Berkeley, CA
Cypress Canker Disease: Model pathosystem for understanding host-pathogen interaction.

0942 – 1006: **James Blodgett** – Forest Pathologist, U.S. Forest Service, Rocky Mountain Region, Forest Health Protection; Rapid City, SD
Diplodia tip blight.

1006 – 1030: **Marcelo Bustamante** – Graduate student, Dept of Plant Pathology, University of California - Davis; Davis, CA
Ghost canker of pines in southern California.

1030 – 1045: Break

1045 – 1150: **Business meeting** Meeting Chair: Jane Stewart

1150 – 1200: **Closing comments & adjourn** Meeting Chair: Jane Stewart

WIFDWC 2023 organizers

Planning Committee & officers

- *Meeting Chair*: **Jane Stewart** – Colorado State University, Dept of Agricultural Biology; Fort Collins, CO
- *Program Chair*: **Brennan Ferguson** – U.S. Forest Service, Forest Health Protection; Wenatchee, WA
- *Secretary*: **Rachel Brooks** – Washington DNR, Forest Health Division; Olympia, WA
- *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*:
  - **Chris Lee** – CalFire, Forest Entomology & Pathology; Fortuna, CA
  - **Tom Smith** – CalFire, Forest Entomology & Pathology; Sacramento, CA
  - **Mary Lou Fairweather** – U.S. Forest Service, Forest Health Protection (retired)

Committee chairs

- *Climate Change & Disease Committee:*
  - **Susan Frankel** – U.S. Forest Service, Pacific Southwest Research Station; Albany, CA
  - **Alex Woods** – British Columbia Public Service; Smithers, BC
  - **Charles "Terry" Shaw** – U.S. Forest Service, Research (retired)
- *Dwarf Mistletoe Committee:*
  - **Dave Shaw** – Oregon State University, Dept of Forest Engineering, Resources, & Management; Corvallis, OR
- *Foliate & Twig Committee:*
  - Standing in for Jared LeBoldus: **Kelsey Sondreli** – Oregon State University; Corvallis, OR **Adam Carson** – 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:*
  - **Blakey Lockman** – U.S. Forest Service, Forest Health Protection; Portland, OR
- *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 for the first panel talks. (photo: Rachel Brooks)

California and its northwestern corner: Immense ecological diversity, immense forest health challenges

Tom Smith[1]* and Chris Lee[2]*

WIFDWC 2023 met in Rohnert Park, in the heart of Sonoma County, one of California's more economically and culturally dynamic counties over the past half-century and at or near the nexus of many travel, business, historical, and ecological regions. To the east of the WIFDWC meeting point stand the Mayacamas Mountains, dividing Sonoma County's vineyards from those of Napa County. To the west, overshadowing the coast, stand the Coast Range hills and peaks, deeply dissected by many streams, sparsely populated, and catching vast amounts of precipitation moving in from the Pacific Ocean. The topographic and biological diversity on display in Sonoma County mirrors that in the rest of northwestern California, an even larger crossroads for the Pacific Northwest, the Great Basin and associated high deserts, the Klamath Mountains ecoregion, and California's Coast Ranges and Great Central Valley. These ecoregional intersections, with their multitude of geological parent materials and climatic gradients, make this part of California a center of vegetative diversity rivaled on the continent only by parts of the Appalachians.

California: Distinctive and Diverse

Before considering northwestern California specifically, it's worth stepping back to briefly survey California's diversity as a whole. California is different from the rest of the western United States, and those differences have an impact on forest diseases and insects. The state's population of nearly forty million people is equal to all the other western states combined. The economy of the state would be the fifth largest in the world if California were a separate country and is on track to becoming the fourth largest economy. As such, international trade is a major aspect of the state and includes the two largest ports in the country, millions of vehicles entering and exiting the state on an annual basis, and all the dangers of pest introductions that trade and movement entails.

The ecological and physical diversity of California is immense, and the California Floristic Province has been identified as one of 25 biodiversity conservation hotspots worldwide (Myers et al. 2000). The state has a largely Mediterranean climate but ranges from near temperate rainforest to extreme desert conditions. Altitude varies from the lowest point in North America to the highest point in the lower 48 states. California includes the oldest, tallest, and largest trees known in the world. Over 33 million acres of the State are forested, with a mix of federal, industry and private land ownership. For all that diversity, there are few timber mills for use in forest management operations. This diversity and lack of management opportunities result in a multitude of pest problems.

Recent situations in California have included a twenty-year drought and the largest and most destructive wildfires in State history. At one point six of the largest wildfires known to the state were burning simultaneously. Add to these conditions the continual introduction of non-native, invasive tree pests, and the impacts on forests, woodlands and the urban tree canopy have been extreme.

Sonoma County and Northwestern California

For thousands of years Sonoma County has been occupied by several tribes of original inhabitants. The county's name, in fact, derives from the Western Wappo, who lived in the northern part of the Russian River Valley and two of whose settlement place names were *Tsi'mitu-tso-noma* and *Tekanan-tso-noma.* Southern Sonoma County was the territory of the Coast Miwok tribe, while the coast and near-coastal areas were occupied by the Kashia

---

[1] California Department of Forestry and Fire Protection (CalFire); Sacramento, CA, USA
[2] California Department of Forestry and Fire Protection (CalFire); Fortuna, CA, USA
*christopher.lee@fire.ca.gov and tom.smith@fire.ca.gov

Pomo. The Southern Pomo lived in the area from Cotati/Rohnert Park (where WIFDWC 2023 took place) up what is now the Highway 101 corridor through the Cloverdale area (Wynne 2024). Ancestors of all these tribes still live in these ancestral territories, maintaining a vibrant cultural presence and practicing traditional means of stewarding the landscape.

Just as Sonoma County's biodiversity echoes that of greater northwest California, so does its diversity of native inhabitants: over twenty-five tribes lived in the area we call northwestern California alone (Northern California Indian Development Council 2024). Each of these tribes shaped its lifestyle to the landscape features among which it lived, particularly the rivers and oceans (Elsasser and Heizer 1971), and the mutual interdependence of people and geography accounts for a large part of the fantastic diversity of terrain and vegetation we see here.

Geologic history accounts for another large part, with mountainous terrains sheltering flora that would have otherwise have been destroyed by episodic geologic and climatic events such as glaciations, lava flows, and submersion as well as a wide variety of parent materials that foster plants specialized for survival on harsh parent materials and in particular microsites (Whittaker 1960). In some places, drastic contrasts in vegetation occur within short distances because although parent materials in both are identical, weathering and depth of those parent materials control water distribution very differently. One prominent example is in the so-called Franciscan terrane of the north coast counties, where deeply weathered Franciscan sediments nearer the coast support well-developed conifer-dominated forests containing redwoods and Douglas-firs, while less weathered Franciscan landscapes in the interior hills with very shallow depth to bedrock and flashy hydrology support primarily oak woodlands (Hahm et al. 2020).

Moreover, steep climatic gradients abound in this corner of California, contributing further to vegetation diversity and to a relatively fine-grained mosaic of vegetation type distribution. While some areas near the coast receive upwards of 140 inches of precipitation a year, others may receive less than twenty, and this gradient spans only around fifty miles as the crow flies in the northernmost part of the state.

Northwestern California Vegetation Types and Forest Pests

This complex mosaic of parent materials and climate leads to at least seven very rough regional vegetation "types" presented somewhat arbitrarily as examples of northwestern California vegetation (Figure 1). These include the following:

(1) The vegetation of the coastal strip, including serotinous pine and cypress forests; "Pacific Northwest-like" forests with Sitka spruce, western hemlock, and grand fir; and coastal scrub and chaparral.
(2) Forests of the North Coast Ranges, including redwood forests; Douglas-fir/tanoak forests (the so-called "mixed evergreen" stands); slightly higher elevation mixed-conifer types; oak woodlands; and chaparral.
(3) A wide variety of Klamath Mountains forests, including white fir/Douglas-fir forests; upper-elevation mixed conifer forests; sky islands containing widely spaced, high-elevation conifer species; and serpentine-soil forests with many taxa specializing in harsh conditions.
(4) The northern Central Valley, with distinctive ghost pine (aka "gray pine") woodlands and chaparral.
(5) Bay Area forests, including urban forests; Douglas-fir/tanoak forests and oak woodlands similar to those farther north; and oak-pine forests.
(6) Great Basin-influenced forests, primarily juniper woodlands.
(7) Riparian vegetation types, including a wide variety of riparian hardwoods and mountain meadows and wetlands.

Figure 1. Representative regional vegetation “types” in northwestern California, with some associated forest pest issues. Top, left to right: coastal grassland grading into bishop pine forest (Coastal Strip); redwood forest (North Coast Ranges); ghost pine woodland, with tree in foreground infected by *Diplodia sapinea* (North Central Valley); juniper woodland (Great Basin Influenced—photo courtesy Joseph DiTomaso, UC ANR, bugwood.org). Bottom, left to right: Jeffrey pine woodland on serpentine soil (Klamath Mountains); lake surrounded by Port Orford-cedar killed by *Phytophthora lateralis* (Riparian/Klamath Mountains); urban forest with true oaks killed by several secondary agents (San Francisco Bay Area).

Unsurprisingly, this vegetative variety has also given rise to many forest pest problems. The inclusion of “urban forests” in the list above indicates an additional kind of diversity—a diversity of population density—that provides its own kinds of problems, as some of the pests are imported, such as *Phytophthora lateralis* (cause of Port Orford-cedar root disease), *Phytophthora ramorum* (cause of sudden oak death), *Fusarium circinatum* (cause of pine pitch canker), the Mediterranean oak borer, the Kuroshio and polyphagous shothole borers, the balsam woolly adelgid, the green spruce aphid, and innumerable non-native weedy plants.

Moreover, we are still in the process of discovering that even among the native forests in northwestern California, many are understudied and some still undiscovered. For example, native pest problems only recently elucidated in northwestern California include the recently named *Calonectria californiensis,* cause of a foliar blight of several woody tree and shrub species; *Tubakia californica,* a fungus that progressively defoliates tanoaks, coast live oaks, California black oaks, and probably other related trees; and *Onnia subtriquetra,* a stem decay fungus previously thought to be restricted to the eastern U.S. Other newly recognized threats are simultaneously being recognized and further studied in both northern and southern California; these include *Phytophthora cinnamomi* and other non-native *Phytophthora* species on many host plants, *Diplodia corticola* on tanoaks and true oaks throughout the state and up into Oregon, several bot canker fungi such as *Neofusicoccum* spp. on both hardwoods and conifers, and acute oak decline associated with a suite of apparently pathogenic bacteria.

Table 1 shows some of the most commonly forest pest problems encountered in northwestern California indexed by the regional types mentioned above. It should be kept in mind that every quadrant of California could have a similar table of its own, filled with a similarly diverse list of players. And given California’s exceptional levels of human activity, its exceptional physical and biological variety, and an ever-changing climate, it is likely that these players will only continue to multiply, providing forest health specialists of all stripes with plenty to do in the future. In June 2023, we were delighted to welcome the forest pathologists of WIFDWC to California to get a taste of all this.

Table 1. Northwestern California regional vegetation "types" and some of the most common associated forest pests. Note that each "type" is primarily a geographic designation and in reality contains many diverse vegetation assemblages.

Regional vegetation "type"	**Some associated forest pests**
Coastal Strip	Western gall rust Green spruce aphid Balsam woolly adelgid Pitch canker *Phytophthora cinnamomi*
North Coast Ranges	*Phaeolus schweinitzii* *Heterobasidion occidentale* Flatheaded fir borer Sudden oak death Black stain root disease
Klamath Mountains	Port Orford-cedar root disease Dwarf mistletoes White pine blister rust Cytospora canker
Northern Central Valley	Diplodia shoot and branch blight Flatheaded fir borer Western bark beetle CA five-spined Ips
San Francisco Bay Area	Sudden oak death Mediterranean oak borer Bot cankers Pitch canker
Great Basin Influenced	Fir engraver *Dendroctonus* spp. Dwarf and leafy mistletoes
Riparian/wet vegetation	Native foliar and twig blights Alder bark beetle Non-native *Phytophthora* spp.

References

Elsasser, A.B. and Heizer, R.F. 1971. Speculations on the prehistory of northern California. pp 225-230 in *The California Indians: A Source Book.* Ed. R.F. Heizer and M.A. Whipple. Berkeley: UC Press.

Hahm, W.J., Rempe, D.M., Dralle, D.N., Dawson, T.E., and Dietrich, W.E. 2020. Oak transpiration drawn from weathered bedrock vadose zone in the summer dry season. Water Resources Research 56, e2020WR027419. https://doi.org/10.1029/2020WR027419.

Myers, N., Mittermeir, R.A., Mittermeier, C.G., da Fonseca, G.A.B., and Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

Northern California Indian Development Council. 2024. California Indian pre-contact tribal territories. https://ncidc.org/California_Indian_Pre-Contact_Tribal_Territories. Accessed January 11, 2024.

Whittaker, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30 (3): 279-338.

Wynne, M. 2024. Native American heritage in Sonoma County. https://www.sonomacounty.com/articles/native-american-heritage-sonoma-county. Accessed January 11, 2024.

Panel: New (or Relatively New) Disease Issues

Moderator: Betsy Goodrich

Dave Shaw sharing mistletoe samples to the fieldtrip crew (photo: Rachel Brooks).

Aspen running canker in Alaska: A widespread new disease and new fungus

Lori Winton[1]*, Roger Ruess[2], and Gerry Adams[3]

Aspen running canker is widespread throughout the accessible areas of Alaska’s interior and south-central boreal forest (Figure 1). First discovered in 2015, we surveyed over 16,000 trees and found canker at 82% of the 88 study sites (Ruess et al 2021). The site average of cankered trees ranged from 0% - 69%, with the highest incidence northwards of the Alaska Range. However, of the trees that had canker, average mortality (~85%) was consistently high and invariant. Small understory trees were the most susceptible and could be girdled and killed within a single season. We have measured over 1 cm horizontal growth within three days (Figure 2). Sites with higher summer vapor pressure deficit, a contributor to drought-induced mortality, consistently had higher canker incidence. Existing forest inventory data showed that aspen mortality has increased by about 11% per year since 2000. We believe drought and the ubiquitous aspen leafminer (*Phyllocnistis populiella*) have stressed host trees making them more susceptible to a pathogen that is the ultimate driver of widespread mortality. Increasing wildfires throughout interior Alaska have favored a shift from black spruce to Alaska paper birch and aspen. However, widespread aspen mortality has significant potential to reshape successional trajectories, stand structure, and ecosystem function, particularly on sites too dry for birch.

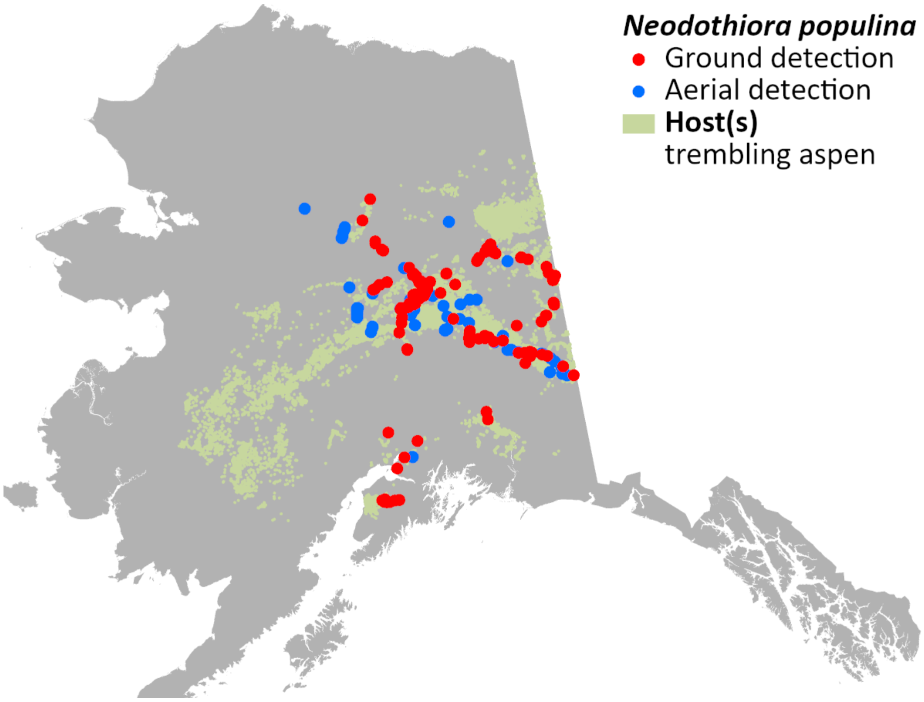


Figure 1: Aspen running canker cumulative mapped locations as of 2022 and modeled trembling aspen distribution.

---

[1] USDA Forest Service, Alaska Region, Forest Health Protection; Fairbanks, AK, USA
[2] University of Nebraska, Department of Plant Pathology; Lincoln, NE, USA
[3] University of Alaska, Institute of Arctic Biology; Fairbanks, AK, USA
*loretta.winton@usda.gov

Figure 2: The margin of an aspen running canker advanced over 1 cm over the course of three days in 2019.

The lack of diagnostic fruiting bodies in the field, difficulty with isolations, and indeterminate cultural characteristics delayed identification of the causal agent. Pathogenicity tests (Winton et al 2022) of 12 candidate isolates, including 5 yeasty species (Figure 3), determined that the causal agent is a yeast-like fungus new to science that we have named *Neodothiora populina* Crous, G.C. Adams & Winton (Crous et al 2020). Continuing studies by numerous partners at the University of Alaska Fairbanks include: 1) transcriptomics to look at how drought, aspen leaf miner, and pathogen infection affect aspen defense mechanisms, 2) whether the rapid expansion of the pathogen within trees is achieved by transportation within the xylem, 3) long term ecological effects on the boreal ecosystem, 4) improve our understanding the negative implications of aspen mortality by outreach to stakeholders involved in fire management and fire modeling and Alaska Native Corporations involved in carbon-credit programs, and 5) engage the broader public by partnering with the environmental arts-humanities-science program *In a Time of Change* (Figure 4).

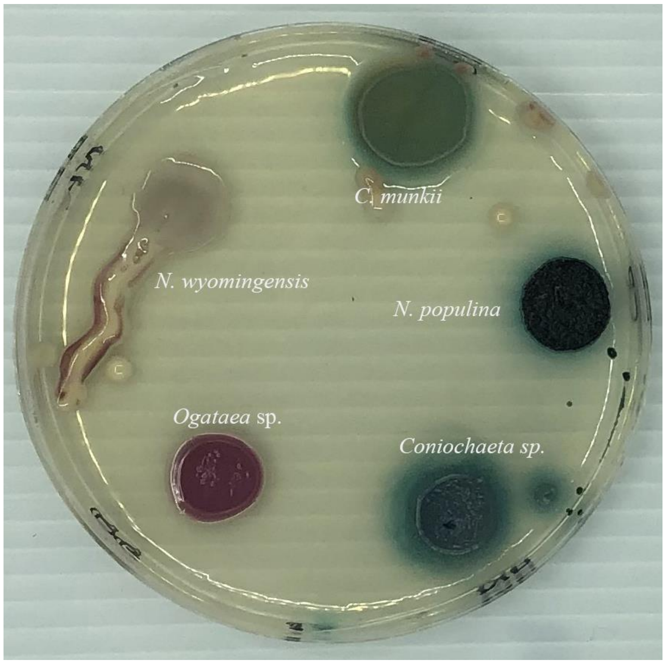


Figure 3: Isolates of pale yeast-like colonies can be differentiated rapidly by color when grown on CHROMagar® Candida at 25° C for 72 hours (Figure 3 from Winton et al 2021).

Figure 4: Acrylic on canvas painting entitled *The Margin Between* by Gail Priday from the environmental arts-humanities-science program *In a Time of Change* (https://itoc.alaska.edu/the-margin-between/).

Literature Cited

Ruess, R.W., Winton, L.M., Adams, G.C. 2021. Widespread mortality of trembling aspen (*Populus tremuloides*) throughout interior Alaskan boreal forests resulting from a novel canker disease. (2021) PLoS ONE, 16 (4 April), art. no. e0250078. https://doi.org/10.1371/journal.pone.0250078

Winton, L.M., Adams, G.C., Ruess, R.W. 2022. Determining the novel pathogen *Neodothiora populina* as the causal agent of the aspen running canker disease in Alaska. Canadian Journal of Plant Pathology, 44 (1), pp. 103-114.

Crous, P.W., Cowan, D.A., Maggs-Kölling, G., Yilmaz, N., et al. 2020. Fungal planet description sheets: 1112–1181. Persoonia: Molecular Phylogeny and Evolution of Fungi, 45, pp. 251-409.

Sooty bark disease of maple in Washington State

Rachel Brooks[1]* and Dan Omdal[1]

Dieback of urban trees associated with sooty dark patches of bark was noted in Seattle, WA starting in 2017. Seattle Parks & Recreation contracted with a private company and confirmed the presence of *Cryptostroma corticale* in collected samples. This is of note, as previously *C. corticale* was only recorded twice on dead maple wood in Washington: once in 1968 in Whitman County and once in 2007 in Lewis County. This fungus is thought to be native to the Great Lakes Region of North America where it is considered a saprophyte. In Europe, by contrast, the fungus is considered invasive, where it causes sooty bark disease (SBD) on maple trees (*Acer spp.*) resulting in tree mortality, as confirmed with Koch's Postulates. Additional research in Europe has shown that the fungus only causes disease on trees within the maple genus but is capable of growing on dead wood from a variety of other tree genera. SBD in Europe can reach outbreak levels in maple stands and urban plantings and has been associated with tree stress, including stress caused by hot, dry summers.

Cryptostroma corticale in Europe has been shown to infect trees when airborne spores germinate on recently injured wood. The fungus then grows into the vascular tissues, often growing from damaged upper branches into lower portions of the tree where it may remain latent as an endophyte for many years until it reacts to tree stress and causes symptoms. As woody tissues die, the fungus can produce characteristic gray-black fruiting bodies (subcortical stromata) and release large quantities of airborne spores. These airborne spores, in addition to infecting other trees, may cause hypersensitivity pneumonitis ("maple bark disease") in humans, a type of allergic reaction. Individuals at risk are those with intensive occupational contact with spore-producing wood and possibly those that are immunocompromised and exposed. Healthy individuals not working extensively with infected tree tissues are considered not vulnerable. (Please see https://doh.wa.gov/node/12614 for more guidance).

In Washington State, little is currently known about *C. corticale*. It has been confirmed on samples taken from a variety of maple tree and a few other urban tree species, but no pathology tests have been completed using Washington isolates, our native maples, or other non-maple tree species. Symptoms observed on maples testing positive for *C. corticale* have included branch dieback, epicormic sprouting, and tree death. Green-brown vascular staining may be observed on recently cut stems, but colors fade with time. Subcortical stromata may become visible on dead potions of the tree beneath blistered bark. Currently, nested PCR is used to confirm the pathogens presence, though spore morphology and culturing can also aid in diagnosis. A diagnostic guide for Washington has been produced for reference (Brooks et al. 2022).

A field survey was completed in 2022 with the goal of determining the current distribution of *C. corticale* in western Washington on *A. macrophyllum.* Fifty appropriate Washington State Park Properties were selected for the survey in addition to two control sites. During a two-hour visit to each site, *A. macrophyllum* trees were visually identified and bark samples from symptomatic trees and core samples from asymptomatic trees were collected. Molecular confirmation was completed using nested PCR. Results showed that *A. macrophyllum* was prevalent on park properties, and that overall the species appeared vigorous in most properties surveyed. In total, 181 trees were sampled at 48 parks containing *A. macrophyllum* with 89% of those parks having at least one positive *C. corticale* detection. Despite *C. corticale* appearing ubiquitous in western Washington State Park properties, *C. corticale* fruiting bodies were rare on individual trees observed. These findings likely suggest an even broader distribution outside of the sampled area, and may indicate *C. corticale* was not recently introduced but has been here long enough to become well distributed. This survey work was recently published and is publically available for reference (Brooks et al. 2023).

---

[1] Washington State Department of Natural Resources, Forest Resilience Division; Olympia, WA, USA
*Rachel.Brooks@dnr.wa.gov

Current recommendations to land managers include minimizing tree stress and ensuring those working directly with dead maple wood are aware of *C. corticale* fruiting body identification and possible health risks. Additional work is needed to confirm the pathogenicity of local *C. corticale* isolates on our native maples (*A. macrophyllum* and *A. circinatum*), determine the nativity of the fungus, and predict its impacts to our forests and urban trees.

Literature Cited

Brooks, RK, Hulbert, JM, Omdal, D, Elliott, M, Chastagner, GA. (2022) Sooty bark disease diagnostic guide. Washington State University Extension. FS375E. https://pubs.extension.wsu.edu/sooty-bark-disease-diagnostic-guide

Washington State Department of Health. Maple Bark Disease. Available online: https://doh.wa.gov/node/12614. Accessed November 2023.

Brooks, RK, Omdal, D, Brown, S, Marshall, CJ, Hulbert, JM, Elliott, M, Chastnager, G (2023) *Cryptostroma corticale*, the causal agent of sooty bark disease of maple, appears widespread in western Washington State, USA. Forest Pathology.1-12. https://doi.org/10.1111/efp.12835

Outbreak of Septoria canker caused by *Sphaerulina musiva* on *Populus trichocarpa* in Oregon

Kelsey L. Søndreli[1]* and Jared M. LeBoldus[1,2]

The fungus *Sphaerulina musiva* (Syn. = *Septoria musiva*) causes Septoria stem canker on *Populus* spp. These girdling stem cankers can weaken stems, increasing the risk of wind breakage, or can kill trees outright. This pathogen has never been found west of the Rocky Mountains in the United States until October of 2018. Cankers were recently found on a *Populus* plantation in northeast Oregon and *S. musiva* was positively identified. The introduction of this pathogen in Oregon could have devastating impacts to *Populus trichocarpa*, a native tree species in Oregon, which is known to be very susceptible to this disease. This important tree species provides wildlife habitat in riparian areas and is a keystone species in Oregon ecosystems.

S. musiva isolates collected from Oregon fit into the BC2 population in Canada based on sequencing, which showed less severity in terms of canker production on *P. trichocarpa*. This highlights the fact that introductions from other parts of the U.S. and Canada should be avoided. This may cause more severe disease on native populations of the ecologically important native *P. trichocarpa* in the PNW. The trees at the plantation field site have now been cut down and burned to stop the spread of the pathogen to new area. The area surrounding the plantation has been surveyed in 2022 and no new disease has been found.

---

[1] Oregon State University, Department of Botany and Plant Pathology; Corvallis, OR, USA
[2] Oregon State University, Department of Forest Engineering, Resources, and Management; Corvallis, OR, USA
*Kelsey.Sondreli@oregonstate.edu

The Mediterranean Oak Borer (*Xyleborus monographus*) and associated wilt fungi: An emerging invasive ambrosia beetle in Northern California and Oregon

Curtis Ewing[1]*, Michael I. Jones[2]*, Akif Eskalen[3], and Sheri Smith[4]

Introduction

The Mediterranean Oak Borer (MOB) *Xyleborus monographus*(Coleoptera: Curculionidae: Scolytinae) is an ambrosia beetle native to Europe, North Africa, and the Middle East and has been introduced to California (Rabaglia et al. 2020) (Ewing et al. 2020), Oregon (Ripley and Williams 2022) (ODA-IPPMP 2023), Great Britan and South Korea. First collected in California in 2017 and identified in 2019, this species poses a serious threat to white oaks in California. MOB kills trees through a combination of extensive gallery excavation within the sap wood and associated pathogenic wilt fungi which MOB vectors and relies on primarily for the development of brood and also adult maintenance. A literature review and more in depth discussion of the information presented herein has been submitted (Ewing et al. Submitted). Additional information, a printable Pest Alert (Ewing et al. 2020) and a reporting tool for California is available on the MOB Pest Complex Website: https://ucanr.edu/sites/mobpc/ and in Oregon a Pest Alert is available at https://www.oregon.gov/oda/shared/Documents/Publications/IPPM/Pest.Alert.Mediterranean.oak.borer%20(2023).pdf (ODA-IPPMP 2023) and a Forest Facts sheet at https://www.oregon.gov/odf/Documents/forestbenefits/fact-sheet-mediterranean-oak-borer.pdf (Ripley and Williams 2022).

Host Trees

In California MOB is invasive on valley oak (*Quercus lobata*) and blue oak (*Q. douglasii*) and has been confirmed attacking a small number of fire damaged Oregon white oak (*Q. garryana*) (Figure 1) and a single black oak limb. The single confirmed black oak infestation was on an individual in an advanced state of decline, surrounded by infested valley and blue oaks, and only approximately ½ cu. ft. of xylem infested. In its native range it is primarily found on oaks in the white (*Quercus*) and cerris (*Cerris*) sections. Hosts are primarily from the order Fagales. Secondary host genera in Fagaceae are *Fagus* and *Castenea*, Betulacea are *Betulus* and *Carpinus*, and Juglandaceae *Juglans*. They are also known from the Sapindaceae (*Acer*), Rosaceae (*Prunus*), and Oleaceae (*Fraxinus*).

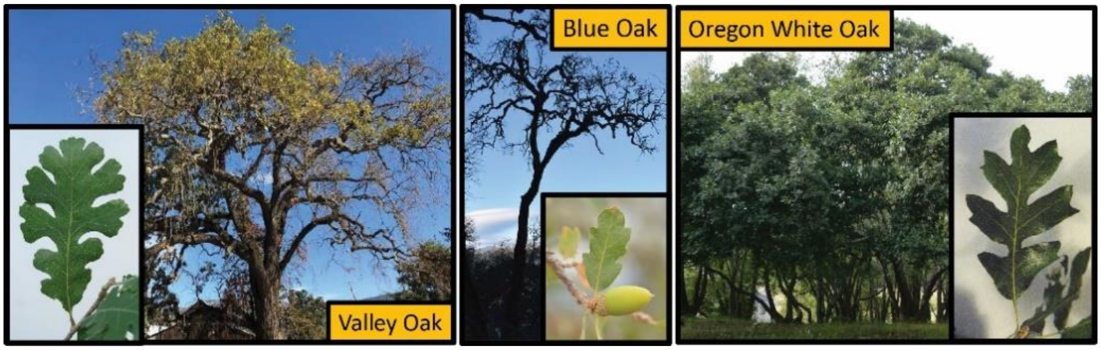


Figure 1: California oaks in the white oak section (*Quercus*).

---

[1] California Department. of Forestry & Fire Protection (CalFire), Forest Entomology & Pathology Program; Sacramento, CA, USA
[2] University of California, Agriculture and Natural Resources, Cooperative Extension; Ukiah, CA, USA
[3] University of California – Davis, Department of Plant Pathology; Davis, CA, USA
[4] USDA Forest Service, Northeastern California Shared Service Area, Forest Health Protection; Susanville, CA, USA
*curtis.ewing@fire.ca.gov and mjones@ucanr.gov

Biology Basics

Xyleborus monographus in a haplodiploid species, as is common in the Xyleborini, with fertilized eggs producing diploid females (Figure 2A) and unfertilized eggs producing flightless, haploid, males (Figure 2B). MOB can be separated from other xyleborine ambrosia beetles using the supplemental couplets in Rabaglia et al.(2020) with the key to North American Xyleborini in Gomez et al. (2018). The most distinctive characters are the large tubercles on the declivity which displace the first striae strongly laterad (Figure 3).

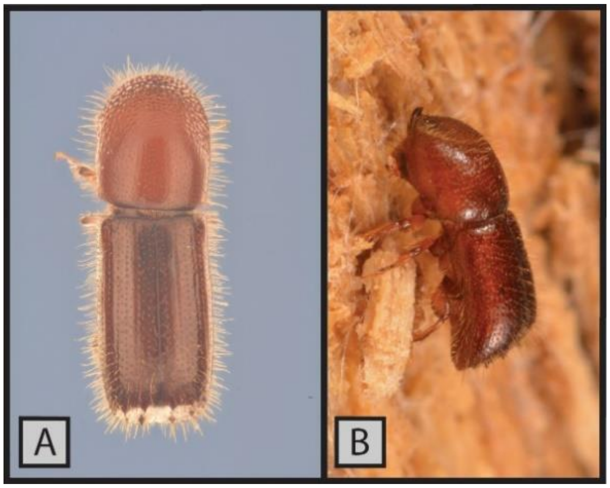


Figure 2: A Female (3.1mm) B Male (2.5mm).

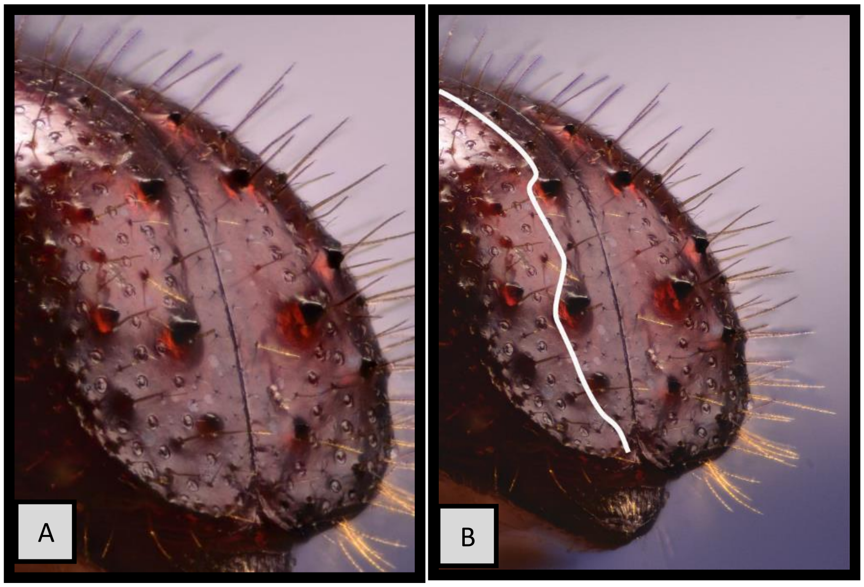


Figure 3: A Declivity showing four large and two small tubercles on first interstria. B Line tracing path of displaced first stria.

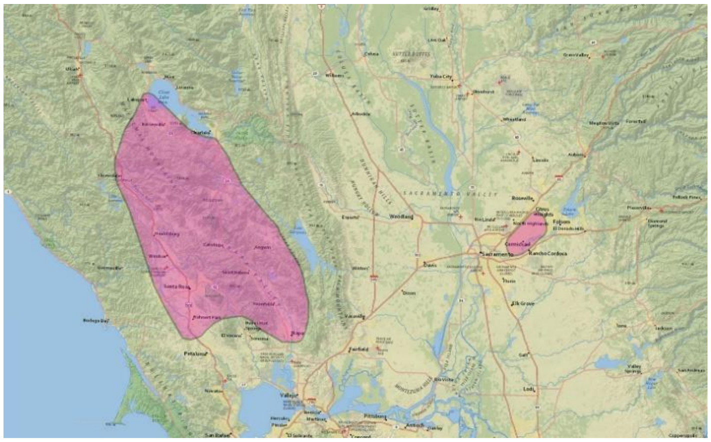
Foundress females mate within the parental galleries prior to dispersal and are gravid when they establish galleries in a new host. The peak period of dispersal in California is weather dependent but is typically late April through early June. Trapping surveys in Napa County have shown that at least some females disperse throughout the year. Large numbers have been observed dispersing as early as January and February during spells of unusually warm weather consisting of relatively warm overnight temperatures and daytime temperatures of at least 75°-80° F. Dispersal is stimulated when temperatures within the gallery system reach a threshold and a single warm day, especially following a cold night, is unlikely to result in high levels of dispersal.

Dissection of infested valley oaks

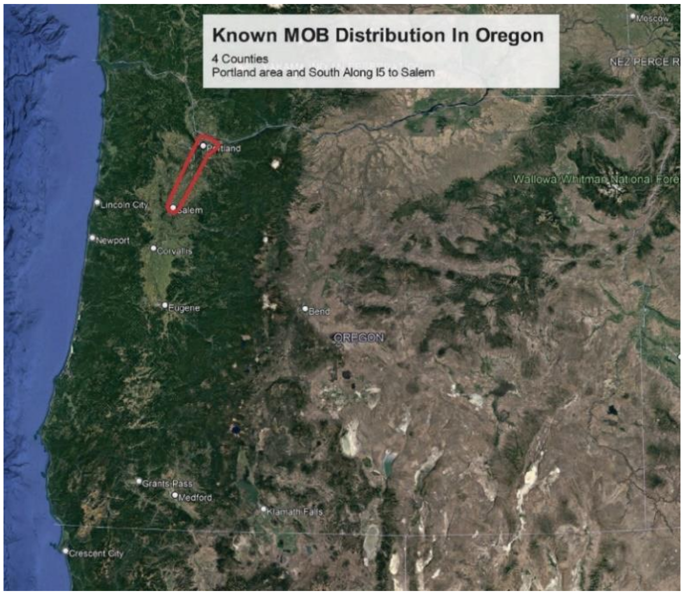
Two valley oaks were dissected on Sept. 30 and Oct. 1 and the galleries contained multiple overlapping generations and all life stages were present, eggs, all three larval instars, pupae, and adult males and females. In its native range it is not known to produce more than two generations within an individual host and multiyear infestations are unknown. The pattern of infestation observed in the dissected oaks was an initial attack in a single branch of approximately 8" diameter in the upper crown followed by gradual movement down the branch to the root collar. The intensity of the infestation increased in density and extent of the gallery systems as it progressed downward. The infestation did not proceed upward when the infestation reached a branching point. Based on multiple observations it is apparent the time from initial infestation to tree death is up to at least four years in health, mature, valley oaks.

Current U.S. Distribution

Within the US MOB is currently known from California and Oregon. In California the initial collections, and greatest degree of infestation, is in Calistoga, Napa County. MOB is also found in Lake, Sonoma and Sacramento Counties (Map 1). In Oregon MOB has been collected in Multnomah, Marion, Clackamas and Washington Counties along the I5 corridor from Portland south to Salem (Map 2).



Map 1: Known MOB distribution in California.



Map 2: Known MOB distribution in Oregon.

Origins of California and Oregon Invasions

Mitochondrial CO1 barcode sequences (658bps) from six specimens from California and four from Oregon were compared with 28 sequences from GenBank. The six California specimens were the same haplotype, and the Oregon populations also represents a single, though different, haplotype (3 bps divergent) (Figure 4). The California haplotype was a 100% match with sequences from France and Belgium and the Oregon sequences matched a haplotype from western Germany and France (Map 3).

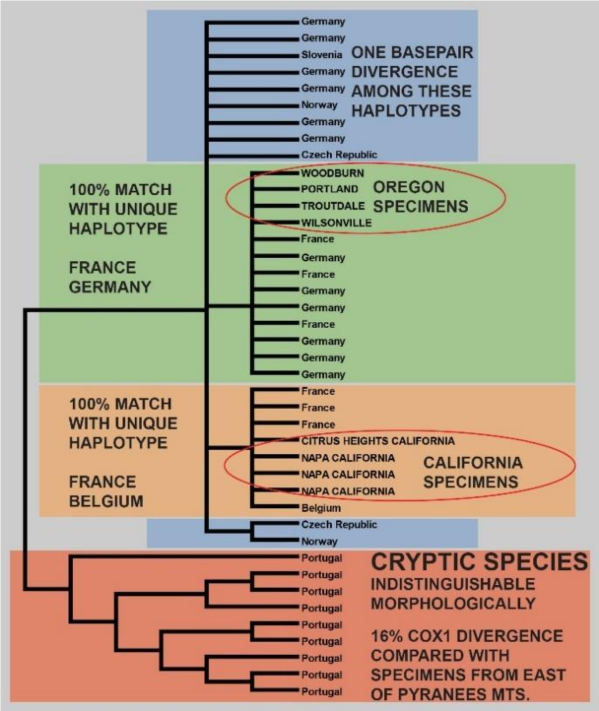
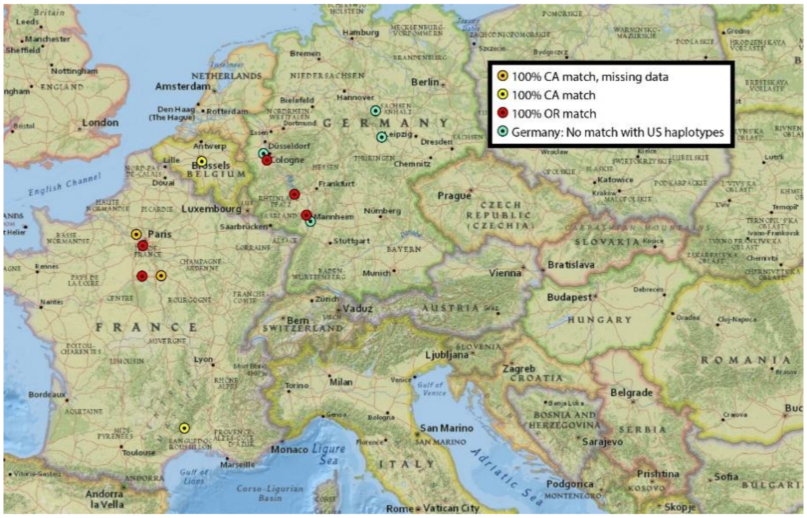


Figure 4: 50% consensus parsimony tree showing California and Oregon CO1 barcode haplotype matches with European sequences from GenBank.



Map 3: Collection localities for haplotypes matching the California and Oregon haplotypes.

Symptoms of Attack

Early symptoms of attack by MOB can be difficult to detect and confirm. Decline of the upper crown, usually in a single branch system, can be caused by a number of causes including insects, disease, and drought. Attacks are initiated in bark crevices, therefore entrance holes are rarely visible. Activity produces fine, light colored xylem boring dust (Figure 5) in contrast to insect species that feed on cambium and inner bark which produced darker boring dust. Removal of bark will reveal gallery entrances (Figure 6) and specimens can often be collected from within gallery entrances in the bark. Examination of transverse break planes through infested xylem reveals distinctive, trellis-like galleries, which are unique to this species (Figure 7). The associated wilt fungi also cause staining in sapwood surrounding gallery systems (Figure 8) (Ewing et al. 2020).

Figure 5: Valley oak with boring dust expelled from gallery entrances in bark crevices.

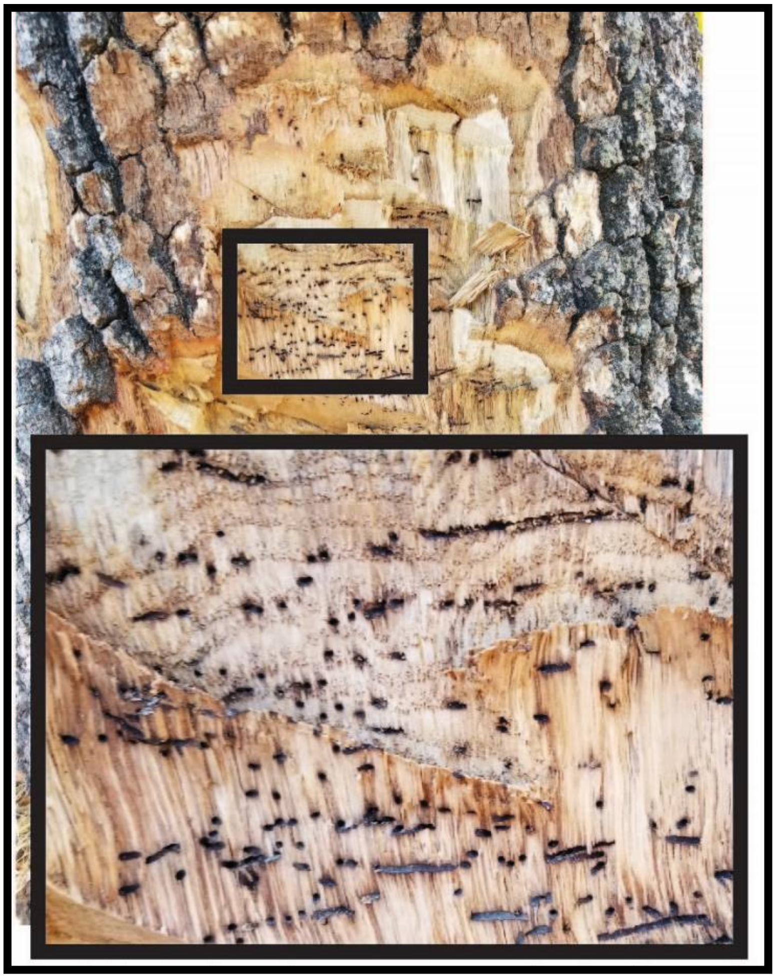


Figure 6: Valley oak bark removed exposing gallery entrances and branches.

Figure 7: Fracture plane of dropped branch from crown of mature valley oak showing trellis-like gallery structure.

Figure 8: Valley oak section showing sapwood with staining and galleries.

Fungal Symbionts

Akif Eskalen (unpublished data) has isolated associated fungi from female mycangia and galleries (Figure 9). Three species have been shown to cause staining and symptoms associated with wilt pathogens. Kochs postulate experiments showed that three of the fungal species *Raffaelea montetyi*, *Fusarium solani* and *Fusarium* sp. moved slowly through the xylem (Figure 10) at rates of 16.1mm, 16.8mm and 15.9mm over 100 days respectively (Figure 9). There is no evidence of a fast-spreading yeast stage which is consistent with the extended lag time between initial infestation and tree death.

Species	Isolate	Vascular discoloration, mm		Re-isolation
Untreated control	-	6.2	a	0%
Leptographium sp.	UCD8382	9.1	b	60%
Saccharomycopsis microspora	UCD8112	8.2	ab	0%
Paecilomyces formosus	UCD8140	7.4	ab	100%
Raffaelea montetyi	UCD8134	16.1	c	40%
Fusarium sp.	UCD8376	15.9	c	100
Fusarium solani	UCD8043	16.8	c	60

Figure 9: Pathogenicity of fungi isolated from female MOB and galleries.

Figure 10: Valley oak Koch's postulates results with inoculation site and fungal staining.

Evaluation of Trap and Lure Efficacy and Dispersal Timing

In 2022 a total of 25 traps in five groups of five were set at three sites in Napa County, California. Each group consisted of one 12 funnel Lindgren funnel trap baited with Ultra-High Release Ethanol sleeves (UHRE), 2 cross-vane panel traps, one with an UHRE lure and one with oak pinhole borer (*Platypus cylindrus*) lure, and two un-baited cross-vane sticky traps, one in the canopy and one at ground level. Traps were centered at 6 ft. above ground with lures affixed at the center of each trap. One group was set on May 8, 2020 to evaluate the trapping methods and the remaining traps were set on May 29, 2020. Cross-vane panel traps with UHRE lures were 2x more efficient than the Lindgren traps (Figure 11). The pinhole borer lure was much less effective and the sticky traps did not capture any MOB at ground level or in the canopy. Dispersal was greatest in May and declined steadily through June and July. From August to September UHRE cross-vane traps avg <2 MOB captures/2 week period (Figure 12).

Figure 11: Cross-vane panel traps caught 2x more than Lindgren funnel traps. Cross-vane panel traps are more prone to spillage in exposed areas due to high winds

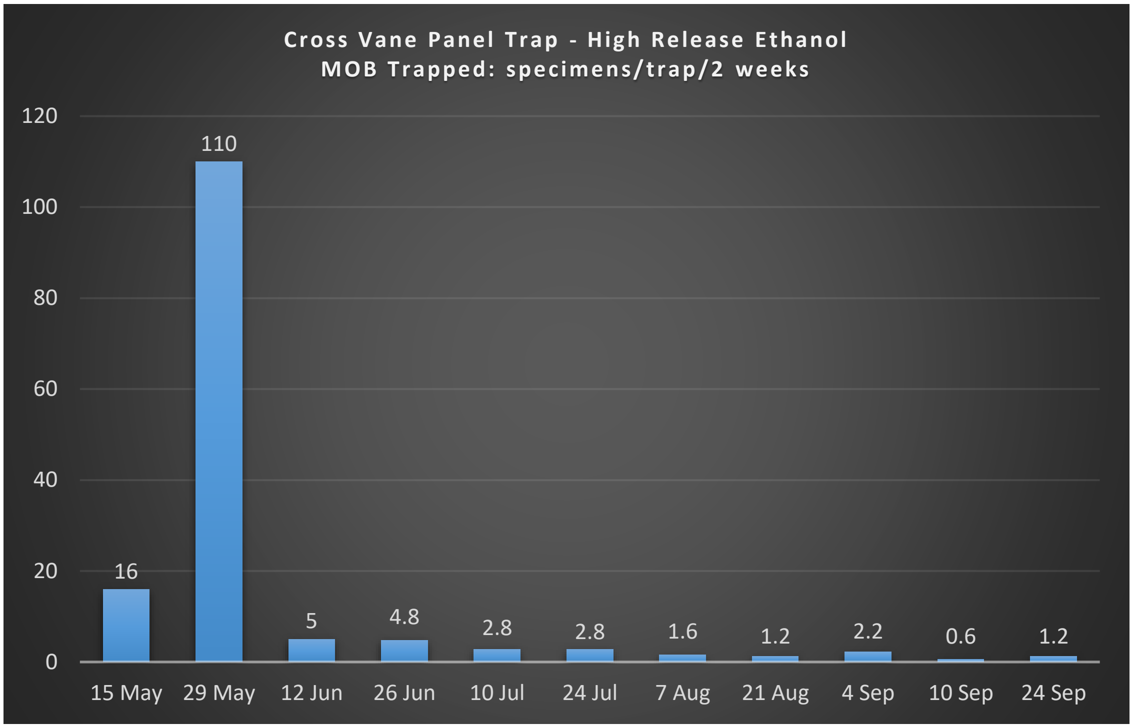


Figure 12: Trap results showing peak dispersal period in late May.

Dispersal Height

To determine if dispersal height two 30’ towers with five 12”x9” un-baited, double sided, sticky cards at 6’ intervals were placed in an open field 1,000 ft. and 700 ft. from known infested trees at the Calistoga wastewater treatment plant. Sticky cards were checked bi-weekly from May – September 2021. Two specimens were trapped, one from each tower, with both on the second highest sticky card at 24 ft. above ground level.

Verbenone evaluation

In 2021 nine groups of three traps were set at the Dunaweal wastewater treatment plant in Calistoga CA to assess the repellency of verbenone. Each group consisted of three cross-vane panel traps: 1) Control without lure, 2) UHRE lure, and 3) UHRE lure combined with 70 g of SPLAT Verb applied to an aluminum flashing panel affixed on the top of the trap. The efficacy of SPLAT Verb to suppress trap captures was tested using an unpaired Student’s t-test. Significantly fewer MOB were captures at the 95% confidence interval for the UHRE+SPLAT Verb vs. UHRE traps at two (9 Apr.) and four weeks (23 Apr.) but no significant deterrent effect at six weeks (14 May) was detected (Figure 13).

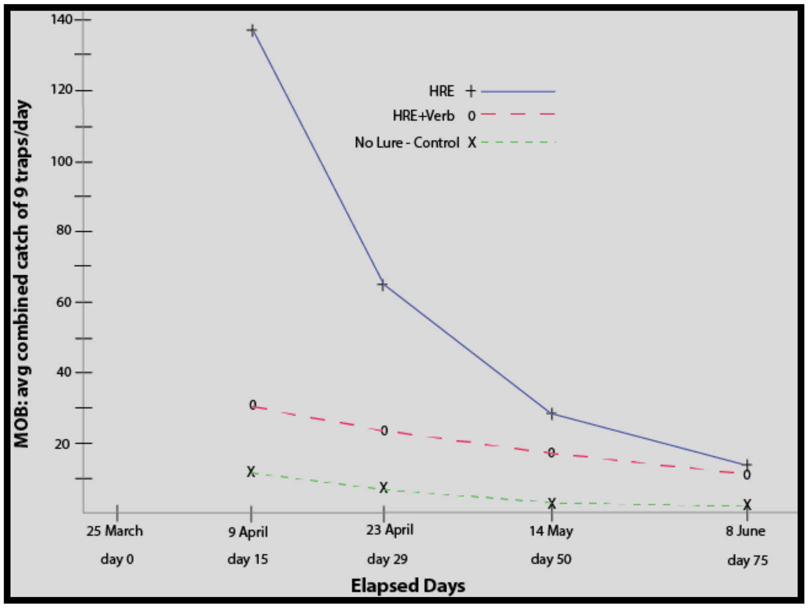


Figure 13: Trap results for SPLAT Verb trial.

Oak Monitoring: Individual valley oaks and paired burned vs. un-burned plots

Two long-term monitoring projects are ongoing. In fall 2020 185 valley oaks were tagged in St. Helena and Calistoga to track the rate of infestation and track decline in the crown and bole symptoms. In 2021 two sets of burned vs. un-burned plots were established on the Glass Fire (2020) perimeter in Napa and Sonoma Counties. Trees are being monitored as above. As of 2022 (one year) there is not enough data to definitively assess the burned vs. unburned plots though no significant decline has been seen. After two years the tagged valley oaks showed noticeable more decline in one area between the City of Calistoga wastewater treatment facility and the Napa Valley Vine Trail (Figure 14 indicated by letter A). The area of greatest decline is also the most highly disturbed.

Figure 14: Results of 2 years of valley oak monitoring at the Calistoga wastewater treatment facility. A indicates area with greatest decline and level of disturbance.

Conclusions

The Mediterranean oak borer presents a serious threat to valley oaks in California and may also significantly impact blue and Oregon white oaks. In its native range MOB is not considered a serious threat to healthy oaks. Our understanding of the invasion biology of this species is severely limited and additional research into all aspects of host attack and the progression of infestation is needed. Valley oaks appear to be most susceptible to attack followed by blue oaks and with Oregon oak infestations being the least commonly detected. To developing effective mitigation strategies for MOB an understanding of its enhanced ability to attack and kill healthy trees is essential. Additional research is also needed into best management practices for the disposal of infested materials including the practicality and efficacy of chipping, burying, and burning.

Literature Cited

Ewing, C.; Dimson, M.; Nobua-Behrmann, B.; Oliver, R.; Kabashima, J. 2020. Pest Alert: Mediterranean oak borer *Xyleborus monographus*. Pest Alert. UC-ANR. 2 p. https://ucanr.edu/sites/mobpc/files/330538.pdf

Ewing, C.; Jones, M.I.; Smith, S.L. Submitted. Mediterranean Oak Borer *Xyleborus monographus* (Coleoptera: Curculionidae: Scolytinae): Literature review and current understanding of invasion biology in California, a guide to future research. In: 8th Annual California Oak Symposium. San Luis Obispo

Gomez, D.F.; Rabaglia, R.J.; Fairbanks, K.E.O.; Hulcr, J. 2018. North American Xyleborini north of Mexico: a review and key to genera and species (Coleoptera: Curculionidae: Scolytinae). ZooKeys. 768: 19–68.

ODA-IPPMP 2023. Pest Alert: Mediterranean oak borer, *Xyleborus monographus* https://www.oregon.gov/oda/shared/Documents/Publications/IPPM/Pest.Alert.Mediterranean.oak.borer%20(2023).pdf

Rabaglia, R.J.; Smith, S.L.; Rugman-Jones, P.; Digirolomo, M.F.; Ewing, C.; Eskalen, A. 2020. Establishment of a non-native xyleborine ambrosia beetle, *Xyleborus monographus* (Fabricius) (Coleoptera: Curculionidae: Scolytinae), new to North America in California. Zootaxa. 4786(2): 269–276.

Ripley, K.; Williams, W. 2022. Forestry Facts: Mediterranean Oak Borer, *Xyleborus monographus* (Fabr.). https://www.oregon.gov/odf/Documents/forestbenefits/fact-sheet-mediterranean-oak-borer.pdf

Panel: Climate & Tree Diseases – I

Moderator: Alex Woods

Chris Lee addressing the group during the field trip. (photo: Rachel Brooks)

Complexity of biological disturbance agents, fuels heterogeneity, and fire in coniferous forests of the western United States

Dave Shaw[1]*

This presentation was based on our paper: 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 (Open Access).

Here is the abstract from the publication!

Forest biological disturbance agents (BDAs) are insects, pathogens, and parasitic plants that affect tree decline, mortality, and forest ecosystems processes. BDAs are commonly thought to increase the likelihood and severity of fire by converting live standing trees to more flammable, dead and downed fuel. However, recent research indicates that BDAs do not necessarily increase, and can reduce, the likelihood or severity of fire. This has led to confusion regarding the role of BDAs in influencing fuels and fire in fire-prone western United States forests. Here, we review the existing literature on BDAs and their effects on fuels and fire in the western US and develop a conceptual framework to better understand the complex relationships between BDAs, fuels and fire. We ask: 1) What are the major BDA groups in western US forests that affect fuels? and 2) How do BDA-affected fuels influence fire risk and outcomes? The conceptual framework is rooted in the spatiotemporal aspects of BDA life histories, which drive forest impacts, fuel characteristics and if ignited, fire outcomes. Life histories vary among BDAs from episodic, landscape-scale outbreaks (bark beetles, defoliators), to chronic, localized disturbance effects (dwarf mistletoes, root rots). Generally, BDAs convert aboveground live biomass to dead biomass, decreasing canopy fuels and increasing surface fuels. However, the rate of conversion varies with time-since-event and among BDAs and forest types, resulting in a wide range of effects on the amount of dead fuels at any given time and place, which interacts with the structure and composition of the stand before and subsequent to BDA events. A major influence on fuels may be that BDAs have emerged as dominant agents of forest heterogeneity creation. Because BDAs play complex roles in fuels and fire heterogeneity across the western US which are further complicated by interactions with climate change, drought, and forest management (fire suppression), their impacts on fuels, fire and ecological consequences cannot be categorized simply as positive or negative but need to be evaluated within the context of BDA life histories and ecosystem dynamics.

---

[1] Oregon State University, College of Forestry; Corvallis, OR, USA
*Dave.Shaw@oregonstate.edu

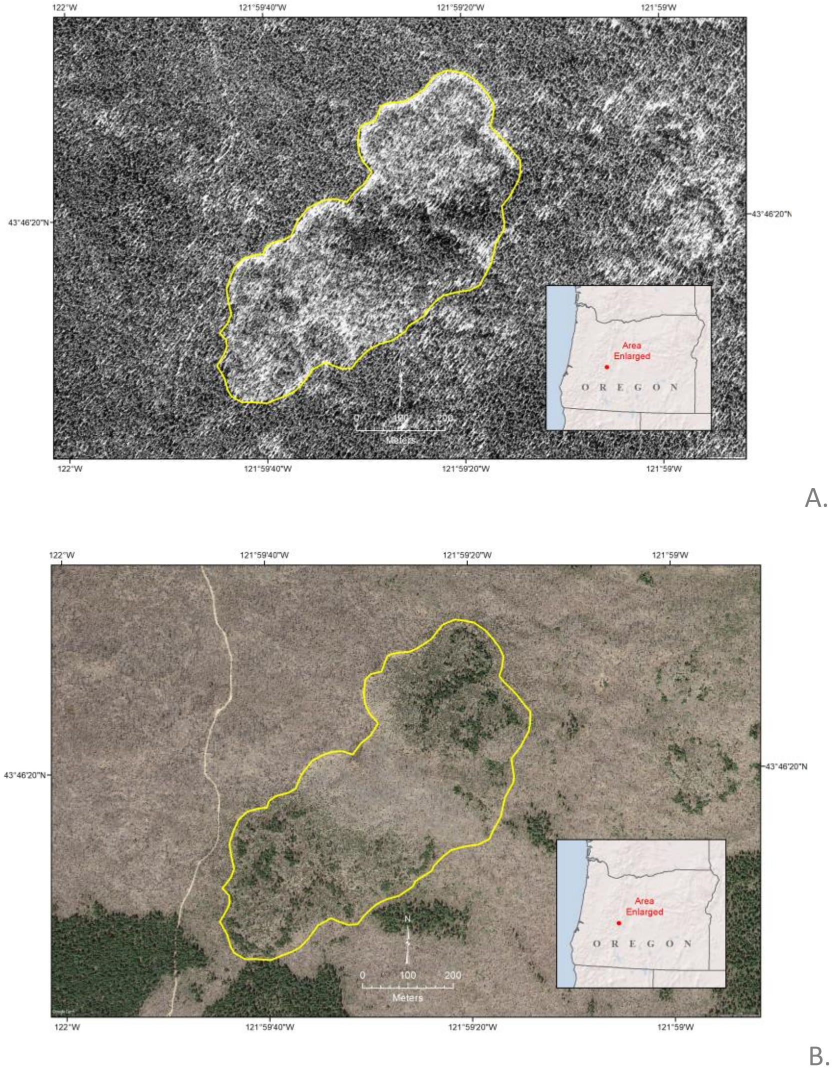


Figure 14: A. A laminated root rot disease center in mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) forests in 1994. B. Google Earth image from 2012 of the same location after the 1996 Charlton Fire. The yellow outline delineates the infection center in 1994 and after the fire in 2012. Note the moderate-severity fire patterns where there were root disease centers. From Shaw et al. 2022. Forest Ecology and Management.

Literature Cited

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

Genetic analysis of Douglas-fir and western redcedar family tolerance to soil moisture extremes in greenhouse studies: survival growth and phenotypic adaptation.

Mike Cruickshank[1]* and Cosmin Filipescu[1]

Seed from coastal Douglas-fir and western redcedar families were germinated in standard reforestation Styrofoam containers and grown in the greenhouse for one year. During the winter seedlings of each family were randomly assigned to larger cell Styrofoam containers and transplanted. All families were represented within two of the containers, and these pairs were assigned randomly to drought or optimal watering. After measuring the tree heights, the drought treatment was applied early in the season and maintained for the growing season. Over the winter of the second year and third year all drought and control blocks were watered optimally. In spring, tree heights were measured, and water was withheld from both previous year two drought and control treatments. The date of each seedling death was recorded to 100% mortality. An optimally watered control the third year had no death. Mixed model for drought treatment (fixed) and family (random) and family by treatment were used to assess drought tolerance (R-LME) and survival (R-COXME). The results for Douglas-fir and cedar indicated that drought caused on average 40% height growth impact over all seedings compared to control; however, impact also varied by family. For the coastal Douglas-fir this ranged from 15 to 65% depending on family. Shorter trees before drought had less drought impact compared to control. The cedar families were similarly affected by drought. Survival after withholding water determined that all Douglas-fir was dead after about 9 weeks, and that initially taller trees had lower survival by as much as 25% after seven weeks. Prior drought treatment increased survival by about 25% at 6 weeks compared to the prior optimal watering treatment. Douglas-fir family time to death at 100% ranged between 5 weeks and 9 weeks. Droughted seedings with greater tolerance also had higher survival times.

Best linear unbiased predictors (BLUPs) describe the family reactions to drought, and these were correlated (Pearson) with family needle, stem, and root biomass and by root surface area by root size classes. Drought increased the proportion of root to total biomass by about 10% compared to control, but not for needle and stem biomass. Changes in current year needle length and weight, but not needle area, were reduced compared to control. The total surface area of the smallest root size classes (<0.5 mm) traded off with all the larger root classes especially the roots 0.5-2mm; moreover, families either favoured smaller or larger root classes and did not interact with drought strongly. Taller seedlings had more proportion of coarse roots, which in turn lowered survival and increased drought impact compared to their respective controls.

Douglas-fir families that had larger proportion of fine root surface area had improved drought tolerance and longer survival times. The problem was that, on average, more productive families were impacted to a greater extent; however, there were a few families that were close to the tallest size and performed well. These results suggest that there are phenotypic traits that can be measured within two years which are correlated with growth and survival to drought. These traits could be used in breeding programs or applied directly through planting existing families.

---

[1] Natural Resources Canada, Canadian Forest Service, Canadian Wood Fibre Centre, Pacific Forestry Centre; Victoria, BC, Canada

*cosmin.filipescu@nrcan-rnac.gc.ca

Urban tree disorders and climate change: A view from the field (Bay Area cities), and a view of the trade-offs in city tree management

Igor Lacan[1]*

Effects of climate change add to the already-numerous challenges experienced by trees planted in cities and urbanized areas ("urban trees"). This presentation reviews the mechanisms of these challenges, introduces some common disorders associated with climate stresses, and concludes with a set of "challenges" to plant pathologists from urban tree managers.

1. Climate change and urban trees: challenging!

In most of California, higher minimum temperatures resulting from climate change have both extended the growing season – leading to greater total demand for water over the course of a year – and extended the "pest season," leading to a longer period of activity for pest insects. In addition, higher average and maximum temperatures have increased vapor pressure deficit, leading to more instances of "physiological drought" (temporary water deficit), and along with the higher evaporation of water from soil (which diminishes the soil water availability) result in more frequent, and longer, drought stress experienced by plants. Our "normal" climate is now warmer and drier than in previous decades – when many of our urban trees were planted – and the increased incidence of "hot droughts" further limits the ability of trees to recover their energy reserves and repair their photosynthetic capacity and water-conducting tissues, all of which makes the urban trees more susceptible to abiotic and biotic disorders.

2. Commonly seen urban tree disorders plausibly associated with climate stresses

While many insect pests and plant disease could be plausibly linked to climate stress, in San Francisco Bay Area I highlight three common, recurring problems.

One common disorder is the general "abiotic decline" of trees, seen as gradual loss of foliage ("thinning"), dieback of terminal twigs then smaller branches, and eventual slow decline of the tree without any pathogens detected in either leaves, vascular tissues, or roots. This appears to be the most "basic" manifestation of the drought/heat stresses over a longer term, i.e., the "new normal" climate and the "hot droughts" impacting trees that had been planted some time ago. The key challenge lies in our inability to predict which trees are likely to be affected because we seldom understand the soil conditions and water availability for a specific tree.

The second common problem is similar to the first, except that it also includes progressive dieback of large branches. Various fungi of the *Botryosphaeriales* clade (*Botryosphaeria*, *Neofusicoccum*, *Nattrassia*, etc.), known to affect stressed trees, are isolated from the margin of affected branches. The challenges here are not only diagnostic (isolations from urban trees may be difficult), but also the difficulty of predicting the speed of decline and the extent of the branch dieback – both of those are important considerations in management of urban trees where the risk of failure is often paramount.

The third common problem is localized outbreaks of wood-boring insect pests, affecting a single tree or at most a few trees. These are often labeled "secondary" pests, i.e., able to successfully infest only the trees already suffering from another disorder. Examples include bark beetles, twig beetles, and ambrosia beetles (*Scolytinae*, *Platypodinae*). The challenge with these situations is that the climate stresses are nearly always compounded with other stresses: construction damage, over-pruning, soil compaction or contamination, etc. Deciding on the

---

[1] University of California Cooperative Extension, San Matea/San Francisco Counties; Moon Bay, California, USA
*ilacan@ucanr.edu

relative contribution of climate stresses to the problem is difficult, but it is also important for managing a specific tree back to health (or for making the decision to remove the tree)

3. Challenge(s) to plant pathologists: urban tree managers need your help

The above examples, although not comprehensive, point to a common need: urban tree managers need help from plant pathologists who are willing to engage with urban tree problems. In that spirit, I offer a few observations of the situations that arborists routinely encounter, but with which forest tree pathologists may be less familiar:

A. *Urban planting sites* are a perennial impediment to tree health – they are often small and contain poor quality substrate. And because urban tree managers are forced to work with “what we have” and plant in marginal sites, the choice of a tree planted does not really reflect the conditions of the site as it would in a forest setting, but rather it is simply “best effort” to create a tree canopy. In other words, poor rooting conditions are the norm, and we need help in diagnosing biotic conditions where they occur and separating those from the near-ubiquitous abiotic limitations.

B. *Bad interactions and repeated injury* are the norm. Tree injury from repeated root cutting, excessive pruning, construction damage (soil compaction, root damage, soil contamination, etc.) is common and its manifestations should be expected in any sample taken from an urban tree. Because abiotic symptom development is often delayed, the symptoms themselves are often non-specific, and the prognosis and recovery potential are usually uncertain, we need help in diagnosing the “secondary” insect or disease that often accompanies such injury. We also need help in identifying and assessing the efficacy of chemical and other control techniques for arresting disease progression in cases of tree injury.

C. Arborists often are asked *to manage a declining tree*; yet few research-based guidelines for this exist. We need help in prognosing the time-frame for decline; in improving site sanitation guidelines after tree removal and for the disposition of woody material; and in improving our understanding of the association between pathogens/pests in a declining tree and the risk of that tree failing.

Urban trees, like their forest cousins, will continue to be challenged by climate change, and so will the people who manage them. Plant pathologists can play a crucial role in helping us meet that challenge!

Managing intense drought and monarch butterfly habitat in an urban jungle - Albany Hill Park

Susan J. Frankel[1]*

In fall 2020, hundreds of eucalyptus trees (mostly *Eucalyptus globulus,* blue gum eucalyptus) in Albany Hill Park in Alameda County, California abruptly turned brown and dropped leaves (Figure 1). Rapid deterioration of eucalyptus and other tree and shrub species was also apparent in other areas throughout the San Francisco Bay Area. The City of Albany was particularly concerned because the trees serve as overwintering sites for migrating monarch butterflies (*Danaus plexippus*), and are adjacent to residential neighborhoods, large (many over 50" DBH, 127 cm), tall (over 75 ft, 23 m), and over 100 years old. Park managers hired arborists to evaluate tree hazard and reached out to the U.S. Forest Service for assistance to determine the cause of the problem and for a forest health prognosis for the 40-acre (16.2-ha) urban park.

Figure 1: Eucalyptus trees at Albany Hill in 2021 showing weak crowns. Photo credit: Frankel, USFS PSW

Drought was suspected to be a factor in the dieback but to determine if pathogens were contributing to the problem, the U.S. Forest Service, Pacific Southwest Research Station provided a grant, funded by the San Francisco Public Utilities Commission, to Matteo Garbelotto, UC Berkeley to dissect trees and check for pathogens or insect pests. At Albany Hill and five other forested areas, four trees with dieback symptoms were cut down at each site for examination and fungal isolation. The sampled trees and soil were also tested for the presence of

---

[1]USDA Forest Service, Pacific Southwest Research Station; Albany, CA, USA
*susan.frankel@usda.gov

Phytophthora but all tested negative. The Garbelotto laboratory isolated *Pseudosydowia eucalypti* (synonyms *Sydowia* and *Sphaerulina ecucalypti*) most commonly and from all the sites. *Pseudosydowia eucalypti* was recovered from leaf spots and is not considered pathogenic (Crous and others 2019). The fungus is common worldwide wherever eucalyptus trees have been planted (Garbelotto 2021).

The dissections and isolations eliminated microbes or insects as major contributing factors to the eucalyptus dieback. This points to direct environmental factors, such as weather, soils, topography as well as to the stand history of these non-native, planted trees. A cursory examination of the weather records from 2017 to 2022 indicates that the dieback is associated with environmental stress, excessive evaporative demand, and a lack of water. Periods of extreme heat in 2020 and prolonged drought appears to have overwhelmed the trees' physiological capabilities. By 2022, rainfall increased and most of the trees vigorously resprouted (Figure 2). In general, the trees' form is poor, with epicormic shoots extending along the boles and branches, but the trees are expected to recover (Burrows 2013, Zeppel and others 2015).

Figure 2: Recovering, vigorously resprouting eucalyptus at Albany Hill in 2022. Photo credit: Frankel, USFS PSW

Acknowledgements

I greatly appreciate contributions to this study by Matteo Garbelotto, Doug Schmidt, Tina Popenick, UC Berkeley; Mia Ingolia, San Francisco Public Utilities Commission; Margot Cunningham, City of Albany and Curtis Ewing, CALFIRE.

Literature Cited

Burrows, G.E. 2013. Buds, bushfires and resprouting in the eucalypts. Australian Journal of Botany, 61(5), 331-349.

Crous, P.W., Wingfield, M.J. & others. 2019. Foliar pathogens of eucalypts. Studies in Mycology. 94: 125-298.

Garbelotto, M. 2021. Investigating the fungi responsible for the recent large-scale dieback of blue gum eucalyptus (Eucalyptus globolus) in the San Francisco Bay Area. Report available at https://www.suddenoakdeath.org/bay-area-tree-mortality/.

Zeppel, M.J.B and others. 2015. Drought and resprouting plants. New Phytologist. 206: 583-589.

Panel: Climate & Tree Diseases – II

Moderator: Danny Norlander

View from the lunch spot during Wednesday's fieldtrip. (photo: Rachel Brooks)

Accelerated true fir mortality in central Oregon associated with severe drought, fir engraver, and diseases

Brent W. Oblinger[1]*

Introduction

In recent years, widespread true fir (*Abies*) mortality has been observed throughout much of central and northeast Oregon (Figure 1-2). Numerous calls from the public to U.S. Forest Service offices have been received in 2019 to 2022. Multiple National Forests are also fielding questions on their Facebook pages, or other social media platforms, about all the "dead trees people are seeing across the landscape." Timber sales are being disrupted in cases where buyers had agreed to a certain volume of live trees in a contract and now a larger percentage of dead trees is present in those planned timber sales. Additionally, there are hazard tree concerns along roads and around developed recreation sites due to the ongoing increase in dead true firs. Discussions about changes in fuel loading are arising. As are concerns for large, old trees, or other values at risk, in the event of a fire. These threats are now apparent due to a number of dead trees or down logs around highly valued resources. Altered carbon sink capacity is being questioned in some places. Changes in snag and down wood recruitment are also being considered by wildlife biologists.

Figure 1: Example of recent grand fir mortality in Newberry National Volcanic Monument, Deschutes National Forest in 2022. In the upper portion, stands are comprised of lodgepole and ponderosa pines.

---

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

Figure 2: Example of recent white fir mortality in the Fremont National Forest in 2022.

The vast majority of true firs in eastern Oregon recently observed dying include white (*A. concolor*), Shasta red (*A. magnifica* var. *shastensis*) and grand (*A. grandis*) firs. In comparison, less mortality of Pacific silver fir (*A. amabalis*) and noble fir (*A. procera*) has been observed in higher average annual precipitation zones of the Oregon Cascades (Simpson 2007). A complex of drought, insects and diseases has been reported causing mortality throughout central Oregon in the past, particularly in the 1990's on the Fremont National Forest (Cochran 1998). Also, fire exclusion since the early-1900's at many locations has resulted in high stand densities and an abundance of shade-tolerant, true firs (Hessburg et al. 1994; Voelker et al. 2019). In dry, fire-maintained forests east of the Cascade crest, multiple forest communities would have historically experienced fires more frequently, and resulting in fewer true firs being present compared to current conditions (Haugo et al. 2015).

Fir engraver (*Scolytus ventralis*) has historically been the most significant insect associated with mortality of true firs in central and northeast Oregon (Struble 1937; Cochran 1998). Trees weakened by diseases and stand disturbances, such as drought, defoliator outbreaks, and soil compaction, are particularly susceptible to attacks (Moore et al. 1978; Ferrell 1986; Cochran 1998). Unlike most tree-killing bark beetles, fir engraver needs only to kill a strip of cambium to successfully reproduce, so "strip" attacks are common and can result in a variety of damage including dead branches, topkill, or tree mortality (Ferrell 1986). There is strong evidence that fir engraver preferentially attacks trees infected by root disease pathogens, such as *Armillaria* spp., *Heterobasidion occidentale* and *Coniferiporia sulphurascens* (Goheen and Hansen 1993). Higher populations of fir engraver are typically found associated with root disease centers and often kill trees infected by root disease. However, during prolonged drought events, fir engraver can kill trees in stands with varying density that may not be associated with root disease. The objectives of this assessment were to determine the extent of the recent true fir die-off in central Oregon compared to the last several decades and highlight some of the factors contributing to the mortality event relative to past field surveys and observations.

Methods

To compare recent levels of true fir mortality to mortality over the last 32 years, *Abies* spp. mortality detected during annual aerial surveys was analyzed. Each year most forested land in Oregon is surveyed via cooperative aerial detection surveys conducted by USDA Forest Service and Oregon Department of Forestry staff. Most aerial surveys are conducted in fixed-wing aircraft. Aerial surveys can be used as a first step to provide coarse estimates of recent damage across vast areas. To conduct these surveys, specialists board small aircraft equipped with a digital aerial sketch-mapping system that incorporates tablet computers, a geographic information system, and global positioning system into a single software application (currently "Digital Mobile Sketch Mapper"). The aerial survey team typically flies around 1000 ft above ground level in a grid or at times along ridges in a contour pattern depending on the terrain. Traveling around 100 mph and looking out about two miles, each observer diagnoses and records forest damage by tree species, mapping its extent, and rating the severity of damage on tablets. Surveyors can often distinguish subtle differences between tree species and attribute possible damage causing agents for each tree species.

For this assessment, aerial survey data were queried for mortality of white, Shasta red, and grand firs attributed to fir engraver activity from 1990 to 2022. The study area included locations in the Fremont, Winema, Deschutes, Ochoco and Malheur National Forests where field observations have confirmed recent true fir mortality. The area mapped, containing locations where some level of true fir mortality appeared each year, was calculated using ArcMap. The annual level of mortality was determined by dividing the area with true fir mortality by the total area surveyed that year to account for differences in the area surveyed each year due to fires, smoke or other conditions that may have limited flights. This allows for an annual time-series comparison by accounting for different areas surveyed certain years during the past 32 years.

Crook County, Oregon encompasses much of the Ochoco National Forest and is where elevated grand fir mortality has been reported in recent years based on field observations. Because true fir mortality is known to be associated with drought stress in combination with fir engraver activity (e.g., Cochran 1998,) and other damaging agents such as root disease pathogens, a drought index (Standardized Precipitation Evapotranspiration Index; SPEI) was evaluated for hydrologic years (October through September) in Crook County, Oregon. The SPEI and estimates of average annual temperature and precipitation were also compared to examine any potential differences in temperature over time. Precipitation data from 1901 to 2022 were examined at https://wrcc.dri.edu/wwdt/time/ via the WestWideDroughtTracker from the Western Regional Climate Center (provided by the Regional Climate Centers, Desert Research Institute, NOAA and National Centers for Environmental Information).

Although root diseases such as Heterobasidion, Armillaria and laminated root rot have been found contributing to true fir mortality based on recent field observations, past field survey data from Lane and Goheen (1979) and Schmitt et al. (1984) were examined to determine how widespread root diseases are on true firs in central Oregon. Root diseases are considered "diseases of the site" and remain long-term contributing to ongoing true fir mortality where hosts are present. Therefore, historic survey data could be used to determine how common root diseases are throughout the study area.

Results

Varying levels of true fir mortality have been observed over the last three decades across the locations evaluated (Figure 3). However, a clear recent increase in the proportion of area surveyed with true fir mortality was found across the Winema, Deschutes, Ochoco and Malheur National Forests compared to previous years back to 1990. In 2020 during the global COVID-19 pandemic, visual interpretation of aerial imagery was used to digitize areas with tree mortality in parts of Oregon and no flights occurred. The Deschutes National Forest was not surveyed using either method in 2020. A recent increase in overall mortality was observed on the Fremont National Forest, but in the 1990’s increased true fir mortality also occurred there associated with severe drought. A similar pattern in mortality levels in the 1990’s was found in portions of other National Forests evaluated.

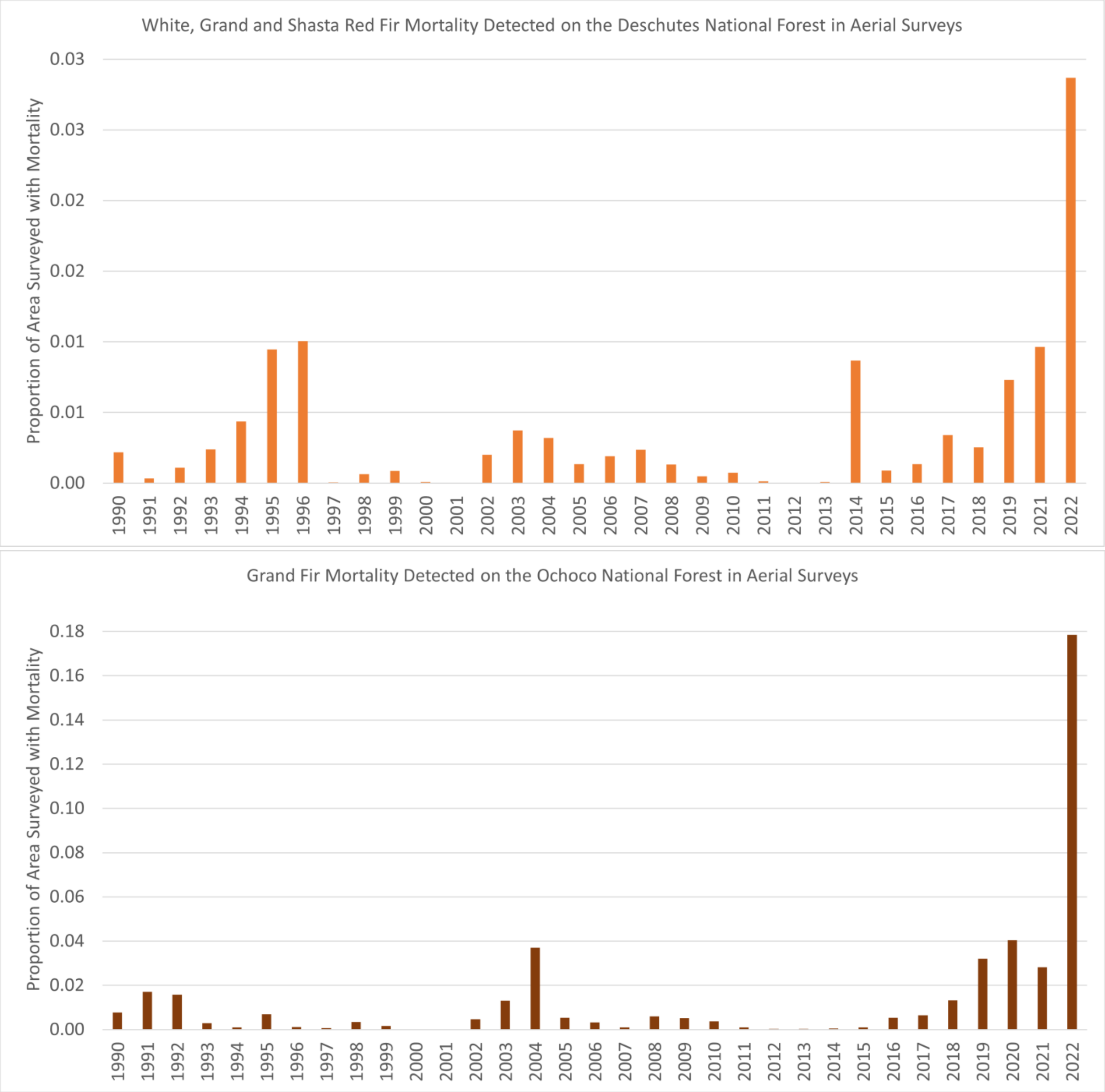


Figure 3: Levels of true fir mortality from 1990 to 2022 across the Deschutes National Forest (Upper); and (Lower) across the Ochoco National Forest.

In recent years prior to 2022, extreme-to-exceptional drought affected portions of central and northeast Oregon with Crook County being one of the most severely impacted (Figure 4). The recent, multi-year drought likely exacerbated the levels of true fir mortality observed. A severe drought in the 1930’s also corresponded with increased tree mortality in historic reports.

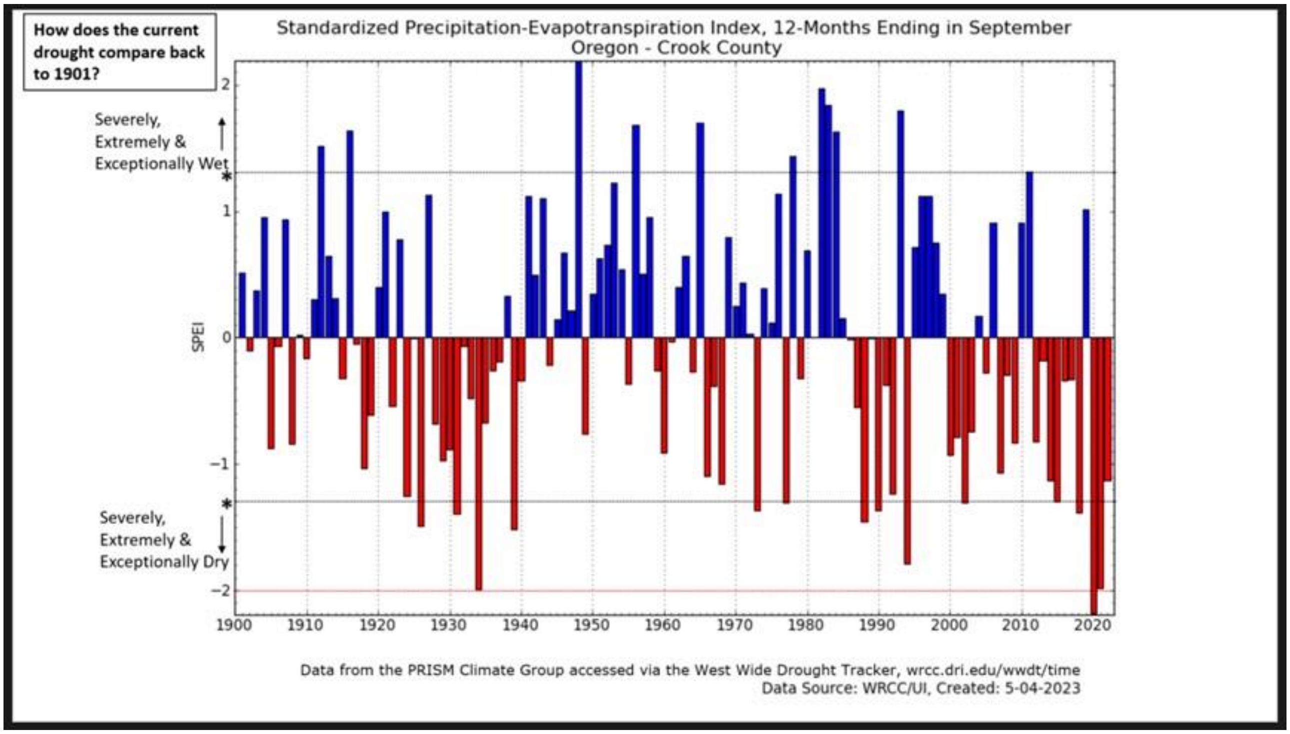


Figure 4: Drought conditions in Crook County, Oregon by hydrologic year (1901-2022).

There is evidence of warmer temperatures coinciding with the recent drought, particularly in Crook County (Figure 5). This recent "hotter drought" likely exacerbated levels of true fir mortality. Since the 1990's, above average mean annual temperatures have been common in Crook County.

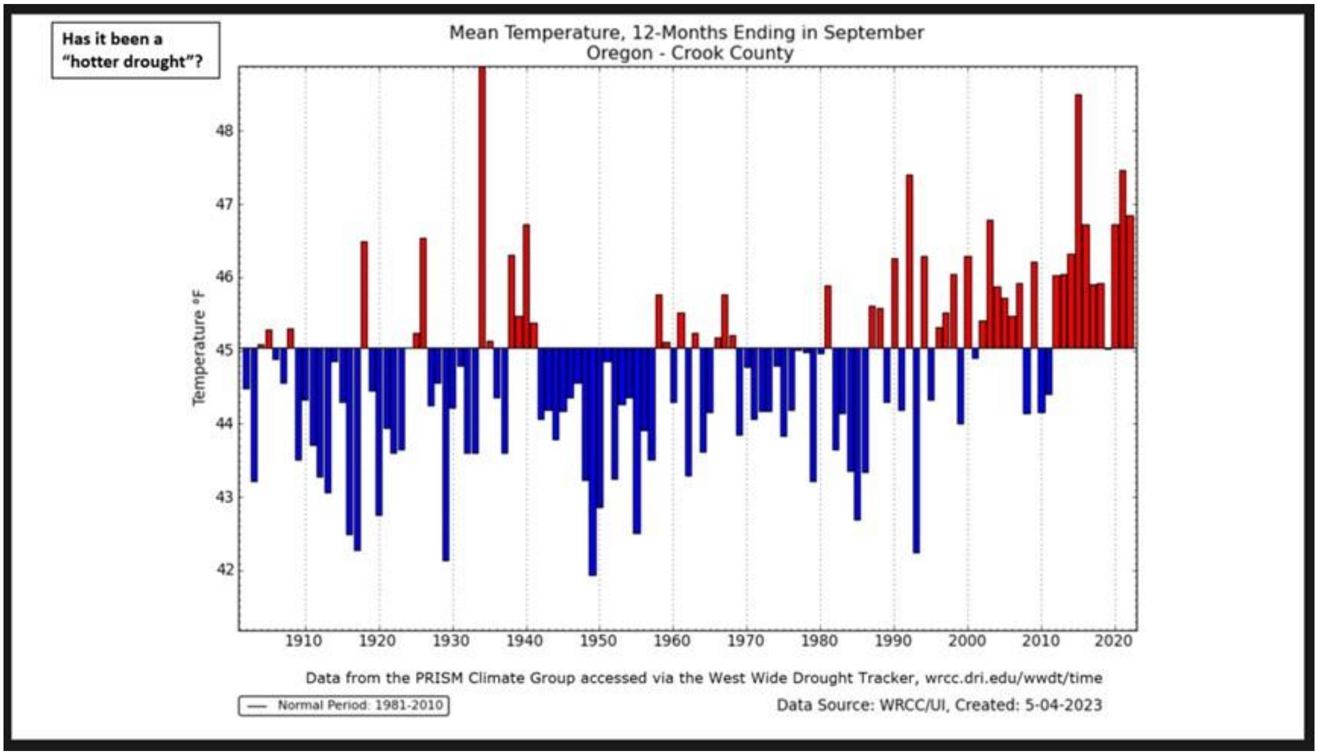


Figure 5. Mean annual temperature in Crook County, Oregon by hydrologic year (1901-2022) compared to the 30 yr normal period of 1981-2010.

In addition to warmer than average annual temperatures recently observed, below average annual precipitation occurred for several years prior to 2022 and extremely low precipitation occurred in in the 2020 hydrologic year Crook County.

Based on field observations in the last several years throughout central and northeast Oregon, fir engraver and root diseases caused by native fungi were commonly found contributing to recent mortality of white, Shasta red and grand fir at many sites. In a field survey reported by Lane and Goheen (1979), the co-occurrence of fir engraver and root disease on dead true firs was >75% on the Warm Springs Reservation, Winema, Deschutes and Ochoco National Forests in central Oregon. Root disease and fir engraver were also widespread contributors to true fir mortality, identified separately or together, on the Ochoco and Fremont National Forests based on surveys in 96 stands of each National Forest reported by Schmitt et al. (1984).

Discussion

The recent true fir die-off in central Oregon appears to be primarily associated with drought, fir engravers and root diseases, among other factors and fits the pattern seen in tree decline (Sinclair 1965; Manion 1991). Based on the drought indices, such as the SPEI, drought is the inciting factor. A close relationship between precipitation during the previous several years and mapped mortality the following year in aerial surveys has been reported before (Preisler et al. 2017). “Hotter drought” occurred in Crook County, Oregon with exceptional drought and warmer temperatures. These conditions prevailed in a large portion of the Ochoco National Forest where some of the most accelerated grand fir mortality was observed in 2022. Part of eastern and southern Oregon extending southward to the southwestern U.S. has been experiencing a “megadrought” which is estimated to be one of the worst droughts dating back to at least 800 CE (Williams et al. 2022). In many cases throughout central and northeast Oregon, drought appears to be the major factor making true firs vulnerable to fir engraver attack (Ferrell 1986; Cochran 1998). The fir engraver is a contributing factor to the die-off. Where true firs are growing in lower average annual precipitation zones, such as 20-30 inches, a higher risk of mortality is expected in southcentral Oregon and northeastern California (Cochran 1998). Drought may also cause hydraulic damage or carbon starvation leading to mortality of *Abies* even in the absence of fir engraver activity (Choat et al. 2018).

In this region, root diseases caused by primary pathogens, such as *Armillaria ostoyae* (=*A. solidipes*) or *Coniferiporia sulphurascens*, can kill true firs alone, or in combination with drought stress or fir engraver (Filip and Goheen 1982; Cochran 1998; Ferguson et al. 2003). Heterobasidion root disease is common on white, grand and Shasta red firs throughout central and northeast Oregon contributing to observed tree mortality based on recent field observations and past surveys (Filip and Goheen 1982; Schmitt et al. 1984). Because root disease is widespread in this region on *Abies* spp., root disease pathogens are likely a predisposing factor for trees infected prior to severe drought events in addition to being a contributing factor. True firs in the Oregon East Cascades are also severely infected by the dwarf mistletoe-Cytospora canker complex at various locations, which has been linked with higher levels of *Abies magnifica* mortality in California (Mortenson et al. 2015) and has significantly reduced growth in Oregon (Filip 1984). Infected true firs are predisposed to stress and mortality prior to the recent drought, and severe infections by the dwarf mistletoe-Cytospora canker complex are likely playing a role in increased tree mortality on the east slope of the Cascades in central Oregon (Kliejunas et al. 2009). Dwarf mistletoe is not known to occur on true firs in northeast Oregon. Under a changing climate, shifts in host and pathogen distributions, and effects of root diseases and dwarf mistletoes are expected (Kliejunas et al. 2009; Kim et al. 2021).

In many places where true fir mortality has recently occurred, high stand densities are also common resulting in competitive stress (Haugo et al. 2015), but potential effects of stand density on the recent mortality event were not thoroughly evaluated. Fire exclusion has led to an abundance of true fir at numerous locations experiencing stress and mortality, and based on reports by Cochran (1998) and Voelker et al. (2019), it is unrealistic to expect to maintain large true fir long-term in this region where drought events, insect activity and root diseases are known to occur. More true fir across the landscape now compared to pre-settlement conditions has resulted in more available hosts for root disease pathogens and fir engraver populations (Hessburg et al. 1994). These patterns and factors have been noted before, however, the nuances of the relative importance of these factors, and other potential factors such as seasonal patterns in precipitation and recent temperatures, and their interactions deserve further investigation. Additional research is underway by the Western Wildland Environmental Threat Assessment Center, University of Idaho, USDA Forest Service Pacific Northwest Research Station and others. It is unknown whether the temperature threshold of true firs was also exceeded in the past several years. Hennon et al. (2021) recently provided seven examples of applying a framework for evaluating climate-disease relationships. My preliminary assessment indicates that additional true fir mortality, and mortality of other species, is expected to continue in the coming years in central and northeast Oregon due to the multi-year drought.

In western North America, droughts have been one of the main drivers of broad-scale tree mortality involving *Abies* spp. and other conifers (Ferrell et al. 1994; Cochran 1998; Kolb et al. 2016). However, alarming examples of forest die-offs have been associated with more extreme drought events (Allen et al. 2015; Fettig et al. 2019). Patterns of drought-related tree mortality around the globe highlight the risk of significant changes under a warming climate (Allen et al. 2010; Senf et al. 2020; Hartmann et al. 2022; Liu et al. 2023). What is potential natural vegetation going forward? Allen and others (2015) conclude with confidence that: 1) droughts eventually occur everywhere; (2) warming produces hotter droughts; 3) atmospheric moisture demand increases nonlinearly with temperature during drought; 4) mortality can occur faster in hotter drought, consistent with fundamental physiology; 5) shorter droughts occur more frequently than longer droughts and can become lethal under warming, increasing the frequency of lethal drought nonlinearly; and (6) mortality happens rapidly relative to growth intervals needed for forest recovery. A useful resource with valuable information on recent drought conditions and expectations for climate change in Oregon, or elsewhere in the Northwest, is the Sixth Oregon Climate Assessment updated annually (Fleishman, ed. 2023). Adapting to a warming climate and increasing drought resistance in Oregon will continue to mean favoring tree species other than true firs at lower risk of drought-related injury and mortality many places.

Acknowledgements

I appreciate fellow aerial surveyors in Oregon from the USDA Forest Service and Oregon Department of Forestry for collecting and compiling aerial detection survey data from 1990 to 2022. I thank Robbie Flowers, USDA Forest Service – Forest Health Protection Central Oregon Service Center entomologist, for providing information on fir engraver.

Literature Cited

Allen, C.D., Breshears, D.D. & McDowell, N.G. (2015). On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. *Ecosphere*, *6*(8), 1-55. https://doi.org/10.1890/ES15-00203.1

Allen, C.D., Macalady, A.K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D.D., Hogg, E.T. & Gonzalez, P. (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest ecology and management*, *259*(4), 660-684. https://doi.org/10.1016/j.foreco.2009.09.001

Choat, B., Brodribb, T.J., Brodersen, C.R., Duursma, R.A., López, R. & Medlyn, B.E. (2018). Triggers of tree mortality under drought. *Nature*, *558* (7711), 531-539. https://doi.org/10.1038/s41586-018-0240-x

Cochran, P.H. (1998). Examples of mortality and reduced annual increments of white fir induced by drought, insects, and disease at different stand densities. Res. Note PNW-RN-525. USDA Forest Service, Pacific Northwest Research Station. 19 p.

Ferguson, B.A., Dreisbach, T.A., Parks, C.G., Filip, G.M. & Schmitt, C.L. (2003). Coarse-scale population structure of pathogenic *Armillaria* species in a mixed-conifer forest in the Blue Mountains of northeast Oregon. *Canadian Journal of Forest Research*, *33*(4), 612-623. https://doi.org/10.1139/x03-065

Ferrell, G.T. (1986). Fir Engraver. Forest Insect and Disease Leaflet #13. USDA Forest Service, 11 p.

Ferrell, G.T., Otrosina, W.J. & Demars Jr., C.J. (1994). Predicting susceptibility of white fir during a drought-associated outbreak of the fir engraver, *Scolytus ventralis*, in California. *Canadian Journal of Forest Research*, *24*(2), 302-305.

Fettig, C.J., Mortenson, L.A., Bulaon, B.M. & Foulk, P.B. (2019). Tree mortality following drought in the central and southern Sierra Nevada, California, US. *Forest Ecology and Management*, *432*, 164-178. https://doi.org/10.1016/j.foreco.2018.09.006

Filip, G.M. (1984). Dwarf mistletoe and Cytospora canker decrease grand fir growth in central Oregon. *Forest Science, 30*, 1071-1079.

Filip, G.M. & Goheen, D.J. (1982). Tree mortality caused by root pathogen complex in Deschutes National Forest, Oregon. *Plant Disease, 66*, 240-243.

Fleishman, E., editor. (2023). Sixth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. 248 p. https://blogs.oregonstate.edu/occri/oregon-climate-assessments

Goheen, D.J. & Hansen, E.M. (1993). Effects of pathogens and bark beetles on forests. In *Beetle-Pathogen Interactions in Conifer Forests.* TD Schowalter and GM Filip, eds. Academic Press. San Diego, CA. pp. 175-196.

Hartmann, H., Bastos, A., Das, A.J., Esquivel-Muelbert, A., Hammond, W.M., Martínez-Vilalta, J., McDowell, N.G., Powers, J.S., Pugh, T.A., Ruthrof, K.X. & Allen, C.D. (2022). Climate change risks to global forest health: emergence of unexpected events of elevated tree mortality worldwide. *Annual Review of Plant Biology*, *73*, 673-702. https://doi.org/10.1146/annurev-arplant-102820-012804

Haugo, R., Zanger, C., DeMeo, T., Ringo, C., Shlisky, A., Blankenship, K., Simpson, M., Mellen-McLean, K., Kertis, J. & Stern, M. (2015). A new approach to evaluate forest structure restoration needs across Oregon and Washington, USA. *Forest Ecology and Management*, *335*, 37-50. https://doi.org/10.1016/j.foreco.2014.09.014

Hessburg, P.F., Mitchell, R.G. & Filip, G.M. (1994). Historical and current roles of insects and pathogens in eastern Oregon and Washington forested landscapes. Gen. Tech. Rep. PNW-GTR-327. USDA Forest Service, Pacific Northwest Research Station. 72 p.

Kim, M.S., Hanna, J.W., Stewart, J.E., Warwell, M.V., McDonald, G.I. & Klopfenstein, N.B. (2021). Predicting present and future suitable climate spaces (potential distributions) for an Armillaria root disease pathogen (*Armillaria solidipes*) and its host, Douglas-fir (*Pseudotsuga menziesii*), under changing climates. *Frontiers in Forests and Global Change*, *4*. https://doi.org/10.3389/ffgc.2021.740994

Kliejunas, J.T., Geils, B.W., Glaeser, J.M., Goheen, E.M., Hennon, P., Kim, M.S., Kope, H., Stone, J., Sturrock, R. & Frankel, S.J. (2009). Review of literature on climate change and forest diseases of western North America. General Technical Rep. PSW-GTR-225, USDA Forest Service, Pacific Southwest Research Station. 54 p.

Lane, B.B. & Goheen, D.J. (1979). Incidence of root disease in bark beetle-infested eastern Oregon and Washington true firs. *Plant Disease Reporter*, *63*(4), 262-266.

Liu, Q., Peng, C., Schneider, R., Cyr, D., McDowell, N.G. & Kneeshaw, D. (2023). Drought-induced increase in tree mortality and corresponding decrease in the carbon sink capacity of Canada's boreal forests from 1970 to 2020. *Global Change Biology*, *29*(8), 2274-2285. https://doi.org/10.1111/gcb.16599

Manion, P.D. (1991). Tree Disease Concepts, 2nd ed. Prentice-Hall. Englewood Cliffs, NJ. 402 p.

Moore, J.A., Schenk, J.A. & Hatch, C.R. (1978). Validation and refinement of a hazard rating model for fir engraver-caused mortality in grand fir stands. *Forest Science, 24(2)*, 309-312.

Mortenson, L.A., Gray, A.N. & Shaw, D.C. (2015). A forest health inventory assessment of red fir (Abies magnifica) in upper montane California. *Ecoscience*, *22*(1), 47-58. https://doi.org/10.1080/11956860.2015.1047142

Preisler, H.K., Grulke, N.E., Heath, Z. & Smith, S.L. (2017). Analysis and out-year forecast of beetle, borer, and drought-induced tree mortality in California. *Forest Ecology and Management*, *399*, 166-178. https://doi.org/10.1016/j.foreco.2017.05.039

Schmitt, C.L., Goheen, D.J., Michaels Goheen, E. & Frankel, S.J. (1984). Effects of management activities and dominant species type on pest-caused mortality losses in true fir on the Fremont and Ochoco National Forests. USDA Forest Service, Pacific Northwest Region, Forest Pest Management. 34 p.

Senf, C., Buras, A., Zang, C.S., Rammig, A. & Seidl, R. (2020). Excess forest mortality is consistently linked to drought across Europe. *Nature communications*, *11*(1), 6200. https://doi.org/10.1038/s41467-020-19924-1

Simpson, M. (2007). Forested plant associations of the Oregon East Cascades. USDA Forest Service R6-NR-ECOL-TP-03-2007, Pacific Northwest Region. 598 p.

Sinclair, W.A. (1965). Comparisons of recent declines of white ash, oaks, and sugar maple in northeastern woodlands. *Cornell Plantations, 20*(4), 62-67.

Struble, G.R. (1937). The fir engraver beetle, a serious enemy of white fir and red fir. Cir. 419. USDA. 11 p.

Voelker, S. L., Merschel, A. G., Meinzer, F. C., Ulrich, D. E., Spies, T. A., & Still, C. J. (2019). Fire deficits have increased drought sensitivity in dry conifer forests: Fire frequency and tree-ring carbon isotope evidence from Central Oregon. *Global Change Biology*, *25*(4), 1247-1262. https://doi.org/10.1111/gcb.14543

Williams, A.P., Cook, B.I. & Smerdon, J.E. (2022). Rapid intensification of the emerging southwestern North American megadrought in 2020–2021. *Nature Climate Change*, *12*(3), 232-234. https://doi.org/10.1038/s41558-022-01290-z

Storm-damaged trees in California's North Coast, 2023: a rapid assessment

Chris Lee[1]*

Abstract

Eight sites in California's north coastal region were investigated to determine tree characteristics and pest prevalence associated with windthrow, windsnap, and tree uprooting from other causes after the extreme winter weather of 2022-2023. This preliminary study confirmed the general small scale and wide variety of stand and site conditions associated with post-storm tree damage in this region. Of the pests associated with storm-damaged trees, *Phaeolus schweinitzii, Dendroctonus pseudotsugae, Ursus americanus,* and *Endocronartium harknessii* stand out as being fairly common and significant either in helping to cause tree failure or in being dependent on tree failure for breeding material. This study served as a pilot for what is hoped will be continuing regular rapid assessments of forest tree failures in these forests in the future, with the ultimate goal of better understanding the overall effects of climate change on cycles of regional pest populations and tree damage.

Introduction

Wind has been studied in various North American forests in the past as an important abiotic generator of stand mortality and interacting disturbance with other abiotic and biotic damage agents (e.g., Foster 1988; Bakken 1995; McBride and Leffingwell 2014). Wind is a primary disturbance in the forests of California's North Coast, although less so than in the forests of the Pacific Northwest (Lorimer et al. 2009). In North Coast forests, windstorms generally create small-scale gaps in the forest canopy, releasing understory on sub-stand scales, and non-wind disturbances such as slope failures also create gaps (Hunter and Parker 1993). Because of this relatively small scale and infrequent timing of windthrow and windsnap events, the relationship of wind to other damage agents has been little studied in this area of California.

The late winter and early spring of 2022-2023 was noteworthy in scale and intensity not only for the North Coast, but also for the rest of California. Most parts of the state received 400-600% of "normal" precipitation during this winter. The December-April period saw twelve atmospheric river-type storms proceed through various parts of the state. A "bomb cyclone" in March blew down hundreds of trees and caused extensive damage to buildings in the San Francisco Bay Area. Snowstorms in late February and early March necessitated dozens of rescues and killed at least four people. Peak wind gusts in areas of northwestern California regularly measured from 70-100 mph (Bland 2023; Canon 2023; Cassidy 2023; Center for Disaster Philanthropy 2023; Erdman and Dolce 2023; Newburger and Jeffery 2023; Western Regional Climate Center 2023).

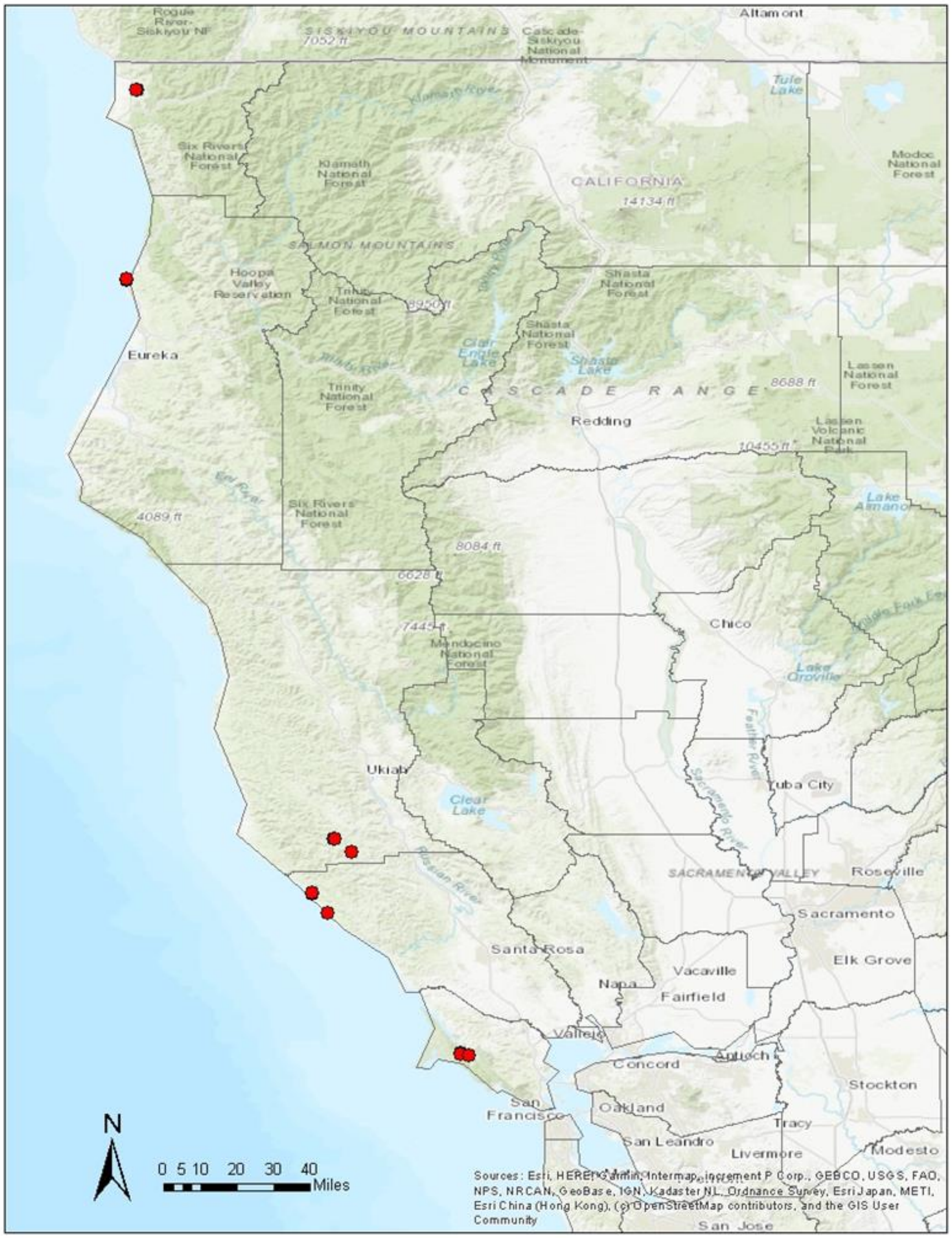
The severity of these storms motivated curiosity about whether increased storm severity in the future could lead to larger-scale tree mortality events, particularly given possible interactions with other climate-related tree stresses such as preceding water stress and consequent invasion by native and non-native pathogen and insect pests. This project aimed to begin a long-term post-winter monitoring program to sample windthrow/windsnap/treefall areas in a variety of northern California coastal forests. The goal of this program is to record tree sizes, species, and other characteristics most commonly associated with windthrow and windsnap. A secondary goal is to record biotic damage agents present on wind-damaged trees. More specifically, it was hoped that the data obtained in this periodic monitoring will allow inferences, obtained relatively rapidly each year over the large territory of northwest coastal California, about whether tree, stand, or site characteristics influence probability of tree damage; how prevalent various damage modes may be; and if obvious damage from forest insects and pathogens is associated with storm damage.

---

[1] California Department of Forestry and Fire Protection; Trinidad, CA, USA
*christopher.lee@fire.ca.gov, 479-739-1484

Methods

The study comprised sites in all the coastal California counties from Marin in the south to Del Norte in the north. Marin, Sonoma, and Mendocino Counties featured two sites each, and Humboldt and Del Norte one each, for a total of eight sites (Figure 1). Within these sites, 2-3 transects were established within obviously wind-damaged stands, beginning with a windthrown or windsnapped tree and proceeding in a randomly chosen direction for 50m. Within a 5-m corridor on each side of this transect, each tree, whether, dead, damaged, or living, was tallied, for a total pseudo-plot area of 500 sq m (0.05 ha).



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure 1: Study site locations in north coastal California.

Diameter at breast height (DBH) and species were recorded for each tallied tree, and each tree was categorized as standing live, standing dead, fallen snapped, or fallen uprooted. Top breakouts were recorded. Additionally, roots condition or the location of the bole at the point of windsnap were inspected for decay and evidence of damaging organisms, with the presence of white rot, brown rot, fruiting bodies, or other signs of biotic agents noted and the approximate percent of exposed root systems with decay estimated. Aspect, slope, elevation and soil type for each site were ascertained *post hoc.* For aspect, slope, and elevation, a publicly available USGS digital elevation model (USGS 2023) was loaded into the *terra* package in R (Hijmans et al. 2022) along with site geocoordinates, and the required variables were then extracted. Site soil classification and characteristics were ascertained for each site using the USDA Natural Resources Conservation Service Web Soil Survey (Natural Resources Conservation Service 2023). Simple summary statistics were computed and plots constructed using Microsoft Excel and the *ggplot* package in R (Wickham 2016). Altogether, 315 trees were surveyed along fourteen transects.

Results

228 of the 315 tallied trees (72%) were standing live, 24 (8%) were standing dead, 27 (9%) were fallen uprooted, and 36 (11%) were fallen snapped. The largest-diameter trees experienced primarily uprooting or top breakage (Figure 2), with standing live trees widely spread over all diameters; smaller trees tended to be standing dead or to be snapped off. Aspects of sites where damage occurred were various, although there were slightly more northwest-facing aspects than others. Plotting damage levels against elevation and slope showed similarly wide scatter, with damage varying nonsystematically with these variables. Unsurprisingly, damage did track with tree density, as number of trees damaged increased with number of trees within the transect corridor (Figure 3).

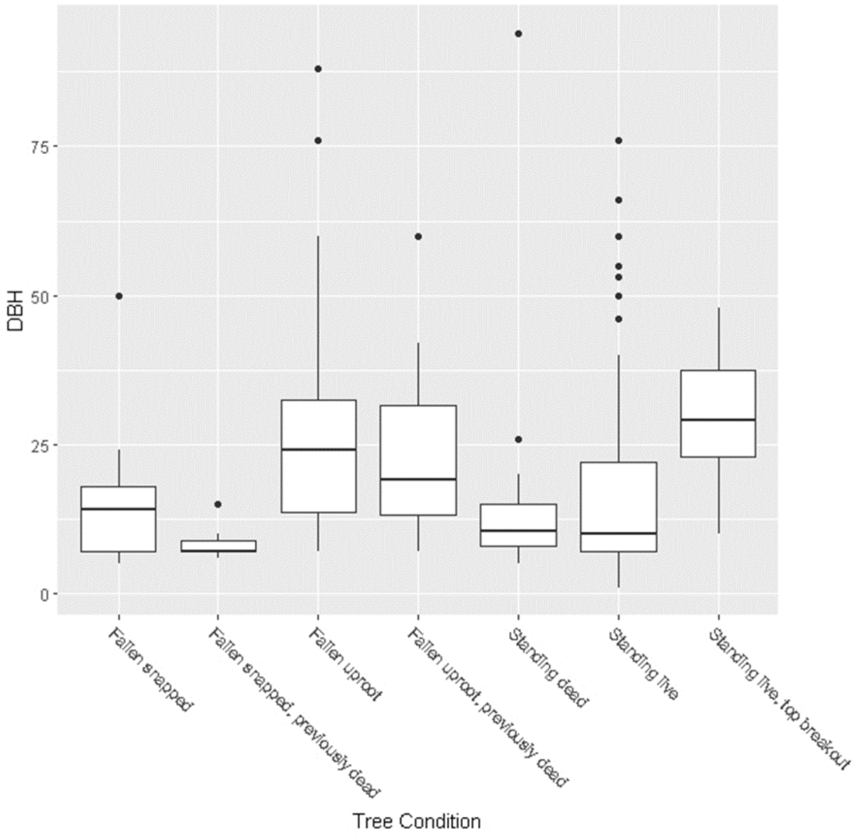


Figure 2: Means and distributions of tree diameters across study sites categorized by tree condition.

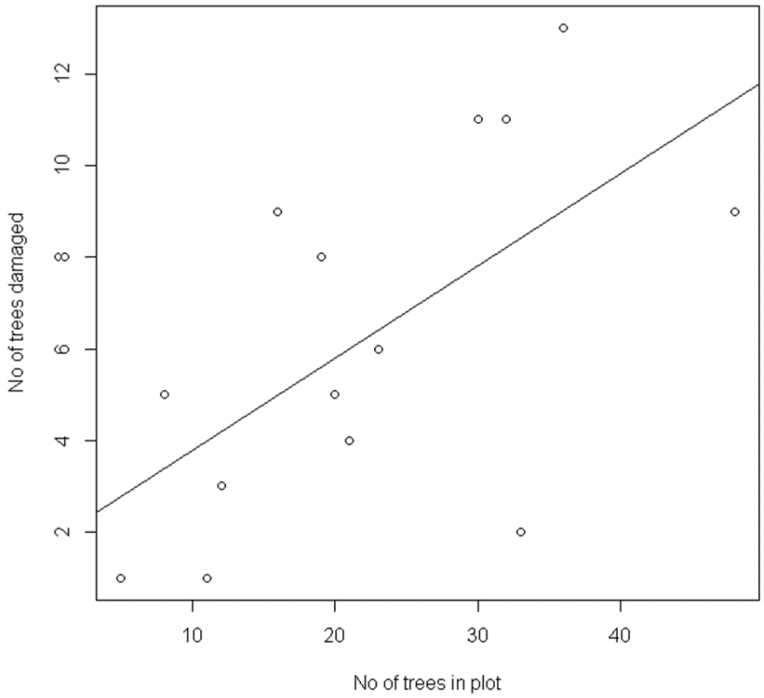


Figure 3: Number of trees damaged per transect "plot" by plot density (measured as trees per plot).

Of uprooted trees where root decay conditions could be examined, 65% were estimated to have only 0-10% of the root system decayed. The next-largest category comprised root systems with extensive decay (90-100% of the roots decayed; 17% of the root systems examined), with the middle categories represented at much lower numbers (Figure 4). Of uprooted trees, 9/36 (25%) showed evidence of brown rot, while 8/36 (22%) showed evidence of white rot. Of fallen, snapped trees, 7/27 (26%) showed evidence of brown rot, while 10/27 (37%) showed evidence of white rot. Organisms noted in uprooted trees included Douglas-fir beetle (*Dendroctonus pseudotsugae)* in 5/36 trees, *Phaeolus schweinitzii* in 4/36, *Armillaria* sp. in 3/36, and balsam woolly adelgid (*Adelges piceae*) on one uprooted grand fir (notably, this location, Salt Point State Park in Sonoma County, represents the current southernmost observation of balsam woolly adelgid in California). Organisms noted in association with snapped trees included black bear (*Ursus americanus*) in 3/27 trees, *Armillaria* sp. in 2/27, and the pouch fungus, *Cryptoporus volvatus,* in 1/27. Organisms noted in association with standing dead trees included black bear (5/24 trees), *Porodaedalea pini* (2/24 trees), *Annulohypoxylon* sp. (1/24 trees), and western gall rust (*Endocronartium harknessii*). The number of trees with *E. harknessii* was uncounted because we assumed that many dead tree crowns contained small galls on high branches where we could not see them.

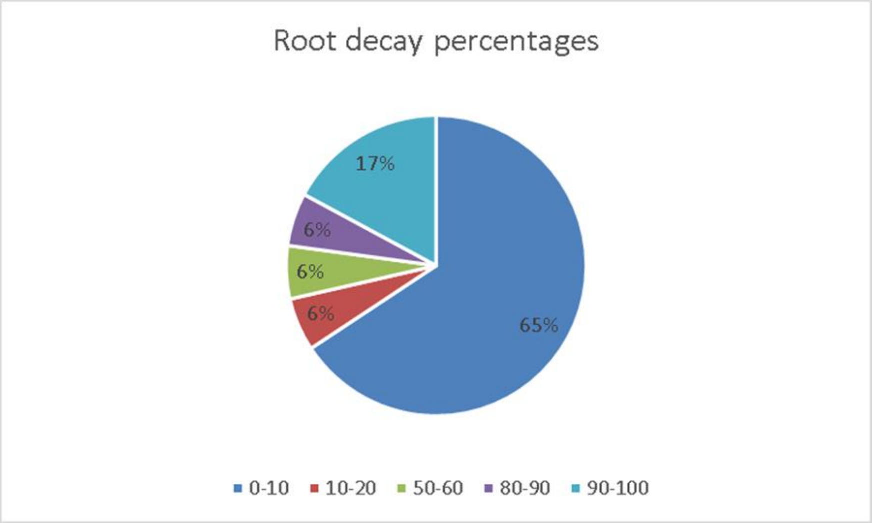


Figure 4: Percentage of trees across study sites in various categories of root system decay.

Soils at most of the study sites are relatively well-developed, although the Humboldt County site does represent an inceptisol (very young soil). Most of them are deep, relatively well-drained, and good for growing trees, although some do contain a significant gravel fraction (Galbreath Preserve in Mendocino County and Point Reyes in Marin County). The Humboldt County inceptisol features a very high water table that encourages the prolific growth of Sitka spruce, which is shallow-rooted and well-adapted to this, but by the same token puts it at high risk for windthrow, both because of the shallow roots and because decay fungi are also well-adapted to the moist conditions.

Discussion

As mentioned above, this very small dataset hopefully represents the beginnings of annual, opportunistic long-term data collection about the characteristics of storm-damaged trees in the north coastal counties in California. This sort of project could establish a baseline understanding of some of these characteristics against which departures associated with climate change might be measured in the future. Currently, as with many other regions, there is significant uncertainty about how long-term climate and seasonal weather patterns in north coastal California will be affected by broad-scale climate change (Cayan et al. 2008). Nevertheless, knowing something about the variety of biotic and abiotic conditions associated with “typical” storm damage in this geographic region will help inform better predictions of damage extent and location as our understanding of climate change comes into sharper focus.

It is important to note the shortcomings and bias inherent in this data collection. Sites were chosen largely because storm damage was noticed during visits to other field sites or because they were brought to land managers’ attention by observers. Within a given stand, the area covered by transect-associated “plots” was small and may not represent typical conditions throughout the rest of the storm-damaged area of the stand in question. Additionally, many variables collected during the study represent visual estimates. Overall this data collection effort represents an attempt to balance depth of variables observed with a need for rapid assessment to cover a larger geographic area. Accordingly, the statistical analysis resulting from the project is necessarily observational and summary in nature, and no valid hypotheses or inferences can be drawn from it.

However, this data can serve as the foundation for the formulation of hypotheses for future testing. Some of the most useful observations from include the following.

These observations add to evidence that *Phaeolus schweinitzii* is a significant pathogen of coastal conifers. From commonly occurring incipient decay in the central cylinders of small- to medium-sized roots, where it seems likely to compromise water transport (Figure 5), to the near-total decay of large structural roots leading to windthrow and windsnap (Figure 6), this pathogen is pervasive and has a large impact on the structure of coastal forests containing its host trees. The observations collected in this project complement other observations made over the years.

Figure 5: Incipient *Phaeolus schweinitzii* decay in the center of a windthrown Sitka spruce root.

Figure 6: Brown cubical decay associated with *P. schweinitzii* presence on a large, fallen Douglas-fir.

Commonly associated with both *P. schwenitzii* and treefall, the Douglas-fir beetle is also more common in coastal California forests than commentators and texts indicate. Small-scale uprooting of Douglas-fir is a likely way for this beetle to maintain populations at endemic levels.

Black bear is another important forest pest in the north coast region, and one of the only ones with a disproportionate impact on coast redwood. Bear attacks and girdling commonly lead to stem decay, which in turn leads to windthrow and other cascading effects.

Western gall rust is significant in many conifer-containing stands. It can contribute to physiological decline through killing of individual branches as well as to stem decay and risk of windsnap. This can happen when large galls produce deformities on main stems that serve as entry courts for pathogens and points of stem weakness (Figure 7).

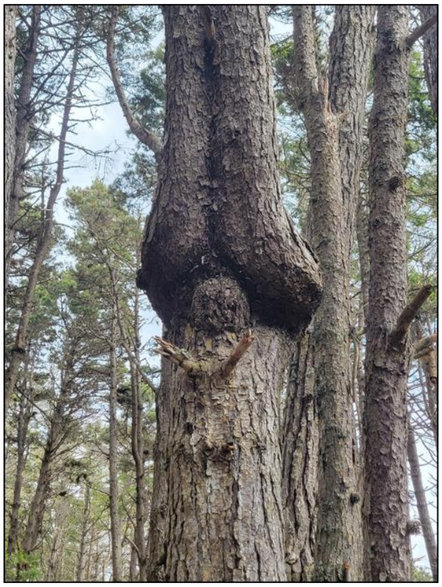


Figure 7: Old *Endocronartium harknessii* gall creating a point of weakness in a bishop pine stem.

Windthrow, windsnap, and tree uprooting from other means seems equally likely to occur on a variety of soils, aspects, and slopes in north coastal California.

Most uprooted root systems inspected were healthy and undecayed, suggesting that storm damage in the north coast operates somewhat independently of pest activity. However, the next-largest category of uprooted root systems contained the highest levels of decay, suggesting that pests could potentially interact with more extreme climate conditions to produce an increased level of damage in the future.

This kind of rapid, post-winter assessment will hopefully be replicated in future years to provide a growing body of data concerning the biotic and abiotic factors associated with storm damage in coastal forests.

Literature Cited

Bakken, S.R. 1995. Group-tree hazard analysis. Journal of Arboriculture 21(3): 150-155.

Bland, A. 2023. California storms create paradox: too much water in reservoirs, too soon. CalMatters. Accessed May 30, 2023. https://calmatters.org/environment/2023/03/california-storm-reservoirs-flooding/.

Cannon, G. 2023. “Strongest snowstorm in years” leaves Californians delighted and frozen. The Guardian. Accessed May 30, 2023. https://www.theguardian.com/us-news/2023/feb/24/california-snow-los-angeles-san-francisco-bay-area.

Cassidy, E. 2023. Storms soak California. NASA Earth Observatory. Accessed November 27, 2023. https://earthobservatory.nasa.gov/images/150823/storms-soak-california#:~:text=According%20to%20the%20National%20Weather,particularly%20hard%20in%20Southern%20California.

Cayan, D.R., Maurer, E.P., Dettinger, M.D., Tyree, M., and Hayhoe, K. 2008. Climate change scenarios for the California region. Climatic Change 87: S1-S42.

Center for Disaster Philanthropy.2023. California storms. Accessed November 27, 2023. https://disasterphilanthropy.org/disasters/california-storms/#:~:text=From%20late%20December%202022%20through,that%20damaged%20roads%20and%20homes.

Cowan, J. 2023. Death toll rises in southern California mountains after blizzards. The New York Times. Accessed November 27, 2023. https://www.nytimes.com/2023/03/08/us/san-bernardino-snow-storm-deaths.html.

Erdman, J. and Dolce, C. 2023. What happened with that California bomb cyclone Tuesday? Bloomberg. Accessed November 27, 2023. https://www.wunderground.com/article/storms/severe/news/2023-03-22-california-bomb-cyclone.

Foster, D.R. 1988. Species and stand response to catastrophic wind in central New England, U.S.A. Journal of Ecology 76(1): 135-151.

Hijmans, R. J., Bivand, R., Forner, K., Ooms, J., Pebesma, E., & Sumner, M. D. (2022). Package ‘terra’. Maintainer: Vienna, Austria.

Hunter, J.C. and Parker, V.T. 1993. The disturbance regime of an old-growth forest in coastal California. Journal of Vegetation Science 4: 19-24.

Lorimer, C.G., Porter, D.L., Madej, M.A., Stuart, J.D., Veirs Jr., S.D., Norman, S.P., O’Hara, K.L., and Libby, W.J. 2009. Presettlement and modern disturbance regimes in coast redwood forests: implications for the conservation of old-growth redwood stands. Forest Ecology and Management 258: 1038-1054.

McBride, J.R. and Leffingwell, J. 2014. Assessing wind throw potential in urban forests of coastal California. ResearchGate. Accessed May 30, 2023. https://www.researchgate.net/profile/Joe-Mcbride-2/publication/237346634_Assessing_Wind_throw_Potential_in_Urban_Forests_of_Coastal_California/links/0a85e53bda22a6882f000000/Assessing-Wind-throw-Potential-in-Urban-Forests-of-Coastal-California.pdf.

Natural Resources Conservation Service. 2023. Web Soil Survey. Accessed May 30, 2023. https://websoilsurvey.nrcs.usda.gov/app/.

Newburger, E. and Jeffery, A. 2023. California winter storms bring heavy snow; Newsom declares state of emergency in 13 counties. MSNBC online. Accessed May 30, 2023. https://www.cnbc.com/2023/03/02/california-winter-storms-newsom-state-of-emergency-in-13-counties.html.

USGS (United States Geological Survey). GIS Data Download. Accessed May 30, 2023. https://www.usgs.gov/the-national-map-data-delivery/gis-data-download.

Western Regional Climate Center. 2023. RAWS USA Climate Archive. Accessed November 27, 2023. https://raws.dri.edu/

Wickham, H. 2016. An introduction to *ggplot:* an implementation of the grammar of graphics in R. Statistics (2006): 1-8.

Intergenerational Conversation on Climate Change and Forest Diseases

A Discussion moderated by Janice Alexander

Panel members: Robert Scharpf, Robin Mulvey, and Alexander Flores. (photo: Rachel Brooks)

Climate, climate change, and tree diseases

Robert Scharpf[1]*

We are living in an unprecedented time of global climate change. Higher than average land and ocean temperatures, more frequent catastrophic wildfires, and continued burning of fossil fuels contribute to the warming of earth. However, it is not known at this time how earth's warming is affecting tree diseases.

The topic I am to present on today is a big order, and I admit that I am not certain that I can address it adequately. Climate change is occurring more rapidly than most of us had envisioned, and its consequences are yet to be determined. The best I can do today is to provide my opinions, personal experiences, and some information based on 30 years as a research plant pathologist with the U.S. Forest Service, and more than 30 years as a wine- grape grower.

The truth is, I never thought much about climate change during my U.S. Forest Service career. My interest was conducting research leading to the management and control of forest diseases. I do recall one case in the 1980s when I was asked the question, "What effect would climate change have on forest diseases?" I don't recall how I responded, but I did not have an answer or consider it an important issue at the time.

After I retired in 1990, we moved to Placerville in El Dorado County. The county is the home of the El Dorado National Forest, a Forest Service nursery, and the Institute of Forest Genetics. El Dorado County includes dry, brushy, foothill woodlands, a rich ranching and agricultural region, and high-elevation and mixed-conifer forests of the Sierra Nevada Mountains. All of these regions are prone to fire during the hot, dry summers, and I did not consider an occasional fire unusual. However, the increase in number and severity of wildfire over the last few years has been of concern.

Our first experience with wildfire was the Chili Bar Fire in September 1979. It was not a "big" fire, but it was dangerous, because it was burning within the city limits of Placerville. Eventually, it burned several thousand acres, five homes, including our neighbor's, and our 20 acres that contained recently planted vineyard. In 2014 the King Fire burned 97,000 acres in the south fork of the American River, and within a half mile of our property. This is when I began to think seriously about the relationship between global climate change, and the frequency of wildfires in our area. Since then, a number of major fires have burned in the state, and have caused loss of life, health problems, and severe damage to property and the environment.

In the last few years, my concern was, what effect a changing climate has had, not only on the frequency and seriousness of wildfires, but also on the health and production of my vineyard? I have observations and some data on 30 plus years of growing wine grapes. A grape vine is not a tree, but it is a perennial, woody plant that should respond to climate change much like a tree.

What I have observed in the vineyard over the years from 1990 to 2021

Irrigation. The vines were on drip irrigation and needed a controlled amount of irrigation over the season for proper growth and ripening. Fortunately, our irrigation district provides adequate irrigation water, and monitors our soil moisture level by taking weekly neutron probe readings during the growing season. Over 30 years of monitoring the soil moisture, the mature vines needed increasingly earlier irrigation and progressively more water as determined by the neutron probe readings.

Disease control. Powdery mildew is a serious disease of grapes. My method of control has been achieved by weekly applications of a fungicide (sulfur) to the foliage until the temperature in the vines reached 90 °F or

---

[1] USDA Forest Service, Pacific Southwest Research Station; Albany, CA, USA
*quartzhillvineyard@gmail.com

higher. High foliage temperatures prevent infection. In general, over 30 years, earlier, and higher average daytime temperatures during spring and summer required fewer fungicidal treatments.

Time of ripening. The ripeness of a wine grape is based on the percentage of sugar (known as the brix) and its acidity (pH). Over the years, the grapes have been progressively ripening earlier. Twenty-five to 30 years ago, a crop of Merlot, for example, would not be ripe and ready to pick before mid to late September. By 2021, the harvest was late August to early September.

Conclusions

From 30 years of records and observation, it appears that the subtle changes in water demand, seasonal growth, and disease control of my grapevines were influenced by climate change. It is reasonable then to assume that the growth and some diseases of trees would also be affected by climate change. Further research on monitoring of growth and disease of forest, orchard and ornamental trees, and other perennial plant species would help to answer these climate and tree disease questions.

As a final comment, I would like to include a portion of a summary from the website of the California Air Resources Board, 2023 (https://ww2.arb.ca.gov/wildfires-climate-change).

Wildfires and Climate Change

Climate change, caused primarily by the burning of fossil fuels, is increasing the frequency and severity of wildfires not only in California but also all over the world. Since 1950, the area burned by California wildfires each year has been increasing, as spring and summer temperatures have warmed, and spring snowmelt has occurred earlier.

During the recent "hotter" drought, (2022) unusually warm temperatures intensified the effects of very low precipitation and snowpack, creating conditions for extreme, high severity wildfires that spread rapidly. Of the 20 largest fires in California's history, eight have occurred in the past three years (since 1970). The August Complex Fire is now the largest recorded fire, surpassing the 2018 Mendocino Complex Fire.

Acknowledgements

I would like to thank Greg Boeger of Boeger Winery; Randy Hansen, Agricultural Pest Control Advisor; and Chuck Mansfield of Gold Bud Farms for reviewing and commenting on this paper.

Climate-disease relationships: A millennial/Gen X perspective

Robin Mulvey[1]*

Climate change is not only expected to occur in the distant future. Climate change is here and now, evidenced by increased variation in temperature and moisture, directional increases in temperature, and catastrophic events. Here, I describe how and why it is necessary for pathologists to work with other disciplines and specialties to address the effects of climate change on forest pathogens. Then, I summarize three seminal publications in our field that focus on climate change and forest pathogens, with a few examples specific to forest health issues in Alaska.

The environment is an essential element of the plant disease triangle, along with a virulent pathogen and a susceptible host. The influence of the environment on pathogen biology has typically been elucidated and quantified through controlled experiments to determine pathogen thresholds and optimum conditions for growth and reproduction. These experiments have become less common, largely replaced by climate-envelope models that identify the range of conditions that occur in locations where the pathogen is active on its host or hosts (Barrett et al. 2012, Hanna et al. 2020, Kim et al. 2021). Therefore, it is important to compare the advantages and limitations of these approaches and whether they account for pathogen biology, spread rates, and migration pathways.

Climate change amplifies our need for interdisciplinary teams. Conceptual frameworks based on the disease triangle can help us to understand what drives increased disease severity across pathosystems. However, we require an intricate understanding of forest health problems and climate interactions that extend beyond the field of pathology. In my professional role, I do not feel equipped or encouraged to crunch large climate datasets among other competing priorities. Many forest pathologists are in positions focused on evaluation and monitoring versus scientist positions with intensive research programs. To take this next step, we must partner with climatologists, statisticians, plant physiologists, ecologists, geneticists, soil scientists, and others. How will these teams form? Who will fund this critical work? Reductions in federal pathology research positions and programs further limit us.

Alongside the workload to advance our mechanistic understanding of forest health problems and links to climate, we must also work with silviculturists, foresters, and managers to develop and implement effective mitigation strategies. Will the ability to predict disease problems translate to the power to alleviate damage or to *just watch it happen*? Mitigation could include planting host trees, or reducing competition around host trees, in environments less prone to predisposing/inciting stressors or less conducive to the key pathogens. This strategy has been recommended in Southeast Alaska, where yellow-cedar decline mortality is caused by root-freezing injury with the loss of winter snowpack (Hennon et al. 2016). By planting yellow-cedar on sites with deeper soils, and reducing competition with other species, its roots are protected from cold temperatures near the soil surface regardless of snowpack. Comprehensive strategies that marry scientific understanding, projected climate change impacts, and sound guidance for specific management zones can provide the basis and specificity required to bring all these elements together.

Three publications focused on climate change and forest pathogens form the backbone for new conceptual frameworks in our field: Sturrock et al. 2011, Hennon et al. 2020, and Hennon et al. 2021. Sturrock et al. (2011) summarize the myriad of ways in which climate change will affect the pathogen, the host, and the interaction; host susceptibility and pathogen growth, reproduction, and infection; the distribution of hosts and diseases (pathogens may play key roles in the range reduction in forest trees); and the interactions between biotic diseases

---

[1] USDA Forest Service, Alaksa Region, Forest Health Protection; Juneau, AK, USA
*robin.mulvey@usda.gov

and abiotic stressors. They hypothesize that: (1) pathogens that typically affect water-stressed hosts are likely to have an increased impact on forests in regions where precipitation is reduced, and (2) pathogens will play an increased role as disturbance agents because they can adapt to new conditions and migrate to new locations faster than their long-lived hosts. Lastly, they suggest that climate change will affect the life cycles and biological synchronicity of many forest trees and pathogens, with ramifications for disease incidence and severity.

Hennon et al. (2020) extend the thought process related to climate impacts on diseases by providing a conceptual framework to evaluate climate effects on forest tree diseases. This approach defines specific elements to associate with climate and describes how they can be evaluated, monitored, and researched (Figure 1). These elements include disease expression across spatial and temporal scales, predisposing factors and vulnerabilities related to stand conditions and tree physiology, and direct influence of climate on pathogen lifecycles. As usual in pathology, it all comes back to the interaction between the host, the pathogen, and the environment in the plant disease triangle, and pathologists are left attempting to address and answer the difficult questions of how environmental change might shift these interactions and alter disease expression.

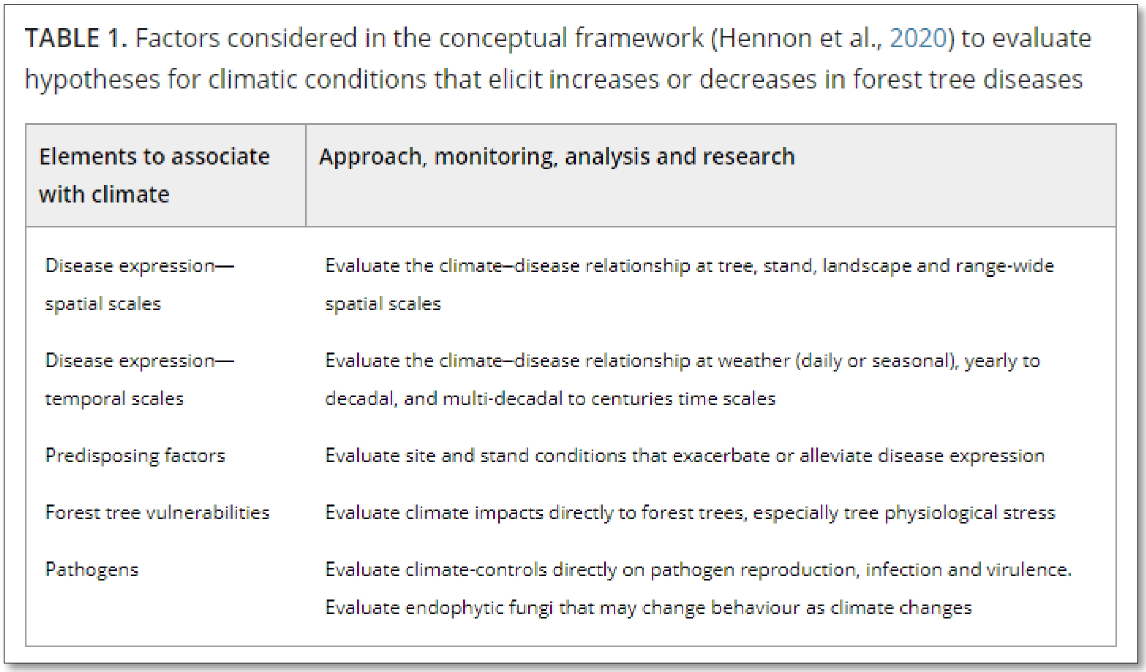


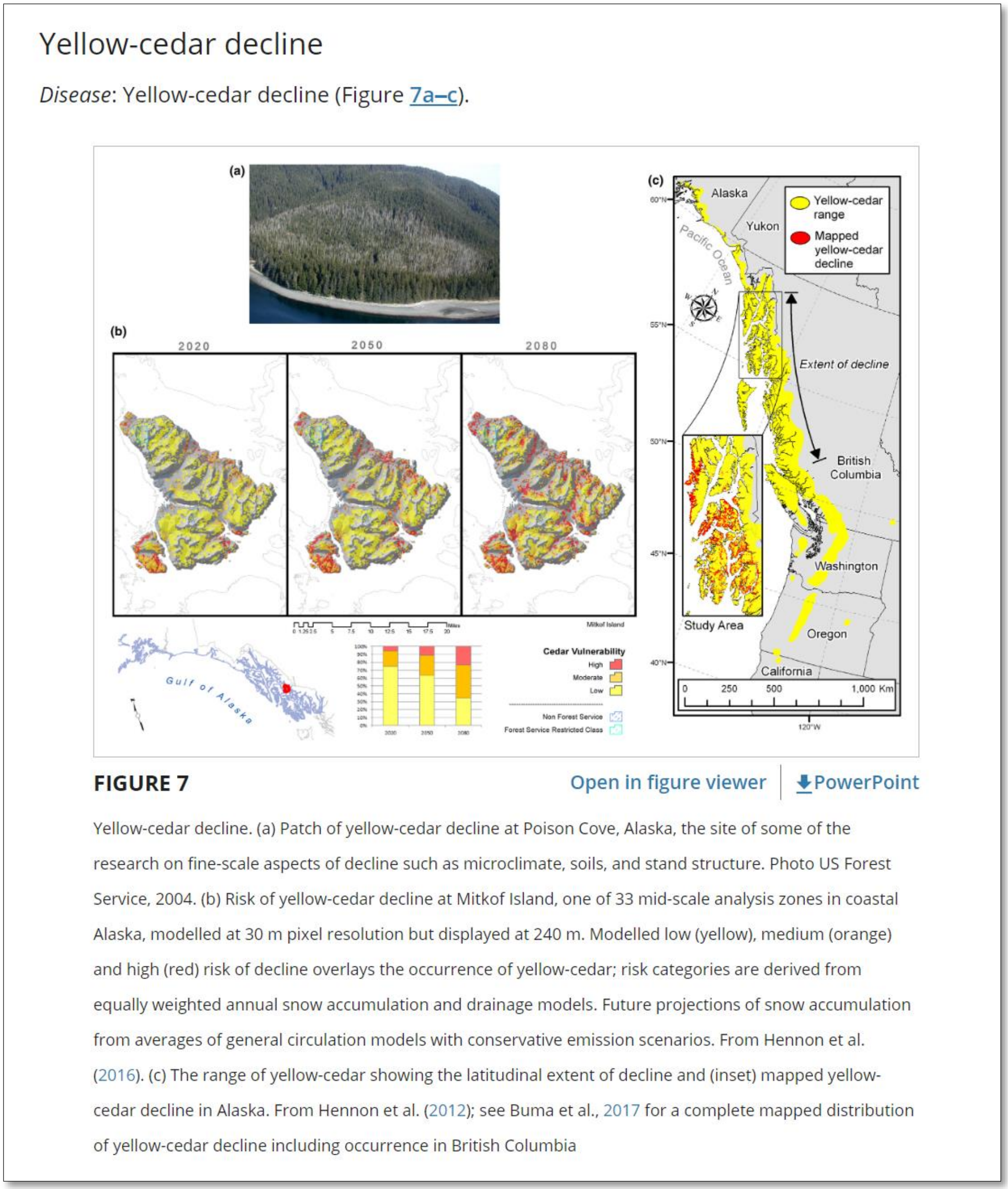
TABLE 1. Factors considered in the conceptual framework (Hennon et al., 2020) to evaluate hypotheses for climatic conditions that elicit increases or decreases in forest tree diseases

Elements to associate with climate	Approach, monitoring, analysis and research
Disease expression—spatial scales	Evaluate the climate–disease relationship at tree, stand, landscape and range-wide spatial scales
Disease expression—temporal scales	Evaluate the climate–disease relationship at weather (daily or seasonal), yearly to decadal, and multi-decadal to centuries time scales
Predisposing factors	Evaluate site and stand conditions that exacerbate or alleviate disease expression
Forest tree vulnerabilities	Evaluate climate impacts directly to forest trees, especially tree physiological stress
Pathogens	Evaluate climate-controls directly on pathogen reproduction, infection and virulence. Evaluate endophytic fungi that may change behaviour as climate changes

Figure 1: Table 1 from Hennon et al. 2020.

The last publication in this trilogy, *Applications of a conceptual framework to assess climate controls of forest tree diseases* (Hennon et al. 2021), provides seven disease examples to illustrate how specific knowledge related to the elements described above can help us to understand what drives changes in disease expression. Although all elements of the plant disease triangle are relevant, this approach identifies the most important triggers for increased disease, categorizing diseases as climate-stress diseases or abiotic decline (driven by climate increasing host susceptibility) or climate-pathogen diseases (driven by climate benefiting the pathogen). Ideally, this categorization can guide mitigation measures that target the causes of increased disease incidence and severity.

Hennon et al. (2021) include three examples of diseases or disorders important in Alaska: yellow-cedar decline, hemlock dwarf mistletoe, and Dothistroma needle blight. Yellow-cedar decline is a noninfectious forest decline driven by changes in snowpack and a unique physiological vulnerability to root freezing injury. In this case, information about hydrology and projected snowpack can allow land managers to prioritize yellow-cedar where it has the best chance of future survival (Figure 2). Hemlock dwarf mistletoe has a more limited range in Alaska compared to its primary host, western hemlock. In this case, warming conditions are expected to favor both the host and the pathogen; however, hemlock dwarf mistletoe is known for its slow dispersal and migration rates. The environmental thresholds and conditions that lead to outbreaks of Dothistroma needle blight have been carefully studied with both classical and modern approaches, giving us powerful tools to understand changes in outbreak dynamics.



Yellow-cedar decline

Disease: Yellow-cedar decline (Figure 7a–c).

FIGURE 7

Open in figure viewer | PowerPoint

Yellow-cedar decline. (a) Patch of yellow-cedar decline at Poison Cove, Alaska, the site of some of the research on fine-scale aspects of decline such as microclimate, soils, and stand structure. Photo US Forest Service, 2004. (b) Risk of yellow-cedar decline at Mitkof Island, one of 33 mid-scale analysis zones in coastal Alaska, modelled at 30 m pixel resolution but displayed at 240 m. Modelled low (yellow), medium (orange) and high (red) risk of decline overlays the occurrence of yellow-cedar; risk categories are derived from equally weighted annual snow accumulation and drainage models. Future projections of snow accumulation from averages of general circulation models with conservative emission scenarios. From Hennon et al. (2016). (c) The range of yellow-cedar showing the latitudinal extent of decline and (inset) mapped yellow-cedar decline in Alaska. From Hennon et al. (2012); see Buma et al., 2017 for a complete mapped distribution of yellow-cedar decline including occurrence in British Columbia

Figure 2: Hennon et al. 2016 Appendix 1 Figure 7

Moving forward, we can utilize this framework to better understand how forest pathogen phenology, pressure, severity, and distribution may be impacted by climate change. However, reality is more complicated than any model, and the links between many diseases and weather, let alone changes in long-term climate, remain poorly understood. The direction and magnitude of temperature and precipitation changes are key, but the specific timing of events and how they align with pathogen and host phenology are equally important and extremely difficult to predict. It remains to be seen whether the ability to predict changes in disease, roughly or with reasonable accuracy, at various temporal and spatial scales, will give us the tools to create meaningful change and increase resilience in our forest ecosystems. Let us continue this critical work and build the necessary partnership infrastructure to meet our greatest challenge.

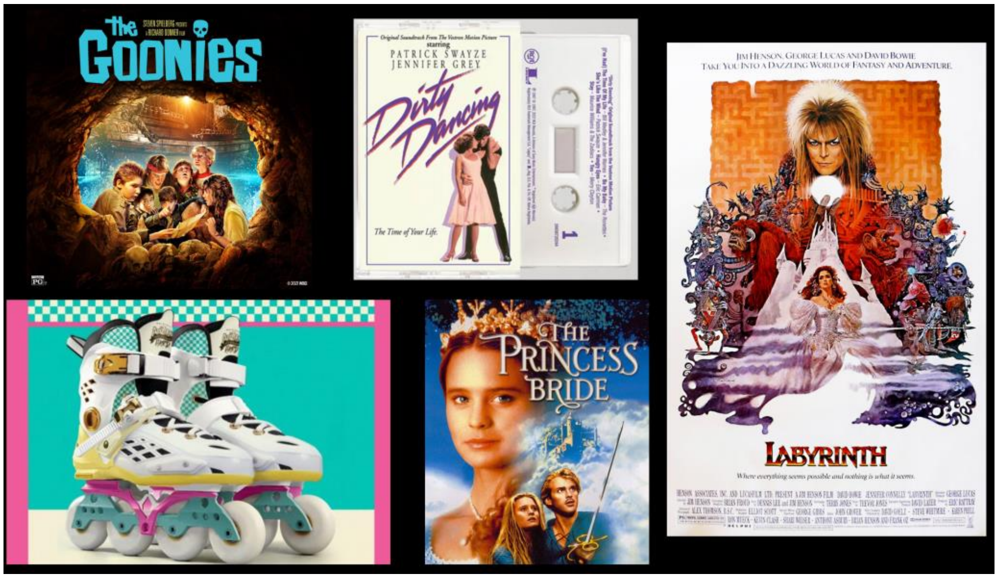


Figure 3: Photos of relevant pop culture item or media.

Literature Cited

Barrett, T.; Latta, G.; Hennon, P. E.; Eskelson, B.; Temesgen, H. 2012. Host–parasite distributions under changing climate: *Tsuga heterophylla* and *Arceuthobium tsugense* in Alaska. Canadian Journal of Forest Research. 42. 642-656. 10.1139/x2012-016.

Hanna, J. W.; Mulvey, R. L.; Kim, M. -S.; Stewart, J. E.; Bright, B. C.; Warwell, M. V.; Klopfenstein, N. B. 2020. Bioclimatic modeling of Armillaria species in southeastern Alaska, including potentially invasive Armillaria species under changing climate. In: Reynolds, Gregory J.; Wilhelmi, Nicholas P.; Palacios, Patsy, compilers. Proceeding of the 66th Western International Forest Disease Work Conference; 3-7 June 2019; Estes Park, CO. WIFDWC: www.wifdwc.org. p. 171-176.

Hennon, P. E.; Frankel, S. J.; Woods, A. J.; Worrall, J. J.; Ramsfield, T. D.; Zambino, P. J.; Shaw, D. C.; Ritkov, G.; Warwell, M. V.; Norlander, D.; Mulvey, R. L.; Shaw, C. G. 2021. Applications of a conceptual framework to assess climate controls of forest tree diseases. Forest Pathology. 51(6): e12719. https://doi.org/10.1111/efp.12719.

Hennon, P. E., Frankel, S. J., Woods, A. J., Worrall, J. J., Norlander, D., Zambino, P. J., Warwell, M. V., & Shaw, C. G. III (2020). A framework to evaluate climate and climate change effects on forest tree diseases. Forest Pathology, 50(6), e12649. https://doi.org/10.1111/ efp.12649

Kim, M. S.; Hanna, J. W.; Stewart, J. E.; Warwell, M. V.; McDonald, G. I.; Klopfenstein, N. B. 2021. Predicting present and future suitable climate spaces (potential distributions) for an Armillaria root disease pathogen (*Armillaria solidipes*) and its host, Douglas-fir (*Pseudotsuga menziesii*), under changing climates. Frontiers in Forests and Global Change. 4: 740994. https://doi.org/10.3389/ffgc.2021.740994.

Sturrock, R. N., Frankel, S. J., Brown, A. V., Hennon, P. E., Kliejunas, J. T., Lewis, K. J., Worrall, J. J., & Woods, A. J. (2011). Climate change and forest diseases. Plant Pathology, 60, 133–149.

Social media and the emergence of Generation Z in the forestry workforce

Alexander Flores[1]*

Emerging foresters from Generation Z, born between 1997 and 2012, have grown up with pervasive exposure to the concept of anthropogenic climate change. This prolonged exposure, starting from an early age, has significantly influenced the attitudes of individuals within Gen Z, leading to a polarization of perspectives—ranging from optimism to pessimism and nihilism—that often converge on social media platforms. While it is nearly impossible to reconcile the impact of climate change at the individual level, those choosing a career in forest research typically maintain a level of optimism in the face of a warming climate. Conversely, a subset of Gen Z, overwhelmed by a sense of doom, disengages from climate discourse due to negative emotional responses. These dynamics, amplified by the widespread use of social media, have been shaping the generational outlook since the early 2010s.

As members of Generation Z enter the workforce, the challenges confronting the field of forestry are poised to intensify. Issues such as wildfires, invasive species, and other threats to forest health will continue to escalate across the United States. These challenges not only impact the careers of foresters but also have broad societal implications. In California, for instance, the annual anticipation of "Mega-fires" is a recurring theme in news coverage. While dramatizing real ecological challenges can engage audiences, it often contributes to the overwhelmingly negative emotions associated with climate nihilism.

As the field of forestry evolves, positive engagement on social media becomes a crucial tool for educating the public and fostering optimism. By offering insights into the actual challenges faced by forest health researchers and foresters, positive engagement can correct skewed public perceptions about forestry. Shedding light on the complexities of forest health research and implementation transparently demonstrates responsible management, reinforcing public trust. Moreover, a more optimistic presentation may inspire individuals from diverse backgrounds to pursue careers in forest health research, filling the void left by retiring generations. Addressing the social aspects of forest health is often overlooked, but it is a critical component in shaping public perceptions, especially for a generation that is so connected through social media.

In conclusion, the challenges posed by climate change and its impact on forestry are both substantial and multifaceted. Generation Z grapples with a spectrum of attitudes shaped by prolonged exposure to climate change discourse. As these emerging foresters enter the workforce, the escalating threats to forest health underscore the need for positive engagement on social media. By fostering a transparent understanding of the challenges faced in forestry, such engagement not only corrects misconceptions but also builds public trust. It is through this proactive approach that we can inspire the next generation of forest health researchers and foresters, ensuring a resilient and sustainable future for our forests and society.

---

[1] Sonoma State University; Rohnert Park, CA, USA
*floredavid@sonoma.edu

Panel: Special Papers – I

Moderator: Tom Smith

A group on Wednesday's field trip. (Photo: Mike McWilliams)

Tree mortality and canopy dieback of western redcedar linked to drier and warmer summers

Robert A. Andrus[1]*, Lulu R. Peach[1], Andrew R. Cinquini[1], Brook Mills[2], Jasmine T. Yusi[1], Christine Buhl[3], Melissa Fischer[4], Betsy A. Goodrich[5], Joseph M. Hulbert[6], Andrés Holz[2], Arjan J.H. Meddens[1], Kevan B. Moffett[7], Aaron Ramirez[8], and Henry D. Adams[1]

Aim: Forest dieback is increasing from unfavorable climate conditions. Western redcedar (WRC)–a culturally, ecologically, and economically important species–has recently experienced anomalously high mortality rates and partial canopy dieback. We investigated how WRC radial growth and dieback responded to climate variability and drought using tree-ring methods.

Location: Pacific Northwest, USA

Taxon: western redcedar (*Thuja plicata*)

Methods: We collected tree cores from three tree health status groups (no canopy dieback, partial canopy dieback, and dead trees) at 11 sites in coastal (maritime climate) and interior (continental climate) WRC populations (Figure 1). From growth rates, we computed four growth indices that assessed the resilience to drought and estimated the year of death.

---

[1] Washington State University, School of the Environment; Pullman, WA, USA
[2] Portland State University, Department of Geography; Portland, OR, USA
[3] Oregon Department of Forestry; Salem, OR, USA
[4] Washington State Department of Natural Resources; Colville, WA, USA
[5] USDA Forest Service, Forest Health Protection; Wenatchee, WA, USA
[6] Washington State University, Department of Plant Pathology; Puyallup, WA, USA
[7] Washington State University, School of the Environment; Vancouver, WA, USA
[8] Reed College, Department of Biology & Environmental Studies; Portland, OR, USA
*robert.andrus@wsu.edu

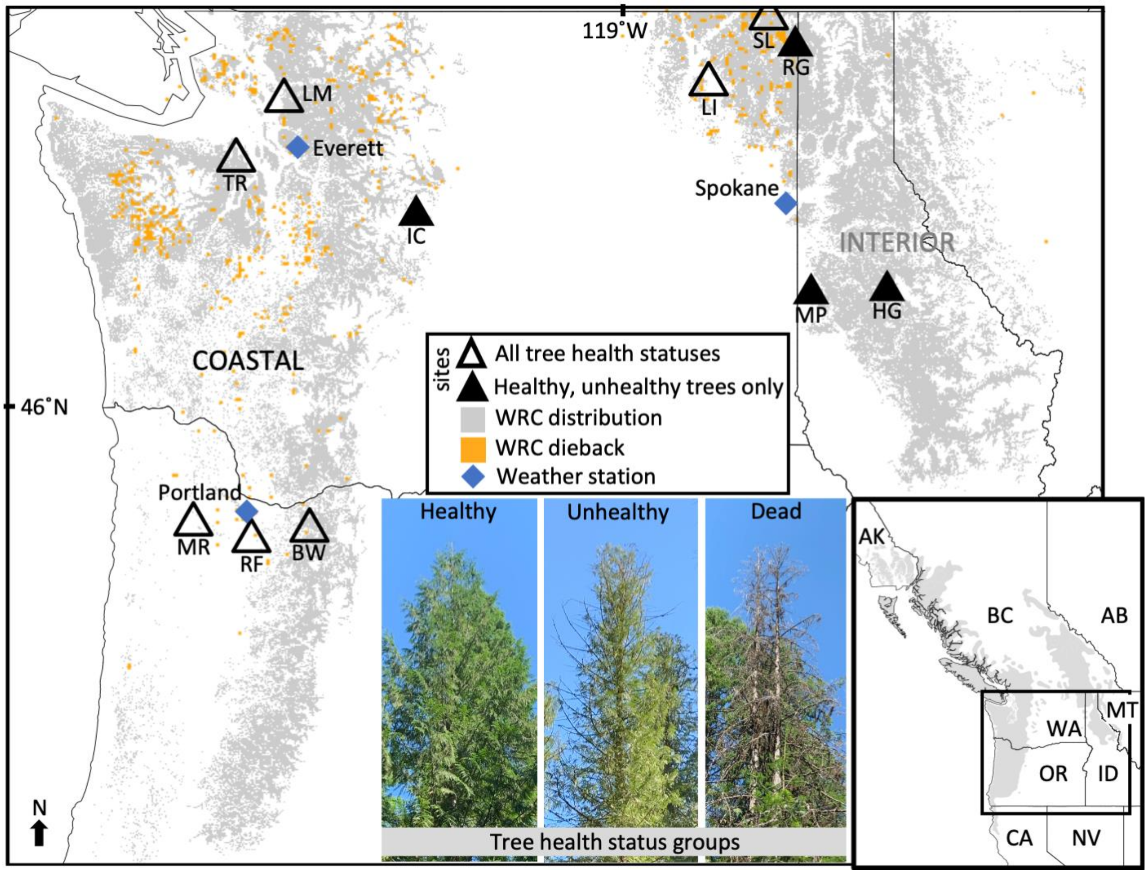


Figure 1: Locations of the 11 sampled sites (triangles) with western redcedar dieback and mortality (orange; USDA Forest Service 2021) within the modeled distribution of western redcedar (gray; Thuja Plicata; Ellenwood et al. 2015) in the northwestern United States (map) and western North America (map inset, Mercator projection; Little 1971)). Photos show examples of trees in three tree health status categories: healthy (<40% canopy dieback), unhealthy (> 40% and < 100% canopy dieback), and dead (no green canopy).

Results: Warmer and drier climate conditions in May/June that extended the annual July-to-September dry season reduced radial growth in 9 of 11 sites (1975-2020). WRC trees recovered growth to pre-drought rates within three years when post-drought climate conditions were cooler/wetter than average. However, recovery from drought was slower or absent when warmer/drier conditions occurred during the post-drought recovery period, possibly leading to the recent and widespread mortality event across the coastal population. WRC tree mortality was portended by 4-5 years of declining growth. Annually-resolved tree mortality in coastal populations predominately occurred in 2017-2018 (80% of sampled dead trees), a period that coincided with exceedingly hot temperatures and the longest regionally dry period from May to September (1970-2020). In interior populations, mortality was dispersed among years but associated with warmer and drier conditions from August to September.

Main conclusions: Our findings forewarn that a warming climate and more frequent and severe summer droughts, especially in consecutive years, will likely increase the vulnerability of WRC to canopy dieback and mortality and possibly other drought-sensitive trees in one of the world's largest forest carbon sinks.

Literature Cited:

Full paper available: https://onlinelibrary.wiley.com/doi/full/10.1111/jbi.14732

Pre-print to bioRxiv available: https://www.biorxiv.org/content/10.1101/2023.01.11.522134v1

Phytophthora species and their associations with Chaparral vegetation in Southern California

Sebastian Fajardo[1]*, David Rizzo[1], Tyler Bourret[1], and Susan J. Frankel[2]

Invasive *Phytophthora* species can potentially be destabilizing to whole ecosystems with detrimental effects on biodiversity and on ecosystem services. Studies have shown that *Phytophthora* species may be introduced into natural areas through outplanting of infested native plant nursery stock. The Angeles National Forest (ANF), located in Southern California, utilizes thousands of nursery-grown native plants for landscape restoration of heavily disturbed areas. Previous pathogen testing performed on ANF restoration sites detected several *Phytophthora* species. Little is known about the ecology and biology of *Phytophthora* species in drier regions of the world, thus a baseline of *Phytophthora* distribution and diversity is needed in ANF lands. Between 2018-2021 forty sites were selected, and soil samples were taken from plant rhizospheres, riverbeds and off-road vehicle tracks in chaparral and oak woodland areas. From these surveys, fourteen species of *Phytophthora* were detected, including three undescribed species and one hybrid species. *Phytophthora* species were found in both chaparral and oak woodland areas with a higher frequency in riparian areas. Selfing species (homothallic), capable of readily producing oospores, were more abundant in drier chaparral areas. *Phytophthora* species were also detected in off-road tracks, dirt trails, and riverbeds, indicating potential natural and anthropogenic associated routes of dispersal. Pathogenicity tests were conducted to test the aggressiveness of detected *Phytophthora* species towards common chaparral plant species. *Phytophthora cactorum, P. multivora*, P. *crassamura* and *P. chlamydospora*, were all capable of causing disease on *Adenostoma fasciculatum*, *Eriogonum fasciculatum*, *Salvia mellifera* and *Eriodictyon crassifolium*. *A. fasciculatum* was determined to be the most susceptible plant species, especially to *P. multivora* and *P. cactorum*. Although the Angeles National Forest is among the driest and most fire prone areas in the United States, these Mediterranean areas harbor a large diversity of *Phytophthora* species indicating a potential risk for the native and endemic Californian chaparral vegetation. The long-term consequences of the presence of Phytophthora species in these locations still needs to be understood.

---

[1]University of California Davis, Department of Plant Pathology; Davis, CA, USA
[2]USDA Forest Service, Pacific Southwest Research Station; Albany, CA, USA
*snfajardo@ucdavis.edu

Hybrids of tree rust pathogens *Cronartium ribicola* and *Cronartium comandrae* are present in ecosystems of the central and southern Rocky Mountains USA

Olga Kozhar[1], Kelly S. Burns[2], Anna W. Schoettle[3], and Jane E. Stewart[1]*

Invasive pathogenic fungi cause significant damage to forest ecosystems around the globe. They directly attack naive host species that lack defenses against alien pathogens. Additionally, invasive fungi can interact with other closely related fungal species driving evolution of novel pathogens via mating, or interspecific hybridization. One recent example of interspecific hybridization is the discovery of a hybrid of two tree rust pathogen species, non-native invasive *Cronartium ribicola* (Cr) and native *C. comandrae* (Cc). This hybrid (CrxCc) was reported from Alberta, Canada, in 2006 (Joly et al. 2006). Following morphological and molecular analyses of hybrid aeciospores collected from *Pinus flexilis* Joly et al. (2006) hypothesized that receptive hyphae of *C. ribicola* was fertilized by *C. comandrae* pycniospores in areas where both pine species (*P. flexilis* and *P. contorta* spp. *latifolia*) coexist. Interestingly, consequent studies did not detect CrxCc hybrids in the same region (Allen 2017). It is currently unknown whether the hybridization process between *C. ribicola* and *C. comandrae* is persistent in ecosystems and whether it occurs in other areas where the two rust species share ecological niches.

Pinus flexilis and *P. contorta* spp. *latifolia* and both rust species coexist with their hosts in the central and southern Rocky Mountains. Hence, hybridization between rust species is possible. The objectives of our study were to determine whether CrxCc hybrids consistently occur in Colorado and Wyoming forests and whether they are infectious and can produce urediniospores on an alternate host.

In total, we collected 726 and 1452 aecia from 178 lodgepole (*Pinus contorta* ssp. *latifolia*) and 357 limber (*P. flexilis*) pines from 25 sites in 4 national forests from 2019-2021. Using morphological and molecular analyses, we identified 71 aecia from 25 *P. flexilis* trees that had intermediate morphology and contained heterozygous SNPs in two genomic regions. Via population analyses we revealed the presence of several distinct hybrid genotypes that varied among locations and years, indicating multiple independent hybridizations and perennial presence of the CrxCc hybrid in the studied region. The frequency of CrxCc hybrid aecia on *P. flexilis* varied between 2.2 and 5.3% among forests and 0.9 and 6.6% among years. Interestingly, no hybrid aeciospores were detected on *P. contorta* spp. *latifolia*, suggesting unidirectional flow of genetic material from native (*C. comandrae*) to non-native (*C. ribicola*) species.

To test whether identified hybrids are pathogenic, we conducted a series of inoculation assays on *Ribes nigrum*, alternate host of *C. ribicola*. The results of inoculation assays revealed that aeciospores from 2 hybrid aecia were capable of infecting *R. nigrum* and produced urediniospores on *R. nigrum* leaves in a growth chamber. Overall, the results of our study suggest that, even though low in frequency, the CrxCc hybrids are persistent in the studied region, and that they have pathogenic potential. Hybrid expansion into the large range of susceptible pines could have cascading impacts on forest ecosystem health, and, therefore, their distribution should be monitored.

---

[1] Colorado State University, Department of Agricultural Biology; Fort Collins, CO, USA
[2] USDA Forest Service, Rocky Mountain Region, Forest Health Protection; Golden, CO, USA
[3] USDA Forest Service, Rocky Mountain Research Station; Fort Collins, CO, USA
*Jane.Stewart@colostate.edu

Panel: Root Diseases

Moderator: Dave Shaw

Wine tasting outside the conference center. (Photo: Kristen Chadwick)

Coniferiporia sulphurascens (a root rot) alters community composition but not forest productivity, Pacific Northwest, USA.

Yung-Hsiang Lan[1]*, David M. Bell[2], Mee-Sook Kim[2], David C. Shaw[3], Holly S.J. Kearns[4], Kristen L. Chadwick[4], Robert J. Pabst[5], and Andrew A. Bluhm[5]

Laminated root rot (LRR; caused by *Coniferiporia sulphurascens*) is the most dangerous root disease of Douglas-fir (PSME, *Pseudotsuga menziesii*) in the Pacific Northwest USA and southwestern Canada. LRR influences on tree mortality and forest productivity have been well-documented in young commercial Douglas-fir forests; however, much less is known about the role of LRR in forest dynamics of older stands (>50 years). The objective of this study was to improve fundamental understanding of the role that LRR plays on forest community composition and forest productivity in Douglas-fir forests of the Pacific Northwest using long-term permanent forest demography plots that are part of a research plot network in NW Oregon and SW Washington State, USA (https://pnwpsp.forestry.oregonstate.edu/). Tree diameter and mortality measurements were made (5-10 year intervals) at 16 plots among five sites established between 1910-1930 in western Oregon and Washington, USA. Each plot was surveyed to assess dead trees for evidence of LRR, LRR-suspected dead trees were cultured, and fungal isolates were identified using DNA sequencing method in 2019-2021. The LRR pathogen was confirmed in 13 of 16 plots. The preliminary analyses showed that elevated LRR severity (which defined as how many dead trees with LRR presence per meter square) resulted in (1) greater PSME tree density decreases; (2) reduced aboveground live biomass (AGB) accumulation in PSME and increased AGB accumulation in other species, with a 20% reduction in PSME AGB relative to total ecosystem AGB; and (3) no changes in ecosystem AGB. These results imply that LRR may accelerate late-seral species establishment, growth, and thus replacement of PSME through forest succession, but may not alter overall AGB dynamics from 50 to 150 years in stand age.

---

[1] Oregon State University, Department of Botany and Plant Pathology; Corvallis, OR, USA
[2] USDA Forest Service, Pacific Northwest Research Station; Corvallis, OR, USA
[3] Oregon State University, Department of Forest, Engineering Resources and Management; Corvallis, OR, USA
[4] USDA Forest Service, Forest Health Protection; Sandy, OR, USA
[5] Oregon State University, Department of Forest Ecosystem and Society; Corvallis, OR, USA
*Yung-Hsiang.Lan@oregonstate.edu

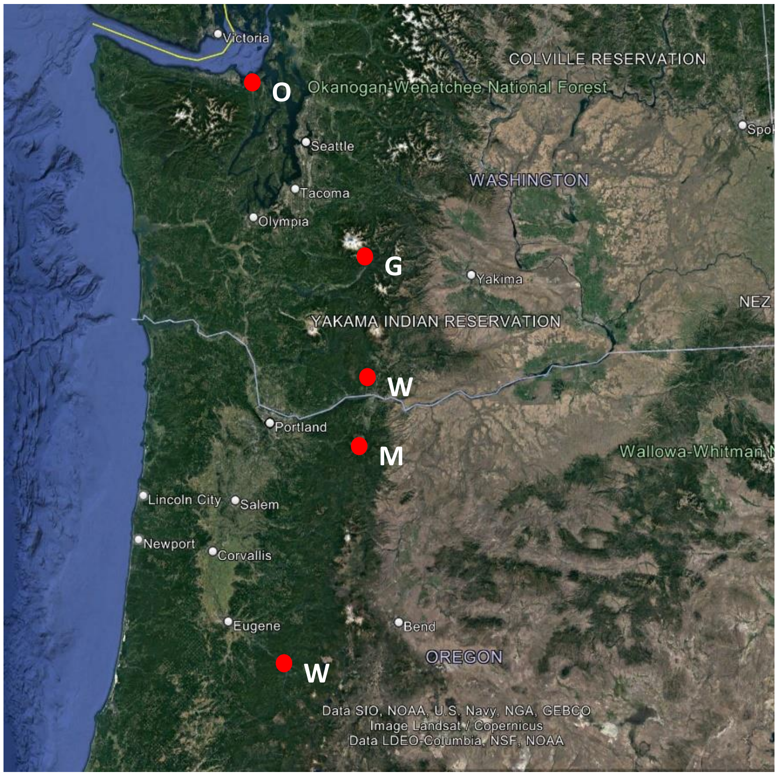


Figure 1: The 16 PSP plots across 5 sites in western Washington and Oregon. From North to South the plots are located in Olympic peninsula (OL), Gifford Pinchot (GP), Wind River (WR), Mount Hood (MH), and Willamette Valley (WI).

Table 1: LRR incidence of 16 plots among 5 sites in the survey. Only tagged Douglas fir were included. From North to South the plots are located in Olympic peninsula (OL), Gifford Pinchot (GP), Wind River (WR), Mount Hood (MH), and Willamette Valley (WI), the number after abbreviation are replicates of the same site. OL plots had the highest LRR incidence, while WI plots had the lowest. In WR plots, LRR presence was various from 0% to 53%, upon to if there is a disease pocket within the plot.

Plot	**Alive(n)**	**Dead(n)**	**Dead by LRR**	**Dead tree percentage**	**Dead by LRR**
OL01	112	57	13	33.7%	22.8%
OL02	47	102	18	68.5%	17.6%
OL03	56	28	15	33.3%	53.6%
OL04	87	54	30	38.3%	55.6%
GP01	43	74	7	63.2%	9.5%
GP03	71	49	1	40.8%	2.0%
GP05	53	57	0	51.8%	0.0%
WR04	40	34	18	45.9%	52.9%
WR05	67	8	0	10.7%	0.0%
WR90	54	18	1	25.0%	5.6%
MH01	70	28	1	28.6%	3.6%
MH02	104	64	14	38.1%	21.9%
MH03	92	63	4	40.6%	6.3%
WI01	73	20	0	21.5%	0.0%
WI02	71	3	1	4.1%	33.3%
WI03	73	13	0	15.1%	0.0%

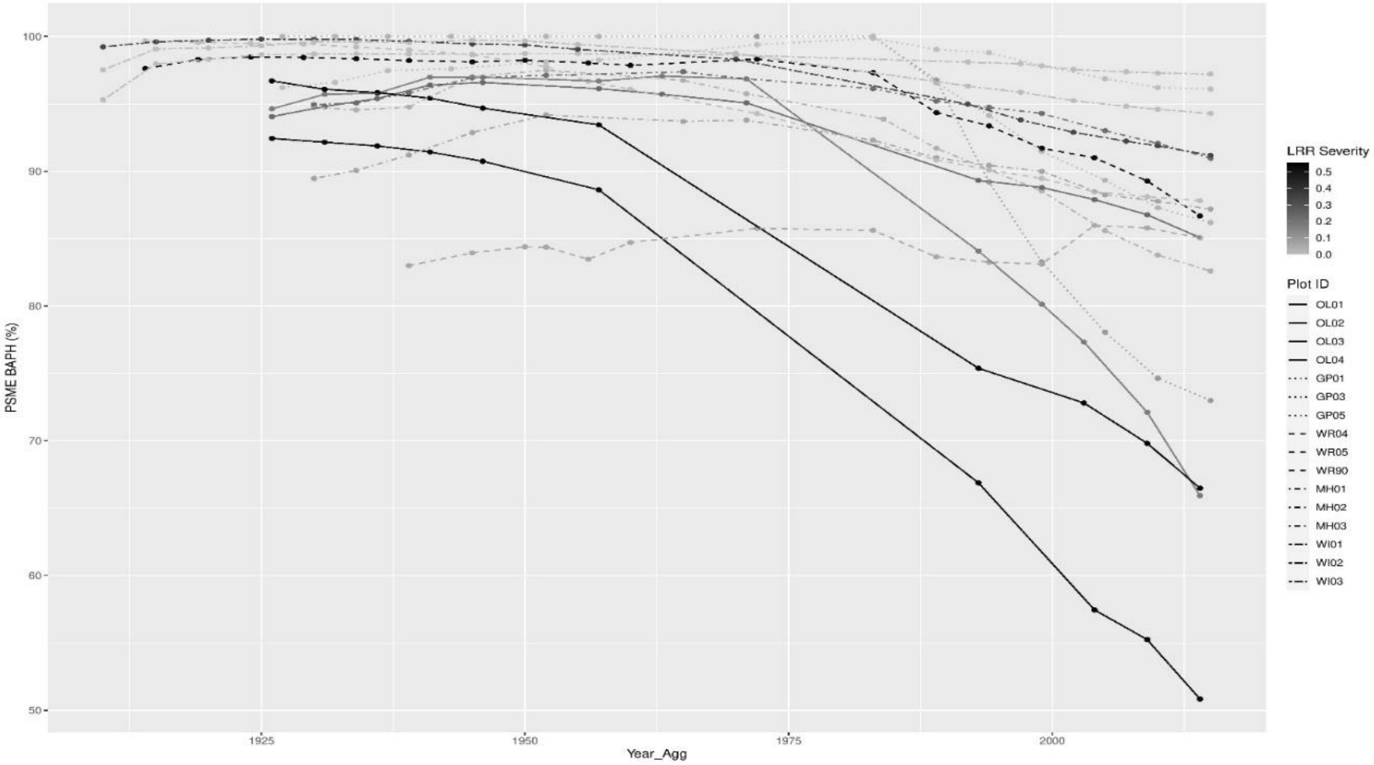


Figure 2: The basal area changes of Douglas fir through the times. The darkness represents the LRR severity (defined as how many dead trees with LRR presence per meter square) of the plot. The same line type represents the plots at the same site. For those plots with high LRR severity, a reduction of Douglas fir basal area per hectare were observed compared to those plots with low LRR severity.

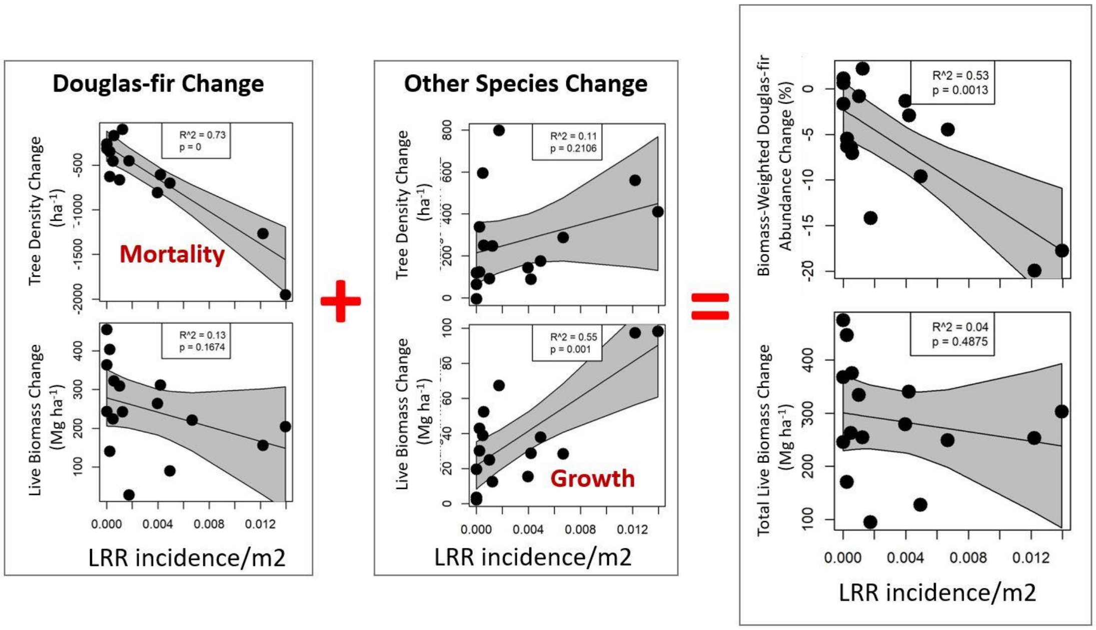


Figure 3: Tree density and living biomass changes through time. With LRR presence, tree density and biomass of Douglas fir reduced from plot initiation to present. However, the total biomass did not reduce due to LRR presence because of increases in other species density and total biomass.

Phylogenomic analysis and vegetative compatibility of *Coniferiporia sulphurascens* and *C. weirii* within North America and Eurasia

Shawn McMurtrey[1,2]* and Jared M. LeBoldus[1,3]

Laminated root rot is a damaging disease that is caused by fungal pathogens belonging to the *Coniferiporia* genus. *Coniferiporia spp.* are wood-inhabiting forest pathogens that can invade healthy roots of coniferous trees (Wang et al. 2022). Currently, there are four different known species of *Coniferiporia* that occur globally (Wang et al. 2022). *Coniferiporia sulphurascens* and *C. weirii* are the only two species of *Coniferiporia* known to occur within North America (Larsen et al. 1994, Zhou et al. 2016). Within this study, 85 whole genome sequences of *C. sulphurascens* and 5 whole genome sequences of *C. weirii* from locations across Canada, Japan, Russia, and the United States (Figure 1, Figure 2) were produced using Illumina HiSeq 3000 technologies. The objectives of this study were to: i.) use genome-wide single nucleotide polymorphism (SNP) data to construct a maximum likelihood phylogenetic tree (Figure 3) and; ii.) combine and compare newly established vegetative compatibility group assignments with results from previous studies. Preliminary phylogenomic results showed indirect evidence of gene flow and migration between North American populations. The vegetative compatibility group assignments were found to be mostly consistent with the structure of the phylogenetic tree. Results from this study agree with other studies that suggest basidiospore dispersal may be of greater biological importance than previously recognized for some root disease pathogens (Edman et al. 2004, Heinzelmann et al. 2012, Chung et al. 2015).

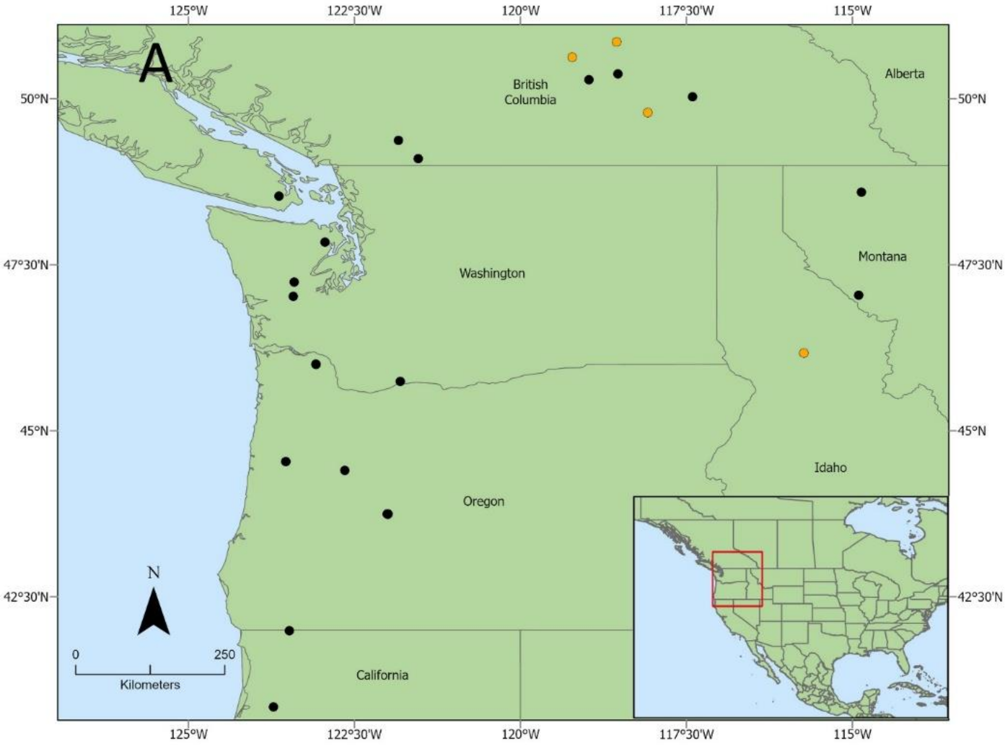


Figure 1: Geographical locations within North America of *Coniferiporia sulphurascens* (black) and *C. weirii* (orange) isolates that were sequenced as part of this study.

---

[1] Oregon State University, Department of Botany and Plant Pathology; Corvallis, OR, USA

[2] USDA Agriculture Research Service; Hood River, OR, USA

[3] Oregon State University, Department of Forest Engineering, Resources, and Management; Corvallis, OR, 97331, USA

*Shawn.Mcmurtrey@usda.gov

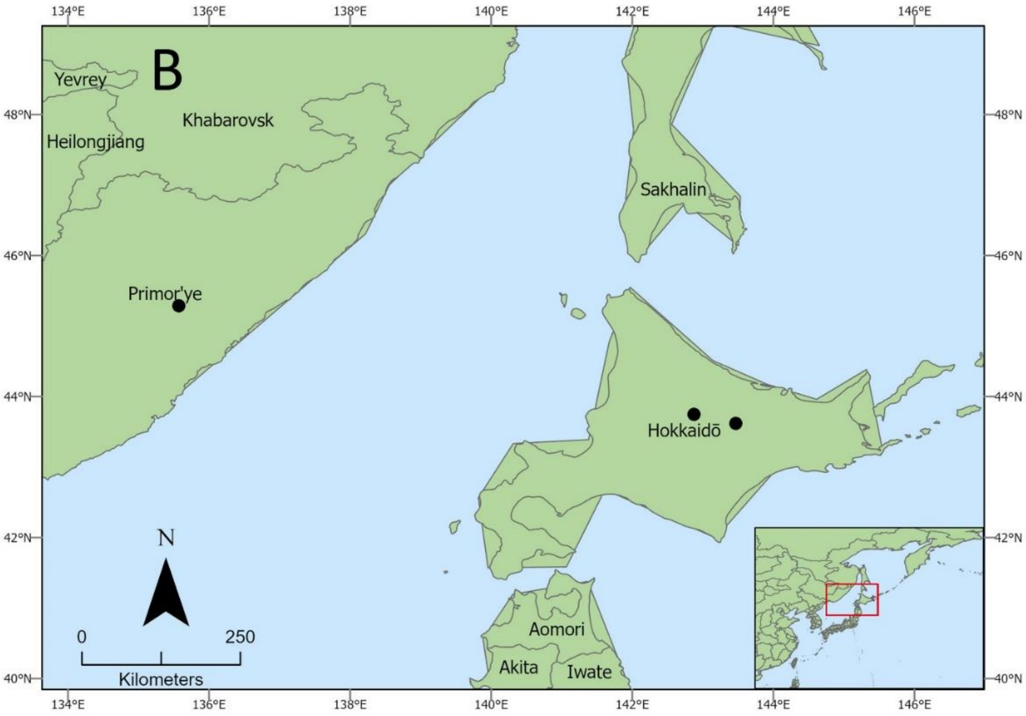


Figure 2: Geographical locations within Eurasia of *C. sulphurascens* (black) isolates that were sequenced as part of this study.

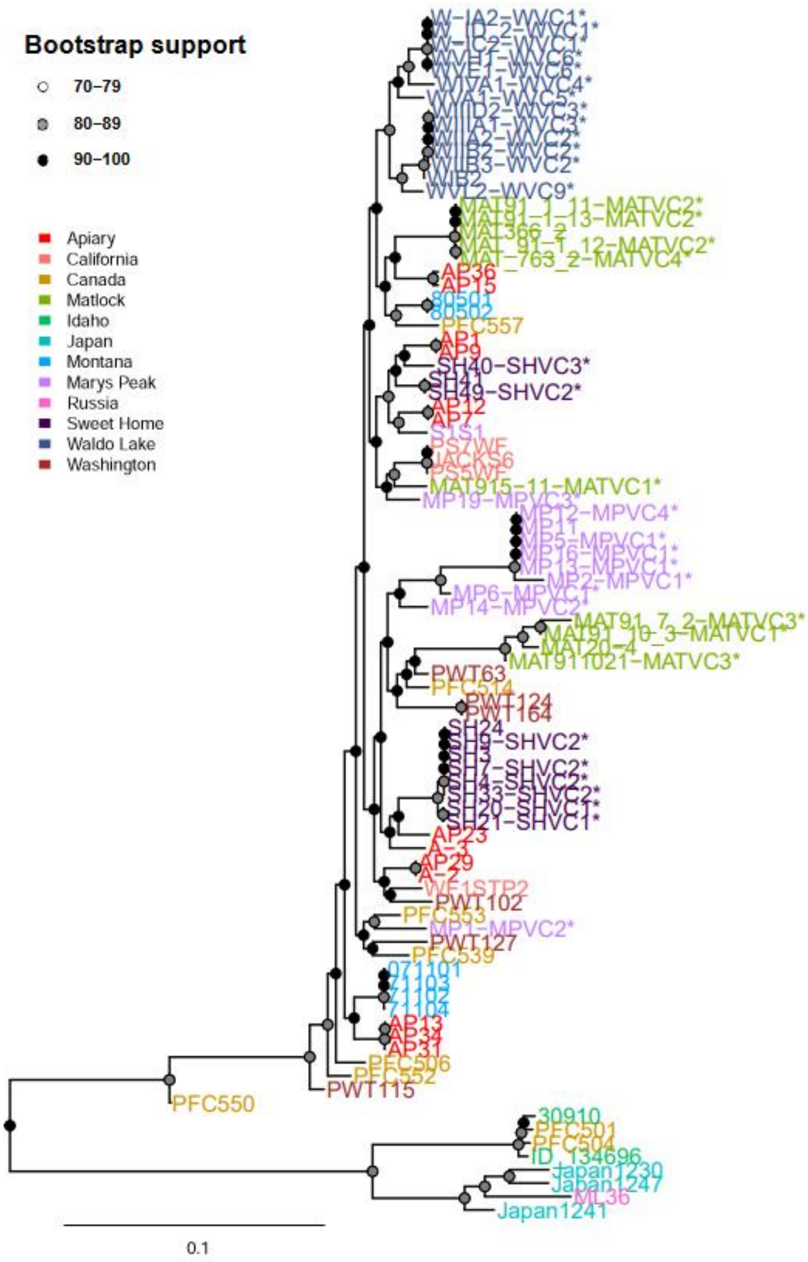


Figure 3: Maximum likelihood phylogenetic tree generated from 14,366 single nucleotide polymorphism data. All isolates are *C. sulphurascens* except for isolates PFC550, 30910, PFC501, PFC504, and ID_134696, which are *C. weirii*. Isolates labelled with an asterisk have been assigned vegetative compatibility groups.

Literature Cited

Edman M, Gustafsson M, Stenlid J, Jonsson BG, Ericson L (2004) Spore deposition of wood-decaying fungi: importance of landscape composition. Ecography 27: 103–111.

Chung, C. L., Huang, S. Y., Huang, Y. C., Tzean, S. S., Ann, P. J., Tsai, J. N., ... and Liou, R. F. 2015. The genetic structure of *Phellinus n*oxius and dissemination pattern of brown root rot disease in Taiwan. Plos One, 10:0139445.

Heinzelmann R, Rigling D, Prospero S (2012) Population genetics of the wood-rotting basidiomycete *Armillaria cepistipes* in a fragmented forest landscape. Fungal Biol 116: 985–994.

Leal, I., Bergeron, M. J., Feau, N., Tsui, C. K. M., Foord, B., Pellow, K., ... & Sturrock, R. N. 2019. Cryptic Speciation in Western North America and Eastern Eurasia of the Pathogens Responsible for Laminated Root Rot. Phytopathology 109:456-468.

M.J. Larsen, F.F. Lombard, J.W. Clark Phellinus sulphurascens and the closely related P. weirii in North America Mycologia, 86 (1994), pp. 121-130

Wang, X. W., Jiang, J. H., Liu, S. L., Gafforov, Y., and Zhou, L. W. 2022. Species diversification of the coniferous pathogenic fungal genus Coniferiporia (Hymenochaetales, Basidiomycota) in association with its biogeography and host plants. Phytopathology 112:404-413.

Zhou, L. W., Vlasák, J., & Dai, Y. C. (2016). Taxonomy and phylogeny of Phellinidium (Hymenochaetales, Basidiomycota): a redefinition and the segregation of Coniferiporia gen. nov. for forest pathogens. Fungal Biology, 120(8), 988-1001.

Species-level recognition of the three varieties of *Leptographium wageneri* (cause of black stain root disease) and prediction of their potential suitable climate spaces in the western USA

Daram Choi[1,5]*, Thomas C. Harrington[2], David C. Shaw[1], Jane E. Stewart[3], Patrick I. Bennett[4], Ned B. Klopfenstein[4], Duncan R. Kroese[5], and Mee-Sook Kim[5]

Black stain root disease (BSRD), a vascular wilt disease of conifers caused by a native insect-vectored fungus, is among the top five most damaging root diseases in forests of the western United States (Hadfield *et al.*, 1986). Previously, the fungi that cause BSRD were described as three varieties of *Leptographium wageneri — L. wageneri* var. *wageneri*, *L. wageneri* var. *ponderosum*, and *L. wageneri* var. *pseudotsugae* (Kendrick) Wingfield (Kendrick, 1962; Wingfield, 1985). These *L. wageneri* varieties were differentiated based on morphology, physiology (Harrington and Cobb, 1987), and ecology including host associations, as follows: 1) *L. wageneri* var. *wageneri* on single-leaf pinyon (*Pinus monophylla*) and pinyon pine (*P. edulis*), 2) *L. wageneri* var. *ponderosum* on Jeffrey pine (*P. jeffreyi*) and ponderosa pine (*P. ponderosa*), and 3) *L. wageneri* var. *pseudotsugae* on Douglas-fir (*Pseudotsuga menziesii*) (Harrington and Cobb, 1984, 1986; Hessburg *et al.*, 1995) (Figure 1). The three pathogens were originally classified as different varieties because their distinguishing characteristics were regarded as relatively minor and early DNA-based characterizations were not definitive, but robust phylogenetic analyses can provide the basis for species-level recognition of the *L. wageneri* varieties (Choi *et al.,* 2023). In addition, bioclimatic models may be useful for predicting the suitable climate space (potential distribution) and adaptability for each BSRD pathogen in western North America under the contemporary and projected future climates.

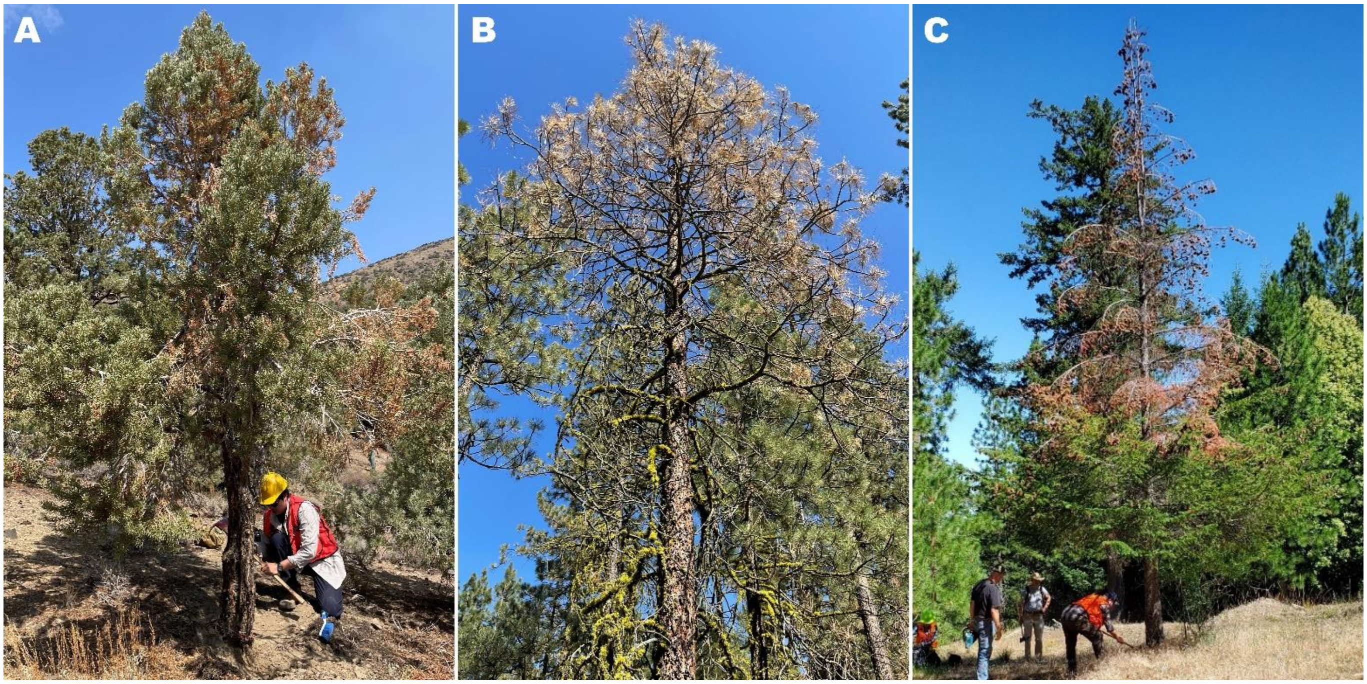


Figure 1: *Leptographium wageneri sensu lato* infected stands show typical crown symptoms such as needle discoloration, needle loss, and tufted needles. Symptoms are showing on (A) a single-leaf pinyon pine (*Pinus*

---

[1] Oregon State University, Department of Forest Engineering, Resources & Management; Corvallis, OR, USA
[2] Iowa State University, Department of Plant Pathology, Entomology and Microbiology; Ames, IA, USA
[3] Colorado State University, Department of Agriculture Biology; Fort Collins, CO, USA
[4] USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA
[5] USDA Forest Service, Pacific Northwest Research Station; Corvallis, OR, USA
*daram0924@gmail.com

monophylla) infected with *L. wageneri sensu stricto*, (B) ponderosa pine (*P. ponderosa*) infected with *L. ponderosum*, and (C) Douglas-fir (*Pseudotsuga menziesii*) infected with *L. pseudotsugae* (Choi *et al.*, 2023).

The objectives of this study are to 1) genetically identify and determine the phylogenetic relationships among the three species (formerly known as varieties) of BSRD pathogens gathered from the western USA, and 2) predict suitable climate space for BSRD pathogens under present and future climate scenarios using Maximum Entropy (MaxEnt) bioclimate modeling.

BSRD samples were collected from several areas where BSRD was previously reported in Oregon and California. The stained-wood samples were punched from black- to brown-streaked areas of xylem from the root collars of symptomatic trees (*P. monophylla*, *P. ponderosa, P. jeffreyi,* and/or *Pseudotsuga menziesii*) (Figure 2). Occurrence data (GPS points, host species, DBH, etc.) were recorded for each sample. The samples were processed for fungal isolation and incubated on selective culture medium to obtain pure cultures (Figure 3). DNA was extracted from 39 *L. wageneri sensu lato* isolates, and 10 different loci (28S large subunit ribosomal, actin, β-tubulin, calmodulin, translation elongation factor 1-alpha, mating-type gene 1-1-3, RNA polymerase II subunit, glyceraldehyde-3-phosphate dehydrogenase, and chitin synthase) were amplified with PCR and the amplicons were used for DNA sequencing.

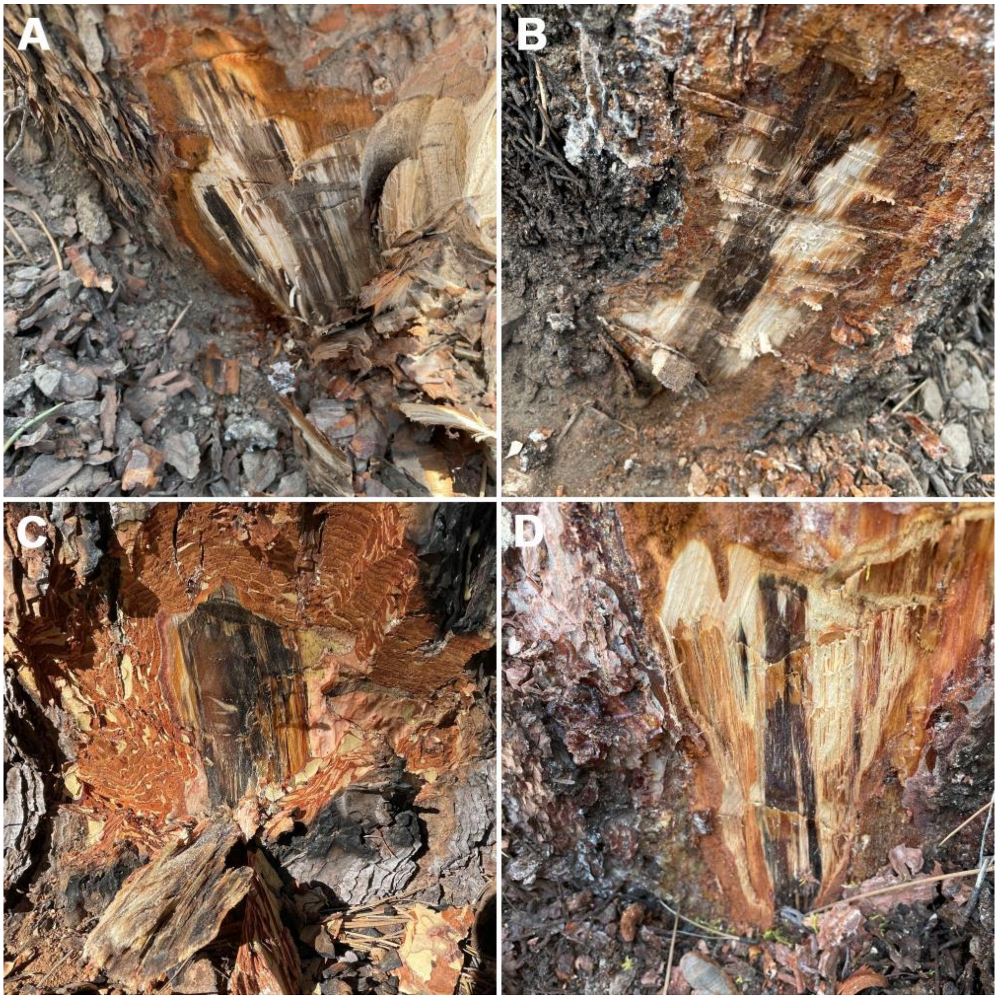


Figure 2: Black stain streaking appears in sapwood in lower stems of (A) and (B) a single-leaf pinyon (*Pinus monophylla*), and (C) and (D) ponderosa pine (*P. ponderosa*).

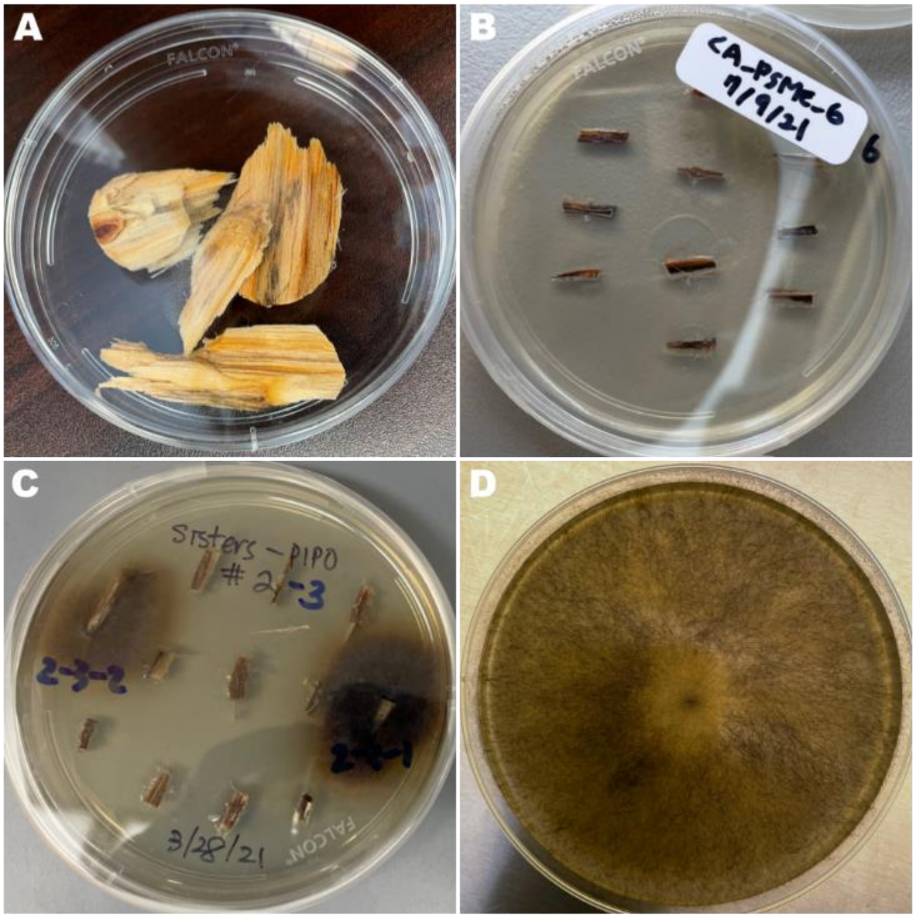


Figure 3: Process for isolating *Leptographium wageneri sensu lato* from collected field samples. (A) Wood samples with stain, (B) embedded wood pieces (ca. 10 x 2.5 x 2.5 mm) on selective CSMA medium, (C) the growth of dark-brown to black-colored hyphae, and (D) the growth of a pure culture derived from hyphal tip isolation (Choi *et al.*, 2023).

Phylogenetic relationships among the three BSRD pathogens were analyzed using maximum likelihood and Bayesian inference of the 10 loci as 1) individual locus, 2) two- and three- loci combinations selected on the basis of parsimony-informative sites, 3) concatenated sequences of all 10 loci, and 4) two-loci combination with multiple outgroups based on phylogenetic analyses from De Beer *et al.* (2022). The results clearly showed that the separation of the three BSRD pathogens (formerly recognized as varieties of *L. wageneri*) into distinct species is well-supported. This genetic evidence combined with previously recognized differences in morphological, physiological, and ecological characteristics strongly supported the species-level recognition of the three BSRD pathogens, as follows: *L*. *wageneri* for *L*. *wageneri* var. *wageneri*, *L*. *ponderosum* for *L*. *wageneri* var. *ponderosum*, and *L*. *pseudotsugae* for *L*. *wageneri* var. *pseudotsugae* (Choi *et al.*, 2023).

Occurrence data were used to predict suitable climate space for BSRD pathogens under contemporary (1970-2000) and future (2041-2060 and 2081-2100) climate scenarios (SSP2-4.5 and SSP5-8.5) with 19 bioclimatic variables at 30-second (~1 km^2) spatial resolution from WorldClim. Three separate models were developed using MaxEnt with DNA-confirmed pathogen occurrence points; *L. wageneri* (N=10), *L. ponderosum* (N=10), and *L. pseudotsugae* (N=38). AUC values of the three bioclimate models ranged from 0.88-0.97, which are considered as reliable predictions. For the *L. wageneri* models, the potential distributions are similar in contemporary and future climates, which predict areas with high probability of suitable climate in the Oregon Cascades and northern Sierra Nevada Mountains, though the host trees (pinyons) do not presently occur in these areas. For the *L. ponderosum* models, California and Oregon contain areas with high probability of suitable climate in all time frames, while the suitable spaces shift northward under the future climate scenarios. For the *L. pseudotsugae* models, the suitable climate spaces are concentrated in the regions adjacent to Pacific Ocean under the contemporary climates, while the suitable climate spaces extend inland under projected future climates. These predictions were produced based on BSRD occurrence, but more reliable predictions might be obtained by comparisons with the potential distributions of each pathogen's host species and this work is underway. Nevertheless, these data offer useful information about present or potentially vulnerable areas to BSRD pathogens that can guide land managers' decisions regarding forest planting and regeneration in targeted areas of the western USA.

Literature Cited

Choi, D., Harrington, T.C., Shaw, D.C., Stewart, J.E., Kroese, D.R., 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. doi: 10.3389/fpls.2023.1286157.

De Beer, Z., Procter, M., Wingfield, M., Marincowitz, S., Duong, T., 2022. Generic boundaries in the *Ophiostomatales* reconsidered and revised. Studies in Mycology 101, 57-120. doi: 10.3114/sim.2022.101.02.

Hadfield, J.S., Goheen, D.J., Filip, G.M., Schmitt, C.L., Harvey, R.D., 1986. Root diseases in Oregon and Washington conifers. R6-FPM-250-86, United States Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR.

Harrington, T.C., Cobb, F.W., Jr., 1984. Host specialization of three morphological variants of *Verticicladiella wageneri*. Phytopathology 74, 286-290. doi: 10.1094/Phyto-74-286.

Harrington, T.C., Cobb, F.W., Jr., 1986. Varieties of *Verticicladiella wageneri*. Mycologia 78, 562-567. doi: 10.1080/00275514.1986.12025290.

Harrington, T.C., Cobb, F.W., Jr., 1987. *Leptographium wageneri* var. *pseudotsugae*, var. *nov*., cause of black stain root disease on Douglas-fir. Mycotaxon 30, 501-507.

Hessburg, P.F., Goheen, D.J., Bega, R.V., 1995. Black stain root disease of conifers. In, Forest insect & disease leaflet 145. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Kendrick, W.B., 1962. The *Leptographium* complex *Verticicladiella* Hughes. Canadian Journal of Botany 40, 772-797. doi: 10.1139/b62-072.

Wingfield, M.J., 1985. Reclassification of *Verticicladiella* based on conidial development. Transactions of the British Mycological Society 85, 81-93. doi: 10.1016/S0007-1536(85)80157-1.

Characterizing the morphological and molecular species relationships in *Onnia* spp. of North America

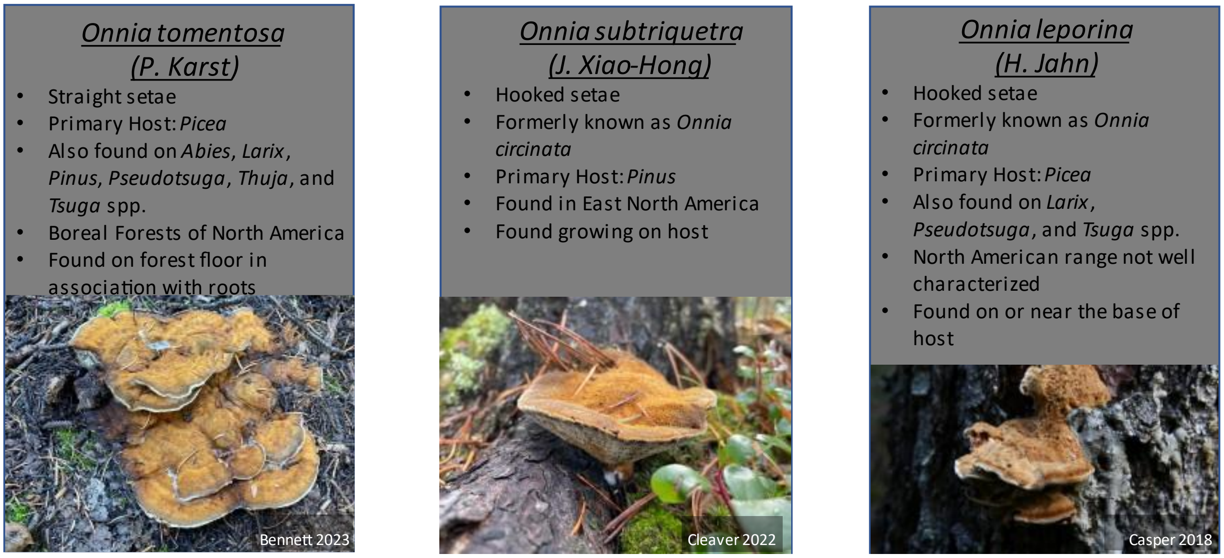
Noah Lindeman[1]*, Patrick Bennett[2], I. Blakey Lockman[3], Brytten Steed[4], Bradley Lalande[5], Maria Newcomb[6], Katherine Minnix[4], and Jane E. Stewart[1]

Tomentosus root disease, caused by fungi in the genus Onnia, presents management issues for large scale timber operations and creates hazardous conditions in recreation sites such as campgrounds and picnic areas (Lockman & Kearns, 2016). These root pathogens are found globally in boreal and sub-boreal forests, resulting in volume losses and tree mortality (Lewis, 1997; Woods & Watts, 2019; Zhao et al., 2022). Due in part to recent taxonomic changes in this genus, the geographic distributions and host ranges of *Onnia* species in North America are not well understood. Accurate identification of *Onnia* spp. and characterization of their host ranges are needed to better manage Tomentosus root disease. Current literature suggests that there are three species found within North America: *Onnia tomentosa* (= *Inonotus Tomentosus*) (P. karst), *O. subtriquetra* (= *O. circinata, I. circinatus*) (J. Xiao-Hong), and *O. leporina* (= *O. circinata, I. circinatus, I. leporinus*) (H. Jahn) (Germain et al., 2002; Ji et al., 2017; Zhao et al., 2022) (Figure 1). Due to the nature of root rot, infected trees often exhibit few above-ground symptoms that are vague and non-diagnostic (Lewis et al., 1992; Reich et al., 2013). This leads to a common scenario where infection is noticed only after tree failure or harvest. The decay itself is also not unique to *Onnia* spp.; Porodaedalea pini (*Phellinus pini*) is a common stem decay fungus that causes white pocket rot that is easily mistaken for Tomentosus root rot (Germain et al., 2002; Hunt, 1997). The presence of basidiocarps enables identification to the genus level. However, basidiocarps can be difficult to find and are not produced annually (Whitney & Fleming, 2005). Identification to the species level can be accomplished by observing the microscopic setae within the hymenial tissue of basidiocarps (Ji et al., 2017). When a basidiocarp is not available, identification typically relies on molecular methods such as PCR and DNA sequencing due to the relative ease of use when compared to other methods (Germain et al., 2002). Both culture-based and molecular methods require equipment and skills that are not typically available to land managers. Our research objectives are: 1) characterize geographic and host ranges of *Onnia* spp. in western North America; and 2) develop a rapid field based molecular assay for detecting and identifying *Onnia* spp. In 2022, samples were collected at 16 locations in Arizona, Colorado, Montana, New Mexico, Oregon, and Utah. Tree cores were collected from lower stems of Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), and subalpine fir (*Abies lasiocarpa*) at some locations. When present, basidiocarps were collected. Several samples were collected by collaborators who supplied host association and/or sequence data. The Center for Forest Mycology Research (CFMR) loaned 80 basidiocarps and 30 cultures identified as Onnia spp., with dates of collection ranging from 1908-2008. Fresh fungal samples were isolated on selective media prior to DNA extraction. The internal transcribed spacer (ITS) was amplified and sequenced for 47 fungal isolates. The morphology of hymenial setae was recorded for each basidiocarp and compared to sequence data for that specimen. Of the 47 isolates, 41 isolates were identified as *O. tomentosa* and six isolates were identified as *O. subtriquetra*. To date, none of our samples have been identified as *O. leporina*. More work is needed to understand the geographic distribution of *O. leporina* in North America. *O. subtriquetra* was found on *Pinus* spp., while *O. tomentosa* demonstrated a wider host range by being found in association with *Abies*, *Larix*, *Picea*, *Pinus*, and *Tsuga*. Setae morphology aligned with sequence data, which indicates that it is a useful taxonomic trait which, along with host species, can be used to

---

[1] Colorado State University, Dept of Agricultural Biology; Fort Collins, CO, USA
[2] USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA
[3] USDA Forest Service, Pacific Northwest Region, State and Private Forestry; Portland, OR, USA
[4] USDA Forest Service, State, Private & Tribal Forestry, Forest Health Protection, Northern Region; Missoula, MT, USA
[5] USDA Forest Service, State, Private & Tribal Forestry, Rocky Mountain Region, Forest Health Protection; Gunnison, CO, USA
[6] USDA Forest Service, State, Private & Tribal Forestry, Forest Health Protection, Intermountain Region; Odgen, UT, USA
*Noah.Lindeman@colostate.edu

differentiate *O. tomentosa* and *O. subtriquetra*. These samples are being used for the development of a Loop-mediated Isothermal Amplification (LAMP) assay, which can be used in the field to detect and identify *Onnia* spp. The LAMP assay is a rapid colorimetric reaction that requires little specialized laboratory equipment, few laboratory skills, and yields results that are easily interpreted visually. This assay will assist land managers and forest pathologists in the detection and identification of these pathogens directly from host tissues, including samples extracted from live asymptomatic trees.



Onnia tomentosa (P. Karst)

- Straight setae
- Primary Host: *Picea*
- Also found on *Abies*, *Larix*, *Pinus*, *Pseudotsuga*, *Thuja*, and *Tsuga* spp.
- Boreal Forests of North America
- Found on forest floor in association with roots

Onnia subtriquetra (J. Xiao-Hong)

- Hooked setae
- Formerly known as *Onnia circinata*
- Primary Host: *Pinus*
- Found in East North America
- Found growing on host

Onnia leporina (H. Jahn)

- Hooked setae
- Formerly known as *Onnia circinata*
- Primary Host: *Picea*
- Also found on *Larix*, *Pseudotsuga*, and *Tsuga* spp.
- North American range not well characterized
- Found on or near the base of host

Figure 1: *Onnia* spp. in North America.

Literature Cited

Germain, H., Laflamme, G., Bernier, L., Boulet, B., & Hamelin, R. C. (2002). DNA polymorphism and molecular diagnosis in Inonotus spp. Canadian Journal of Plant Pathology, 24(2), 194–199. https://doi.org/10.1080/07060660309506995

Hunt, R. S. (1997). Differential medium for *Phellinus pini* and *Inonotus tomentosus*. Fg, 19(3), 307–309. https://doi.org/10.1080/07060669709500529

Ji, X.-H., He, S.-H., Chen, J.-J., Si, J., Wu, F., Zhou, L.-W., Vlasák, J., Tian, X.-M., & Dai, Y.-C. (2017). Global diversity and phylogeny of Onnia (Hymenochaetaceae) species on gymnosperms. Mycologia, 109(1), 27–34. https://doi.org/10.1080/00275514.2016.1274619

Lewis, K. J. (1997). Growth reduction in spruce infected by *Inonotus tomentosus* in central British Columbia. Canadian Journal of Forest Research, 27(10), 1669–1674.

Lewis, K. J., Morrison, D. J., & Hansen, E. M. (1992). Spread of *Inonotus tomentosus* from infection centres in spruce forests in British Columbia. Canadian Journal of Forest Research, 22(1), 68–72. https://doi.org/10.1139/x92-009

Lockman, I. B., & Kearns, H. S. J. (2016). Forest root diseases across the United States (General Technical Report RMRS-GTR-342; pp. 26–29). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://doi.org/10.2737/RMRS-GTR-342

Reich, R., Lewis, K., & Wiensczyk, A. (2013). Tomentosus Root Rot Forest Health Stand Establishment Decision Aid. Journal of Ecosystems and Management, 14(1). https://doi.org/10.22230/jem.2013v14n1a562

Whitney, R. D., & Fleming, R. A. (2005). Quantifying relationships between root rot in a white spruce plantation and sporophores of *Inonotus tomentosus*. Forest Pathology, 35(2), 75–84. https://doi.org/10.1111/j.1439-0329.2004.00386.x

Woods, A. J., & Watts, M. (2019). The extent to which an unforeseen biotic disturbance can challenge timber expectations. Forest Ecology and Management, 453, 117558. https://doi.org/10.1016/j.foreco.2019.117558

Zhao, H., Zhou, M., Liu, X.-Y., Wu, F., & Dai, Y.-C. (2022). Phylogeny, Divergence Time Estimation and Biogeography of the Genus Onnia (Basidiomycota, Hymenochaetaceae). Frontiers in Microbiology, 13, 907961. https://doi.org/10.3389/fmicb.2022.907961

Heterobasidion root disease emergence and impacts over fifty years in montane California forests: A comparison of three host-pathogen systems

Richard C Cobb[1]*

Heterobasidion root disease is a globally distributed group of pathogens which shape natural forest ecosystem structure and can pose a serious challenge to forest management. In the Sierra Nevada and Cascade Mountains of California, *Heterobasidion irregulare* and *H. occidentale* are important pathogens of native yellow pines and incense cedar (Calocedrus decurrens), and native Abies species, respectively. I examined the role of forest structure (community composition, density, basal area) on the duration of disease-center expansion, the reestablishment of canopy trees, and the interactions of management actions on disease dynamics using a set of plots with regular vegetation surveys collected over the past 46-55 years. These results are contrasted with a field trial of *Phlebiopsis* biological control and a dataset examining the role of fuels treatments on Heterobasidion reemergence. The mean size of disease centers were greatly influenced by location, with the mixed species, highly productive ecosystems in Yosemite Valley impacted by *H. irregulare* reaching significantly larger disease center sizes compared to dryer, single species dominated sites of the eastern slope of the Sierra Nevada or mixed species fir forests impacted by *H. occidentale*. The rate of gap expansion during the first 5-10 years of disease emergence was the best predictor of total gap size illustrating the importance of root-to-root contact structure and inoculum levels during the early stages of emergence. Rates of expansion slowed considerably after ~10 years of active mortality which was accompanied by a progressive decrease in the proportion of gaps expanding (~11% in 2006). However, in the east side pine forests (single species – *H. irregulare*) fuels treatments after 2006 resulted in a significant, although modest in terms of area, reemergence of disease (Figure 1). For each pathogen, host mortality increased with tree diameter regardless of the host species. Surprisingly, disease severity, as measured by the proportion of basal area killed within each gap did not differ among study areas, pathogen, or community composition suggesting that estimation of disease impacts to ecosystem processes or community composition only requires an understanding of the size and frequency of disease centers. However, in a separate analysis of these same three study systems, an analysis of community composition revealed that the most diverse forest communities became more dominated by non-hosts (Flores et al. 2023). These impacts were only limited to the most diverse western Sierra Nevada slope forests (*Abies* dominated – *H. occidentale* pathogen system) and were not documented in the single-host (low diversity) East Side Pine or Yosemite Valley (both *H. irregulare*) where the disease centers are largest. In our biological control study, we found *Phlebiopsis* biocontrol efficacy was comparable to better tested treatments such as borates and urea (Poloni et al. 2021), however this study was limited to *H. occidentale* impacted forests. Further evaluation of *Phlebiopsis* in *H. irregulare* impacted forests is justified given the reemergence of disease following fuels treatments and the substantial federal and state investments into forest health into these efforts appropriated up to, and possibly beyond, 2030.

---

[1]California Polytechnic State University, Natural Resources Environmental Science Department; San Luis Obispo, CA, USA
*rccobb@calpoly.edu

Figure 1: Persistent Heterobasidion Root Disease impacts in the Plumas National Forest 51 years after the disease first emerged. Disease in these forests can be reemerge following fuels treatments, which are greatly needed in these eastern Sierra Nevada and Cascade Range Jeffry Pine dominated forests (*Pinus jeffreyi*).

Literature Cited

Flores, D. A., A. L. Poloni, S. J. Frankel, and R. C. Cobb. 2023. Changes to relative stand composition after almost 50 years of Heterobasidion root disease in California true fir and pine forests. Forest Pathology 53:e12811.

Poloni, A. L., M. Garbelotto, C. A. Lee, and R. C. Cobb. 2021. Efficacy of chemical and biological stump treatments for the control of Heterobasidion occidentale infection of California Abies concolor. Pathogens 10:1390.

Panel: Rusts

Moderator: Jane Stewart

Chris Lee on Monday's field trip. (Photo: Kerry Wininger)

Rapid LAMP-based colorimetric assay for the causal agent of white pine blister rust, *Cronartium ribicola*

Olga Kozhar[1], Jorge R. Ibarra Caballero[1]*, Kelly S. Burns[2], and Jane E. Stewart[1]

White pine blister rust (WPBR), caused by *Cronartium ribicola*, is a serious threat to five-needle white pines in western North American forests. All North American white pines are susceptible to the disease, including whitebark, Rocky Mountain bristlecone, and limber pine, which are common and important in the Rocky Mountain Region. Early, reliable, and fast detection of the pathogen, followed by management responses, could help to slow or stop the spread of the disease before it establishes in new areas. However, it can take years for infected trees to produce distinct aecia; characteristic aeciospores last only for a few weeks; before that, branches only develop indistinct swelling; in the alternate host orange pustules are formed, but they can be produced by other rust species.

The objective of this project was to develop methods for fast detection and identification of *C. ribicola*, for potential use in the field. Following the work published by Bergeron et al. (2019), we developed a loop mediated isothermal amplification (LAMP) specific assay for this pathogen. We also developed a simple DNA extraction method for bark/phloem and spores. Both extraction and LAMP can be performed in the field, taking about 80 minutes to complete. The LAMP reaction was performed using the WarmSmart Colorimetric LAMP reagent (NEB); each reaction included 1 µl of DNA sample plus 24 µl of primer mix and LAMP reagent: after a 40 minute incubation, results could be assessed by a color change from pink (negative) to yellow (positive). For the field-based DNA extraction, samples of bark/phloem, aeciospores, or urediniospores were incubated in a 5% Chelex-100 2% PVP solution for 30 minutes at 99°C.

Samples from numerous target and non-target species were tested. Non-target species included *C. comandrae*, *Endocronartium harknessi*, *Peridermium bethelii* and *C. occidentale*. Negative bark/phloem samples were also tested. The LAMP assay showed high specificity: all target samples tested positive, whereas non-target and negative samples all tested negative. Sensitivity tests showed that the assay can detect as little as 40 pg of target DNA, with minor interference from the tissue in the case of bark/phloem samples. To confirm our results, numerous samples were run simultaneously using the LAMP assay and the real-time PCR assay developed by Bergeron et al (2019), obtaining a perfect correlation comparing results from both assays.

Finally, we prepared ready-to-use LAMP reagent which was stored in the freezer for more than 2 weeks. Then, they were taken to the field in a cooler, where bark/phloem, spore, and negative samples were extracted using a portable heat block connected to the car's lighter plug. The same heat block was then used to incubate the LAMP tubes after addition of the extracted-DNA samples. Results from this field test were the same as using LAMP reagent prepared immediately before use in the laboratory.

In conclusion, we developed a field-ready LAMP assay that is highly specific and sensitive for the WPBR pathogen *Cronartium ribicola*. It can be used to test aeciospores, urediniospores, teliospores, and/or bark/phloem samples. The method requires little training, uses inexpensive equipment, and results are easily assessed visually. It can be used to detect the invasive pathogen that causes WPBR by forest managers, forest health specialists, and/or researchers in the field (car) or samples can be run back in a hotel room or office with limited lab equipment. The full methodology and methods were recently published in Forest Pathology (see below).

---

[1] Colorado State University, Department of Agricultural Biology; Fort Collins, CO, USA
[2] USDA Forest Service, Forest Health Protection, Rocky Mountain Region; Golden, CO, USA
*Jorge.Ibarra_Caballero@colostate.edu

Literature Cited

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

Kozhar, O.,Ibarra Caballero, J. R., Burns, K.S., Stewart, J.E. (2023). Field ready: Development of a rapid LAMP-based colorimetric assay for the causal agent of white pine blister rust, *Cronartium ribicola*. Forest Pathology, 53, e12814.https://doi.org/10.1111/efp.12814

Whitebark pine and ESA (Endangered Species Act) implications

Amanda Hendrix[1]*

On December 15, 2022, the Service listed the Whitebark Pine (WBP) (*Pinus albicaulis*) as threatened under the Endangered Species Act (ESA) (2022 Federal Register, https://www.govinfo.gov/content/pkg/FR-2022-12-15/pdf/2022-27087.pdf). This listing rule went into effect on January 17, 2023. Four threats were identified by the Service in the listing decision: white pine blister rust, mountain pine beetle, altered fire regimes, and climate change. White pine blister rust was identified as the main driver of the species' current and future conditions. Mountain pine beetle outbreaks, altered fire regimes, and the accelerating effect of climate change represent a compounding negative effect for the species. The Service determined it is not prudent to designate critical habitat for WBP because neither habitat loss nor range restriction is a threat to this species' continued survival.

Figure 1: White Pine Blister Rust

The listing includes a Final "4(d) Rule" (https://www.fws.gov/sites/default/files/documents/section-4d-rules_0.pdf) authorized under section 4 of the ESA, which allows the Service to tailor the protections and invoke Section 9(a)(2) prohibitions pertinent to the specific conservation needs of a threatened species. Please be aware that these prohibitions apply equally to live or dead plants, their progeny, and parts or products derived from them. Under the 4(d) Rule, the following prohibitions are enacted for WBP:

Prohibit removing, cutting, digging up, damaging, or destroying WBP on Federal lands. This includes malicious damage or destruction of the species on any area under Federal jurisdiction.

Prohibit import, export, transport or sale and activities related to interstate/foreign commerce.

However, the Final 4(d) Rule included exceptions that are intended to allow Federal land management agencies to continue some management of the forest ecosystems where WBP occurs and to continue conducting restoration and research activities that benefit the species. The exception covers silviculture practices and forest management activities that reduce high severity wildfire, insect and disease impacts, vegetation management in existing utility rights-of-ways, wildlife habitat management, and improve overall forest health. These actions include but are not limited to cone collections, planting seedlings or sowing seeds, mechanical cuttings as a restoration tool in stands experiencing advancing succession, full or partial suppression of wildfire in WBP communities, allowing wildfires to burn, and survey and monitoring of tree health status.

---

[1] USDA Forest Service, Northern Region; Missoula, MT, USA
*amanda.hendrix@usda.gov

Figure 2: Whitebark pine seedlings

The 4(d) rule does not preclude the obligation to conduct consultation under Section 7 of the ESA. Under Section 7(a)(1), agencies are responsible to utilize their authorities in the furtherance of the purposes of the ESA by carrying out programs for the conservation of listed species. Under Section 7(a)(2), agencies must ensure that any action authorized, funded, or carried out by such agency will not jeopardize the continued existence of listed species or result in the destruction or adverse modification of habitat. Jeopardy is defined as an action where you could reasonably expect to appreciably reduce the likelihood of both survival and recovery of a listed species in the wild (reproduction, distribution, populations).

Activities that are funded, authorized, or permitted by a federal agency and carried out by a partner (state, tribe, contractor) or partner agency invokes a federal nexxus. In this case, the lead federal agency is responsible for initiating and conducting Section 7 consultation. If multiple federal agencies are involved, then an agreement must be reached to designate the lead federal agency.

Under Section 7, proposed actions must be analyzed to determine the level of effects to individuals, including seeds or trees of any size class. In this process, agencies are directed to use the best scientific and commercial data available in their analysis. Unique to listed plants, incidental take does not apply.

Multiple regions are pursuing consultation streamlining tools. Regions 1 and 4 developed a programmatic consultation for conservation activities pertinent to whitebark pine. These conservation activities align with the draft recovery plan and fulfill the agency obligations under Section 7(a)(1).

This consultation process is complete and provides coverage for conservation efforts on NFS lands as well as sites where activities occur outside of NFS lands. The following conservation activities may be implemented under this programmatic consultation:

1. Cone Collection
2. Scion Collection
3. Pollen Collection
4. Operation Seedling Production
5. Genetic White Pine Blist Rust Screening
6. Planting
7. Insect Control and Prevention

8. Selection and care of mature trees with white pine blister rust resistance
9. Protection of healthy, unsuppressed regenerating stands
10. Clone Banks
11. Seed and Breeding Orchards
12. Genetic Evaluation Plantations
13. Develop Seed Production Areas
14. Surveys
15. Research/Monitoring/Education

Figure 3: Whitebark Pine Pollen

Figure 4: Whitebark pine cone

Additionally, Regions 1 and 4 are pursuing programmatic consultations in the states of MT and ID for all other activities occurring in whitebark pine habitat. Region 6 is pursuing a regional programmatic consultation for similar activities in whitebark pine habitat. Types of activities that may be included in this effort are: grazing, vegetation treatments, winter recreation, and special use permits.

There are lots on cooks in the kitchen with whitebark pine! And subsequently, a multiple of opportunities to work collaboratively. Specific to Forest Health Protection, the monitoring of bark beetle infestations and white pine blister rust infections will help to inform Section 7 analyses and help the agency understand where to focus restoration efforts. Collaborating across resource boundaries, especially when preparing responses to wildfire or suppression activities, will be key. Annual reporting requirements will help to tell our story well with regard to these efforts.

Figure 5: Cooks in the Kitchen

Looking to the future, a recovery team has been designated, and as the recovery plan is further fleshed out, additional restoration opportunities will likely become clear. A large body of science exists for whitebark pine, and yet we are still bumping up against questions that don't have clear answers. Additionally, wilderness may play an important role in the recovery of this species. It will take a village to move the needle towards recovery for whitebark pine. Look forward to continuing to collaborate!

COMING TOGETHER IS A BEGINNING. KEEPING TOGETHER IS PROGRESS. WORKING TOGETHER IS SUCCESS.

– Henry Ford

Figure 6: It will take a village!

Interactions between blister rust and climate indicate vulnerabilities to limber pine health

Kelly S. Burns[1]*, Wade T. Tinkham[2], K.A. Leddy[3], Anna W. Schoettle[2], William R. Jacobi[3], and Jane E. Stewart[3]

Limber pine (*Pinus flexilis*) is a keystone species in the Rocky Mountains, growing on harsh high elevation sites. The species is vulnerable to climate change and is challenged by the non-native, invasive disease, white pine blister rust (*Cronartium ribicola*). The viability of limber pine populations is threatened by the cumulative impacts of these stressors and additional mortality caused by outbreaks of native bark beetles. Maintaining healthy limber pine forests is a concern for land managers. Information on health changes in these populations and long-term impacts is needed to guide management and restoration efforts with climate change. We established 106 long-term monitoring plots across 10 study areas that were surveyed three times between 2004 and 2017. The density and basal area of live limber pine declined significantly, and mortality rates greatly outpaced ingrowth rates. Limber pine health declined significantly with more than 20% of initially live limber pines dead by the last measurement cycle, primarily due to bark beetles and white pine blister rust. Disease incidence and how it changed over time varied among study areas. However, disease severity increased in all study areas, and most infected trees developed stem cankers. Limber pine regeneration was sparse or absent in most sites, and seedling mortality caused by white pine blister rust increased significantly over time. Modeling relationships between white pine blister rust occurrence and severity progression with site, stand, and meteorological variables indicate increasing vulnerabilities to limber pine habitats with projected climate change. Trees in habitats with high vapor pressure deficit (more arid) had a lower likelihood of being infected with *C. ribicola*, but trees that were already infected were more likely to have an increase in disease severity and die. Longer growing seasons increased the likelihood of both *C. ribicola* being present and disease-caused mortality. Vapor pressure deficit and growing season length tended to increase over the course of the study, suggesting that climate change may exacerbate blister rust impacts. Declining health of residual limber pine coupled with high mortality rates, increasing disease severity, and below average natural regeneration suggest successful recovery may not occur in some locations without management intervention. Proactive management strategies to reduce insect and disease impacts and promote stand recovery and resilience should be pursued in remaining, healthy limber pine ecosystems. See Burns and others 2023 for the full manuscript.

Literature Cited

Burns KS, Tinkham WT, Leddy KA, Schoettle AW, Jacobi WR, and Stewart JE. 2023. Interactions between white pine blister rust, bark beetles, and climate over time indicate vulnerabilities to limber pine health. *Front. For. Glob. Change* 6:1149456. doi: 10.3389/ffgc.2023.1149456

---

[1] USDA Forest Service, Rocky Mountain Region, Forest Health Protection; Golden, CO, USA
[2] USDA Forest Service, Rocky Mountain Research Station; Fort Collins, CO, USA
[3] Colorado State University, Department of Agricultural Biology; Fort Collins, CO, USA
*kelly.burns@usda.gov

Limber pine restoration in the Black Hills

James T Blodgett[1]* and Cheryl L Mayer[2]

Limber pine (*Pinus flexilis*) occurs naturally within a two sq mile area in the Black Elk Wilderness and Custer State Park, South Dakota. It grows mainly on harsh, north-facing, open rocky ridges with less competition from ponderosa pine (*Pinus ponderosa*). Less than 200 live individuals remain in this area. In the Black Elk Wilderness, the population has recently decreased about 36% due to mountain pine beetle (*Dendroctonus ponderosae*, MPB) and white pine blister rust (*Cronartium ribicola*, WPBR), and trees are still being killed by WPBR. Insects and disease have killed most of the mature limber pine trees in the Wilderness, and many of the remaining seedlings and saplings likely will not become trees, due to shading or harsh growing conditions. Climate change is projected to shift limber pine populations to higher elevations. Since limber pine already occurs at the highest elevations in the Black Hills, suitable habitat under future climatic conditions may be lost in this area.

In 2009, the Forest began an integrated approach to limber pine management which includes: surveying, monitoring, seed collecting (over 3,000 seeds), branch pruning (to remove WPBR), Verbenone pouches (to reduce MPB attacks), and planting. Fifty-nine percent of the trees had WPBR cankers that were pruned. Pruning branches has extended the life of the trees and allowed some trees to reach cone-bearing age. This has resulted in increased seed collections.

Methods

Forest personnel and volunteers planted 440 2-year-old limber pine seedlings (grown from local seed at Bessey Nursery in Nebraska). Seedlings were planted in three batches (2017, 2018, 2021) in the Norbeck Wildlife Preserve, Black Hills National Forest, South Dakota (Figure 1). For the 2021 plantings we used seed collected in 2018 from Custer State Park, South Dakota to increase genetic diversity of the plantings. Six of the planting areas (1-6) have deep soil and an open canopy dominated by ponderosa pine with most mature trees recently killed by MPB. We also cleared ponderosa pine seedlings and saplings 12 ft around plantings. Area 7 is a very rocky site with few ponderosa pines and is similar to the areas where limber pines occur naturally in the Black Elk Wilderness. We planted seedlings in groups of 3 or 4 near "nurse objects" (*i.e.*, stumps, snags, logs) and placed Vexar tubes over the seedlings to protect them from animal browse. Survival, mortality agent, and growth were assessed.

---

[1] USDA Forest Service, Rocky Mountain Region, Forest Health Protection; Rapid City, SD, USA
[2] USDA Forest Service, Rocky Mountain Region, Black Hills National Forest; Custer, SD, USA
*james.blodgett@usda.gov

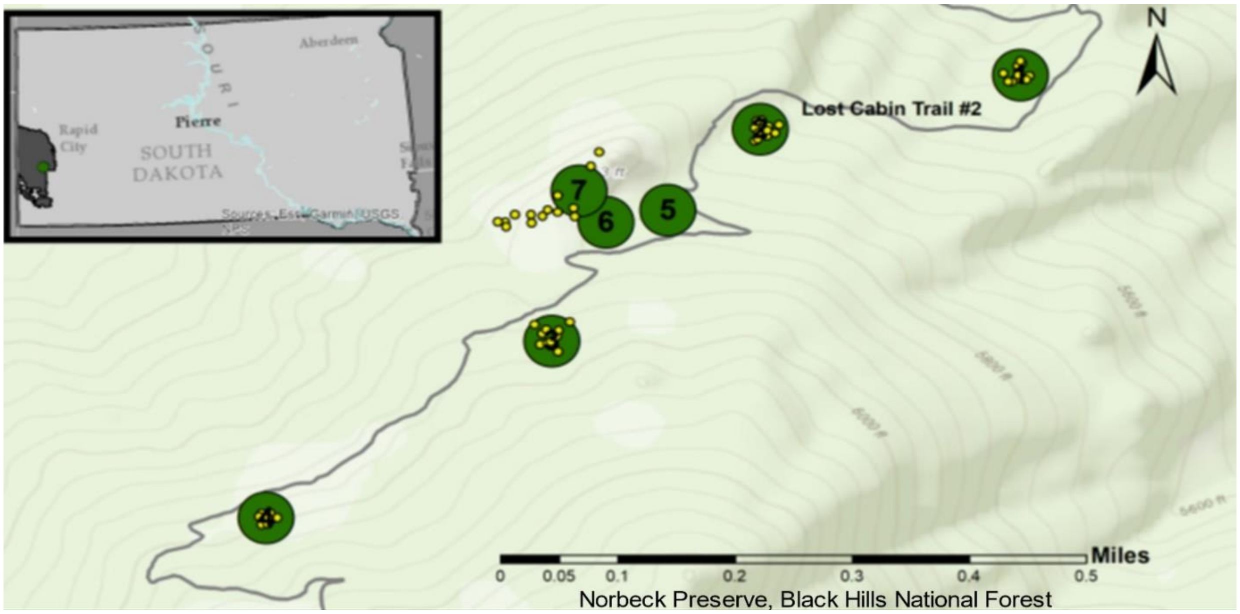


Figure 1: Limber pine planting site in the Norbeck Wildlife Preserve, Black Hills National Forest. Green circles represent the seven planting areas; yellow dots are groups of monitored trees.

Results

The initial, exceptional survival rate of 96.4% for all sites combined (Figure 2), suggests the planted trees were establishing well. Percentage alive increased in 2021 due to new plantings. However, a wildfire in 2022 killed trees at areas 2, 5, and 6 accounting for 55% of the total mortality (Table 1). Data show good growth at all sites, but faster growth at areas 1 to 4 compared to area 7 (Figure 3). The average growth was 7.3 cm/year with an exponential growth rate. The most recent growth measurements averaged 11.6 cm/year.

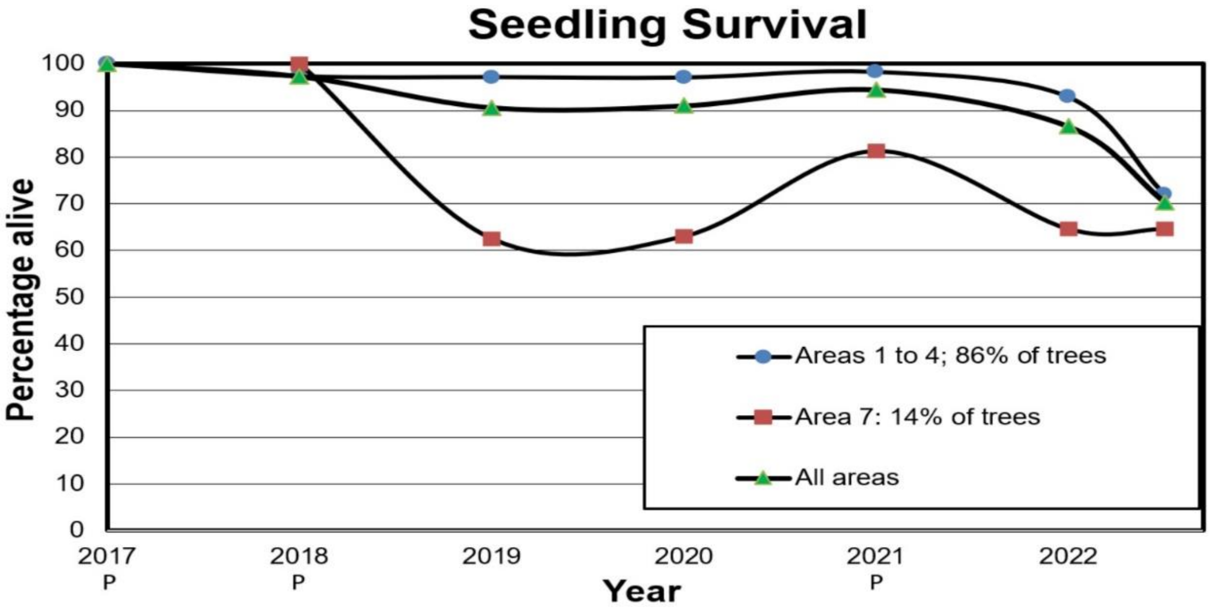


Figure 2: Percentage of live limber pine by year at the Norbeck Wildlife Preserve planting site in the Black Hills National Forest (based on seedlings selected for long-term monitoring). The graph compares the ponderosa pine sites (areas 1 to 4), the rocky site (area 7), and all sites combined. "P" under the year indicates a planting year. The 2021 values increased due to new plantings. The 2022 points are before and after the 2022 fire.

Table 1: Mortality agents and percentage mortality at the Norbeck Wildlife Preserve planting site in the Black Hills National Forest for all years combined (based on seedlings selected for long-term monitoring).

Damage agent	Dead (%)
Fire	16.2
Damping off (likely a *Fusarium* spp.)	6.0
Missing (likely animal caused)	2.8
Armillaria root rot (likely *A. solidipes*)	1.4
Black stained roots (likely *Leptographium terebrantis*)	1.4
Improper planting	0.9
Rodent (chewing at base of stem)	0.5
Unknown	0.5
TOTAL	29.7

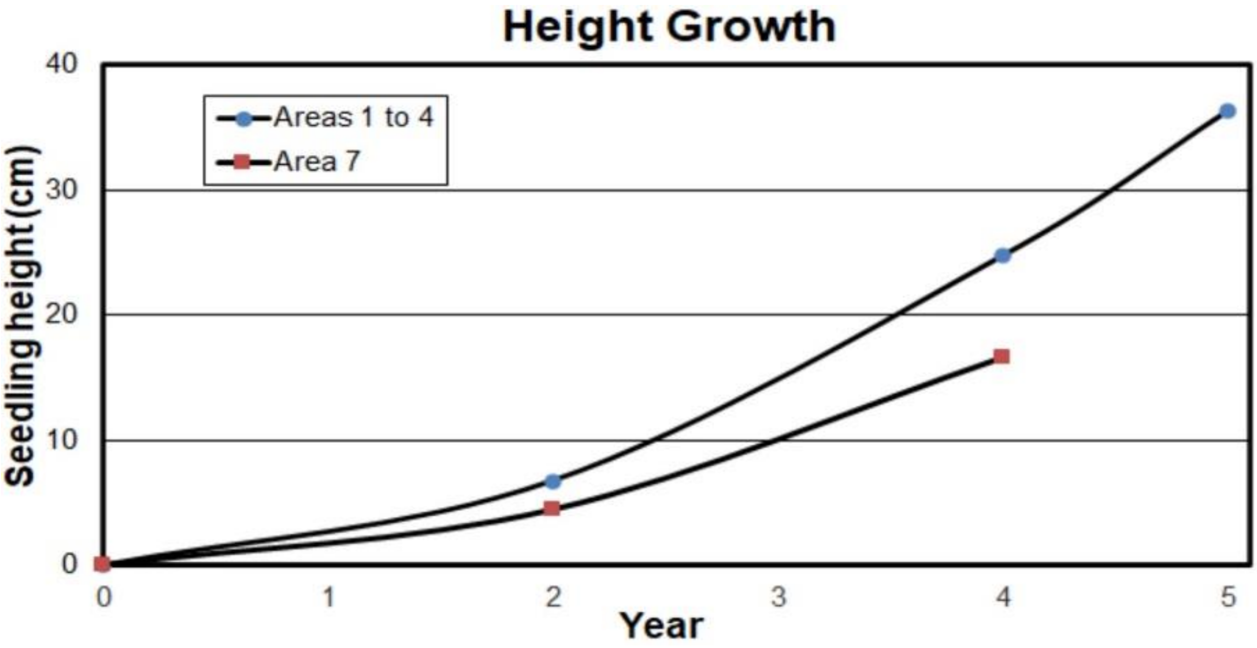


Figure 3: Seedling height growth by seedling age at the Norbeck Wildlife Preserve planting site in the Black Hills National Forest. Data show good exponential height growth at all sites, but faster growth on the ponderosa pine sites (areas 1 to 4) compared to the rocky site (area 7).

Figure 4: Many of the original Black Elk Wilderness trees are dead or might not survive (left and middle). However, the planted seedlings are growing well (right).

Summary

The planted seedlings are growing well (Figure 4). Results suggest limber pines grow better in deep loam soils with no overstory competition. Limber pines are often found on poor sites (harsh, rocky, thin-gravely-soil sites) likely due to the lack of tree competition. We will plant additional seedlings in 2025 to replace the ones killed by fire.

Possible reasons for the good growth and low mortality include:

- Use of local seed adapted to the area.
- Black Hills area gets good spring rains most years.
- Selected planting sites provided trees with deep loam soils.
- Prior years’ high MPB mortality at these sites combined with the clearing of ponderosa pine seedlings/saplings reduced interspecific competition.
- Planting near "nurse objects" (*i.e.*, stumps, snags, logs) likely reduced water stress and ungulate activity.
- Vexar tubes (animal protection) lowered browse-related damage and mortality.
- Use of healthy, high-quality, 2-year seedlings from Bessey Nursery in Nebraska, combined with the gentle planting by Forest personnel and volunteers likely reduced planting stress.

White pine blister rust in British Columbia

Michael Murray[1]*

White pine blister rust, caused by the non-native fungal pathogen *Cronartium ribicola* is well-established in British Columbia (BC). There are three native trees in BC that are susceptible: western white pine (*Pinus monticola*), whitebark pine (*P. albicaulis*), and limber pine (*P. flexilis*). Wherever these five-needle pines occur, infected trees have been detected. White pine blister rust is considered a high hazard in all ecosystems of British Columbia. Observations of heavy impacts (infection and mortality) indicate that southeast BC has the highest levels (Murray and Moody 2023; Shepherd and others 2018). In 2012, whitebark pine was placed on the federal endangered list, primarily due to the impacts of blister rust.

Strategies to address impacts of white pine blister rust typically focus on ecosystem conservation (primarily whitebark and limber pine) or improving timber yield (primarily western white pine). It's generally agreed that eradicating this fungal disease from North America is not feasible. Thus, management emphasizes the hosts. Treatments for western white pine include thinning and pruning (Zeglen and others 2010). An experimental use of a phosphite fungicide (Phostrol) to treat cankers is underway.

Fundamentally, the successful maintenance of five-needle pines relies on the availability of native tree genotypes naturally resistant to white pine blister rust. Much success has been gained promoting resistance in western white pine. Building upon this, efforts are underway to identify resistant whitebark pine trees (Murray and Strong 2021). This process is modeled from the successful white pine screening approach and the current US Forest Service five-needle pine screening program (Sniezko and others 2011). Every year, seedlings from new candidate parent trees are accepted for testing. Overall, nearly 300 parent trees have been assessed (Figure 1). This screening process requires at least five years of repeated annual surveys to assess seedlings from each parent tree. Once confirmed, resistant parent trees are protected from other agents (e.g. fire and insects) in order to serve as seed sources. The development of seed orchards for producing resistant seeds recently launched in BC. A single orchard was established in 2022 near Merrit. This is a cooperative effort between the BC Ministry of Forests and the Whitebark Pine Ecosystem Foundation of Canada. As more resistant parent trees are identified, scion from these parents will be grafted to rootstock for this orchard.

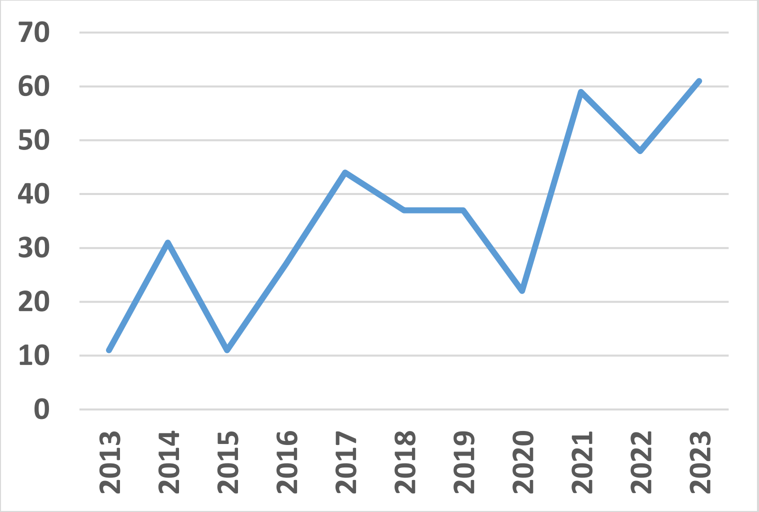


Figure 1: Number of rust-resistant candidate trees (whitebark pine) that have been inoculated in Canada.

---

[1] British Columbia Ministry of Lands and Natural Resource Operations; Nelson, BC, Canada

*Michael.Murray@gov.bc.ca

Literature Cited

Murray, M.P., & Moody, R. 2023. Blister rust distribution, trends, and resistance screening in southern British Columbia's endangered whitebark pine. In: Krakowski, J., W. Strong, and R.A. Sniezko (compilers). Proceedings of the International Union of Forest Research Organizations. 2019 Joint Conference: genetics of five-needle pines and rusts of forest trees. Prov. B.C., Victoria, B.C. Tech. Rep. 142. 8-12.

Murray, M.P., & Strong, W. 2021. Disease screening for endangered whitebark pine ecosystem recovery in Canada. Journal of Ecosystems and Management 21(1):1–7.

Shepherd, B., Jones, B., Sissons, R., Cochrane, J., Park, J., C.M. Smith, et al. 2018. Ten years of monitoring illustrates a cascade of effects of white pine blister rust and focuses whitebark pine restoration in the Canadian Rocky and Columbia Mountains. Forests 9:138.

Sniezko, Richard A.; Mahalovich, Mary F.; Schoettle, Anna W.; Vogler, Detlev R. 2011. Past and current investigations of the genetic resistance to *Cronartium ribicola* in high-elevation five-needle pines. In: Keane, Robert E.; Tomback, Diana F.; Murray, Michael P.; Smith, Cyndi M., eds. The future of high-elevation, five-needle white pines in Western North America: Proceedings of the High Five Symposium. 28-30 June 2010; Missoula, MT. Proceedings RMRS-P-63. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 246-264

Zeglen, S.; Pronos, J.; Merler, H. 2010. Silvicultural management of whit pines in western North America. Forest Pathology 40(2010): 347-368.

Climatic adaptation in the genetic lineages of the Swiss needle cast pathogen *Nothophaeocryptopus gaeumanii*

Nicolas Feau[1*] and Richard C. Hamelin[2]

Climate change is threatening the health of forest ecosystems through direct and indirect effects. The impacts of this change are already being observed on trees, with consequences such as reduction in the overall vigor of trees, increased maladaptation and reduction of their resilience to biotic disturbances. Changes in climatic conditions has also been associated with severe epidemics caused by endemic and usually innocuous pathogens. One noticeable example is *Nothophaeocryptopus gaeumannii*, an endophytic fungal associate of Douglas-fir in the coastal forests of the Pacific Northwest (PNW). This fungus is the agent responsible for the Swiss Needle Cast (SNC) disease which causes needle chlorosis and premature shedding. In recent decades, changing environmental conditions have coincided with periodic epidemics of SNC that started on the Oregon coast and that are now spreading to higher latitudes (Shaw et al. 2021). Using genomics approaches, we identified genetic differences in *N. gaeumannii* that could constitute a source of variability in climate response and disease severity. Two highly divergent genetic lineages of *N. gaeumannii* (lineage 1 and 2), with different levels of suitability to climates, have been identified, increasing concerns that the pathogen may rapidly adapt to new environments. We found that lineage 1 can be further subdivided in lineage 1c and 1i. Modeling of their demographic and evolutionary history indicated that lineages 1c and 1i diverged from a common ancestor about 20,000 years ago, coinciding with the divergence between their respective hosts, the coastal Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) and the Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), after the last glacial maximum. The absence of genomic barriers to sexual reproduction as-well-as a strong conservation of the mating-type genes among lineages refuted invalidated the original hypothesis of complete reproductive isolation between these lineages. Instead, strong evidence of introgressive hybridization was detected between lineage 1c and 1i and lineage 2 into 1c; the genome regions introgressed are still under investigation. Using a genotype-by-environment association approach we found that a significant part of the genetic variation between the lineage 1c and 2 can be explained by environmental variables. Lineage 2 is adapted to cooler temperatures in cold months, while lineage 1c contains genomic signatures of adaptation to lower precipitation during summer months and the larger range of temperatures observed inland. These predictions were corroborated by phenotyping data that showed that lineage 1c had a higher adaptive plasticity to temperatures than lineage 2. Modeling of their distribution under future climatic conditions suggested that the current environmental tolerance range of lineage 1c should keep exceeding that of lineage 2. We expect lineage 1 to expand further inland, while lineage 2 will remain constrained to its current range on the coast (Herpin-Saunier et al. 2022). Our results indicate that lineage 1 might be the “lottery winner” in the climate change contest by becoming the dominant lineage in the PNW. We hypothesize that the higher adaptive plasticity of this lineage for temperature and drought is facilitating its spread and fuelling the SNC epidemics under the current changing climate.

Literature Cited

---

[1]Canadian Forest Service/Natural Resources, Pacific Forestry Centre; Victoria, BC, Canada
[2]University of British Columbia, Department of Forest and Conservation Sciences; Vancouver, BC, Canada
*nicolas.feau@NRCan-RNCan.gc.ca

Shaw DC, Ritóková G, Lan Y-H, Mainwaring DB, Russo A, Comeleo R, Navarro S, Norlander D and B Smith. 2021. Persistence of the Swiss Needle Cast outbreak in Oregon coastal Douglas-Fir and new insights from research and monitoring. Journal of Forestry, 119: 407–421.

Herpin-Saunier N, Sambaraju KR, Yin X, Feau N, Zeglen S, Ritokova G, Omdal D, Cote C and RC Hamelin. 2022. Genetic lineage distribution modeling to predict epidemics of a conifer disease. Frontiers in Forests and Global Change. doi: 10.3389/ffgc.2021.756678.

Slowing the spread of sudden oak death in Oregon: An overview of a landscape scale disease management program

Sarah Navarro[1]*, Gabriela Ritokova [2], Jared Leboldus[3], Ebba Peterson[3], Kelsey Søndreli[3], Elizabeth Stamm[3], Nicholas Grunwald[4], Valerie Fieland[4], Charles Grell[1], Randall Wiese[2], and Casara Nichols[2]

Sudden Oak Death (SOD), caused by *Phytophthora ramorum*, is lethal to tanoak (*Notholithocarpus densiflorus*) and threatens this species throughout its range in Oregon. Since the discovery of SOD in coastal southwestern Oregon forests in 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. The 2010 SOD Quarantine also designated a Generally Infested Area (GIA) within the quarantine area where eradication treatment of infested sites is no longer required. The GIA was expanded in late 2020 and now covers 123 square miles of disease establishment and intensification within the quarantine area; approximately 19 miles north-south and nine miles east-west. The current quarantine area for *P. ramorum* has reached 515 square miles in Curry County or 31% of the county. Survey, detection, and monitoring efforts compose of ground, aerial and stream bait surveys. Ground-based detection and delimitation surveys around infested sites are conducted year-round. Aerial surveys, both fixed winged and helicopter, are conducted four times per year; the main surveys occur in July and October when current-year mortality is most visible. Aerial surveys cover a cumulative area of at least 700,000 acres of forest; ground surveys cover 600 acres. Eradication treatments, totaling approximately 9,000 acres, eliminated disease from most infested sites, but the disease continued to spread slowly, mostly in a northward direction. A new SOD infestation, just outside Port Orford, 21 miles northwest of the Rogue River and 13 miles south of Coos Co., was detected April 27, 2021 along Highway 101 by Oregon State University (OSU) Researcher Ebba Peterson. Since April this infestation has been the program's top priority with ODF, USFS, and OSU surveying over 400 acres with ground transects and collecting over 200 samples resulting in 154 positive detections. Samples collected have tested positive at for the NA2 variant of *P. ramorum* (two samples are NA1). Previously found only in nurseries, this is the first time that variant has been found in wildlands. Given the number of infected trees and new variant, Oregon SOD pathologists believe this to be a separate introduction to Oregon forests that has been intensifying in the area for at least 4 years. This presentation will review program developments in treatments, funding, and continued stakeholder involvement in Oregon as well as lessons learned over the last 20 years.

---

[1] USDA Forest Service, Forest Health Protection; Portland, OR, USA

[2] Oregon Department of Forestry; Salem, OR, USA

[3] Oregon State University, Department of Botany and Plant Pathology; Corvallis, OR, USA

[4] USDA ARS, Horticultural Crops Research Lab; Corvallis, OR, USA

*sarah.navarro@usda.gov

Hazard-rating activities

Bruce Moltzan[1]*

Many Hazard Tree litigations have been leveled against the Fores Service in 2023. One case in particular was seeking damages exceeding 50 million dollars. In response to mitigation, Office of General Council (OGC) reached out to Forest Health Protection to improve ways to reduce such litigation. Purpose of this talk today is to highlight the response to date due to this increased activity. Forest Health has an all-Lands mission within the Forest Service working with many stakeholders in addition to units within Forest Service. In this capacity FHP trainings on hazard tree recognition are conducted annually to assist with roadside, FS Campground, and Forest Service holding surveys, as will as serve and lead on all questions surrounding hazard tree inspection. The material used in our FHP Trainings is subject to OGC approval across Forest Service Regions. To date reviews of these materials have been conducted in R2, R5, R6, R8, and R9. These informative sessions have promoted opportunities to share changes to Hazard Tree Policies and form the basis of cross functional working groups between OGC, Engineering, Recreation and Permitting. A disclaimer for FHP materials is now in use in response to mitigating liability to protect Forest Service staff. The process of communication is very important to effort to ensure public safety and will continue to be further developed into the future.

---

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

Panel: Special papers III

Moderator: Chris Lee

A group on Monday's field trip. (Photo: Kerry Wininger)

Community engagement for healthy forests

Joey M. Hulbert[1]*, Marianne Elliott[1], and Gary Chastagner[1]

Engaging communities can enhance surveillance and research of forest pathogens. There are many methods of engagement and many opportunities for including stakeholders and communities within the processes of managing a biological invasion (Hulbert et al. 2023). While not all research topics are suitable for community science approaches, the value of community contributions to research has been demonstrated in some fields of forest pathology. For example, Lanning et al. (2023) reviewed the contributions of community members in five *Phytophthora* studies in the Western United States and found great value in research, extension and educational outcomes. Once an issue is identified and community science is determined a feasible approach, the general process of implementing a community science approach involves designing the project, building the community, managing the data, evaluating the project, and sharing results (Fraisl et al. 2022). The Forest Health Watch (https://foresthealth.org) is an example of a program that engages communities in forest pathology projects. The pilot project focused on the dieback of western redcedar because it was identified as a priority issue by partners and stakeholders. Community science was determined to be a feasible approach because of the breadth and urgency of the issue. The Western Redcedar Dieback Map project was then co-designed with partners in the USFS Forest Health and Protection (Region 6), Washington Department of Natural Resources, and the Oregon Department of Forestry. After the project was designed, a network of community scientists was developed through many outreach and engagement activities. More than 250 individuals have signed up as community scientists and more than 150 of those individuals have indicated a willingness to collect physical samples. Members of this network have also contributed to research about the emergence of sooty bark disease. Engaging these individuals in the Forest Health Watch program has increased the number of people watching for forest health issues, raised awareness of priority concerns, fostered inclusion of a diversity of perspectives and generally shared the responsibilities of biosecurity. Networks like the community scientist network of the Forest Health Watch are valuable assets for expanding the breadth and timeliness of future research projects and addressing needs for detecting and monitoring forest pathogen invasions.

Literature Cited

Fraisl D, Hager G, Bedessem B, et al (2022) Citizen science in environmental and ecological sciences. Nat Rev Methods Primers 2:1–20. https://doi.org/10.1038/s43586-022-00144-4

Hulbert JM, Hallett RA, Roy HE, Cleary M (2023) Citizen science can enhance strategies to detect and manage invasive forest pests and pathogens. Frontiers in Ecology and Evolution 11:

Lanning KK, Kline N, Elliott M, et al (2023) Citizen science can add value to Phytophthora monitoring: five case studies from western North America. Frontiers in Environmental Science 11:

---

[1]Washington State University, Department of Plant Pathology, Puyallup Research and Extension Center; Puyallup, WA, USA
*hulbe@wsu.edu

Fusarioid community structure among conifer nurseries of the contiguous USA and virulence of conifer-associated *Fusarium commune*

John T. Dobbs[1]*, Mee-Sook Kim[2], Gregory Reynolds[3], Nicholas Wilhelmi[3], Ned B. Klopfenstein[4], and Jane E. Stewart[1]

Fusaria can be introduced into novel landscapes through latent-infected nursery stock and cause seedling mortality. Molecular tools can rapidly identify and track Fusarioid pathogens to mitigate novel pathogen introductions by informing both pathogen composition and pathogenicity of different *Fusarium* spp. Understanding the community structure and population genetics of *Fusarium* spp. is a prerequisite for developing robust primers to detect pathogenic species. Accessory chromosomes have been identified in fungi that house virulence genes that can be horizontally transferred among species and populations. These accessory chromosomes and/or associated virulence genes are prime targets for developing diagnostic probes to identify conifer pathogens. *Fusarium commune* is an understudied species that can be pathogenic to both herbaceous crops and timber trees; however, its virulence mechanisms for conifers have not been elucidated. *Fusarium annulatum* has recently been described as a distinct species from *F. proliferatum*, a species that is a known pathogen of conifers. Subsequently, *F. annulatum* virulence to conifers is not well studied. Our work has three objectives: 1) evaluate Fusarioid fungal community structure in conifer nurseries across the U.S.A. by identifying host associations and geographic distributions, 2) evaluate virulence of conifer-associated Fusarioid isolates on ponderosa pine (*Pinus ponderosa*), loblolly pine (*P. taeda*), and Douglas-fir (*Pseudotsuga menziesii*) seedlings, and 3) use genomic tools to identify candidate virulence genes in host-pathogen interactions that allow design of diagnostic primers for rapid identification and tracking of Fusarioid pathogens. In this study, ca. 26 *Fusarium* spp., including *F. commune* and *F. annulatum*, were collected from conifer nurseries. Unique genomic regions and virulence genes of 15 Fusarioid fungal genomes were compared to identify diagnostic primer targets. Further, three conifer-derived *F. commune* isolates (two from Douglas-fir and one from ponderosa pine) were compared with two non-conifer *F. commune* isolates [from rice (*Oryza sativa*) and tomato (*Solanum lycopersicum*)] to identify genes involved in pathogenicity to conifer hosts (Figure 1). This work will identify virulence factors of *Fusarium* that determine host specificity and genomic regions for developing tools that quantify the inoculum density of *Fusarium* pathogen in conifer nurseries and/or track Fusarioid pathogens from nurseries to prevent/monitor their spread into the forest landscape.

---

[1] Colorado State University, Department of Agriculture Biology; Fort Collins, CO, USA
[2] USDA Forest Service, Pacific Northwest Research Station; Corvallis, OR, USA
[3] USDA Forest Service, Forest Health Protection, Region 3; Albuquerque, NM, USA
[4] USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA
*john.dobbs@colostate.edu

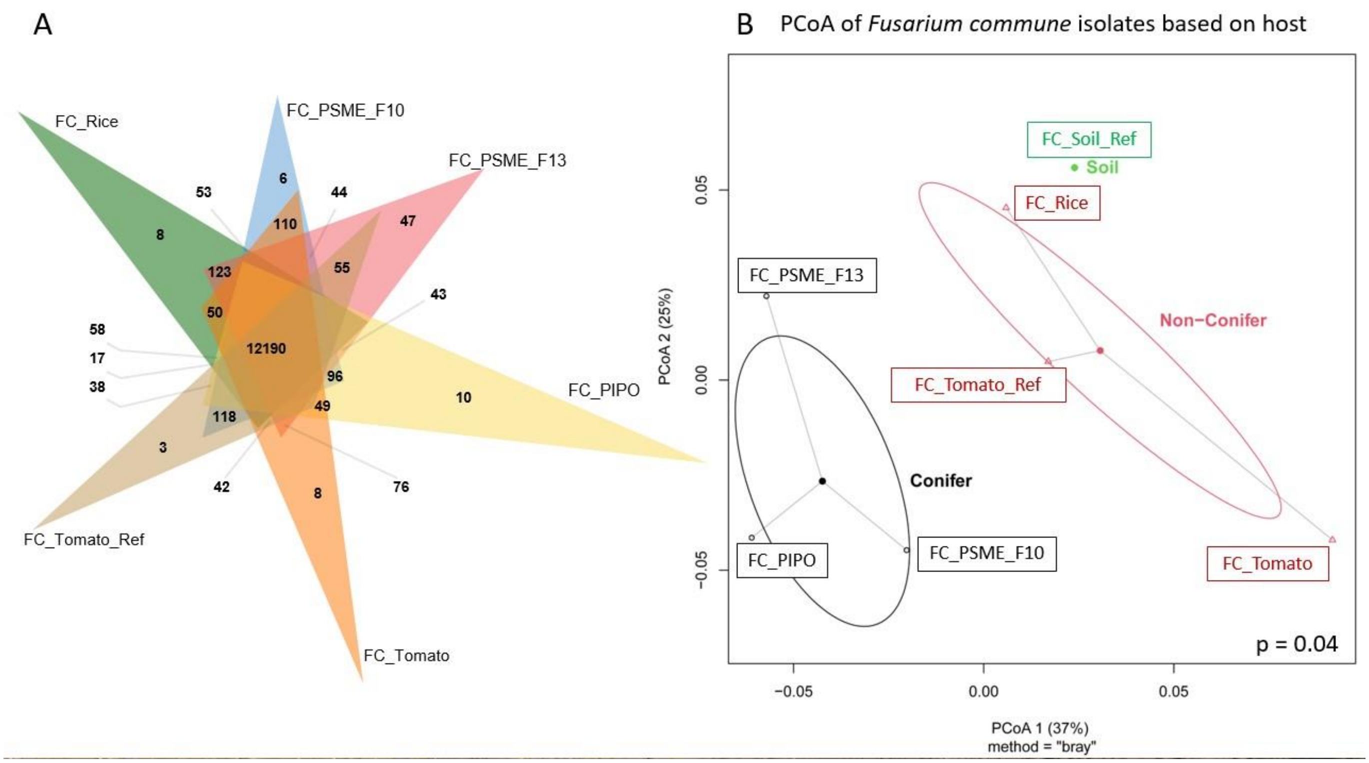


Figure 1: (A) Comparisons of orthologous proteins based on shared orthogroups among *Fusarium commune* (FC) isolates collected from conifer [Douglas-fir (*Pseudotsuga menziesii*; PSME) and ponderosa pine (*Pinus ponderosa*; PIPO)] and non-conifer hosts [rice (*Oryza sativa*) and tomato (*Solanum lycopersicum*)]. These isolates were also compared with two *F. commune* reference genomes collected from tomato (Accession #: JABFES000000000) and soil (Accession #: BCHB00000000) retrieved from GenBank. (B) A principal coordinate analysis was used to assess the similarity of isolates based on hosts from which they were collected and showed significant groupings of isolates based on their host origins.

Cypress canker disease: A model pathosystem for understanding host-pathogen interaction

Edoardo Scali[1]* and Matteo Garbelotto[1]

Cypress canker disease is caused by seven species of *Seiridium* affecting plants belonging to the Cupressaceae family. It serves as a remarkable example of a pandemic in forest pathology. The disease cycle begins when a spore successfully germinates in the tissues of a cypress plant, usually following an injury. At this point, cortical cankers start to develop, leading to dieback and the formation of acervuli from the cortical tissue. In order to better characterize the evolutionary relationship and different plant responses, two experiments were designed.

The first experiment involves a phylogenomic analysis of three *Seiridium* species (*S. cardinale*, *S. cupressi*, *S. unicorne*). The isolates selected for this genomic analysis have diverse geographical origins, enabling an evolutionary comparison to understand the genetic differences that have allowed Seiridium to adapt to new environments.

The second experiment consists of a dual RNA-seq analysis aimed at characterizing the diverse responses of cypress plants to the inoculation of *Seiridium cardinale*. The plants chosen for this experiment include clones of *Cupressus sempervirens* previously characterized based on disease resistance and susceptibility. The expected results of this research open up various scenarios that anticipate further experimentation. These additional experiments include genome annotation and the possibility of conducting further Dual RNA-Seq studies incorporating climatic variables. This will allow the integration of CCD research into a context of climate change.

---

[1] University of California, Department of Environmental Science, Policy and Management; Berkeley, CA, USA
*edoardo_scali@berkeley.edu

Diplodia in Wyoming and potential link to climate change

James T Blodgett[1]*

Diplodia sapinea causes shoot blight, cankers, crown wilt, root collar disease, and root disease of pines and other conifers throughout the world. It affects trees of all ages causing shoot, branch, and top death; reduced growth; and tree mortality (Figure 1). In August 2018, aerial surveys detected Diplodia type symptoms in ponderosa pine (*Pinus ponderosa*) at several locations in Crook County, Wyoming (WY). The original objectives of this study were to determine if *D. sapinea* is present in WY and if the WY isolates are aggressive in ponderosa pine. However, a potential link to climate change was examined during the presentation.

Figure 1: Diplodia shoot blight and canker disease in seedlings (left), branches (middle), and a larger tree (right).

Methods and Results

Areas were ground-checked in Crook County, WY for Diplodia shoot blight and canker disease in 2019. Early symptoms of the disease were common. Branch samples were collected, the pathogen was isolated (in pure-culture), and *D. sapinea* was confirmed by fruiting bodies (pycnidia), spores (conidia), and DNA analysis (ITS with species-specific primers).

Ponderosa pine seedlings were inoculated with the isolates in greenhouses (3 isolates and wounded control, 2 trials) at the Charles E Bessey Nursery, Halsey, Nebraska. Diplodia symptoms were observed as early as 5 days after inoculation. Symptoms were measured 4 weeks after the inoculations (Figure 2). The pathogen was reisolated from 100% of the inoculated seedlings and was never isolated from controls.

---

[1] USDA Forest Service, Rocky Mountain Region, Forest Health Protection; Rapid City, SD, USA
*james.blodgett@usda.gov

Figure 2: Diplodia shoot blight and canker symptoms 4 weeks after inoculation with two different isolates (left and middle photographs) and a control at 4 weeks (right photograph). Graph showing average canker length resulting from inoculation with three different isolates and a control (far right).

Diplodia sapinea is present in WY and is an aggressive pathogen of ponderosa pine.

Discussion

Weather is measured in relatively short increments of time. However, climate is typically measured in 30-year or greater increments. This talk was partly based on a *Plant Disease* first report of Diplodia in WY (Blodgett et al. 2021). However, after examining the 42-year-old geographic distribution map of Diplodia (Peterson 1981), learning about recent discoveries of this disease in other states, and the sudden and extensive out-break of this disease in WY, a potential link to climate was hypothesized.

Life-cycle attributes of this pathogen might allow it to adapt well to changing climate conditions. These include its ability to survive for years as a latent pathogen, increased disease severity after environmental stresses (including drought, excessive moisture, hail damage, and off-site planting), and its quick response to extreme wet and dry conditions. This disease was not reported in most western states, including WY, and was not reported in many Southern states (Peterson 1981) until recently (Figure 3).

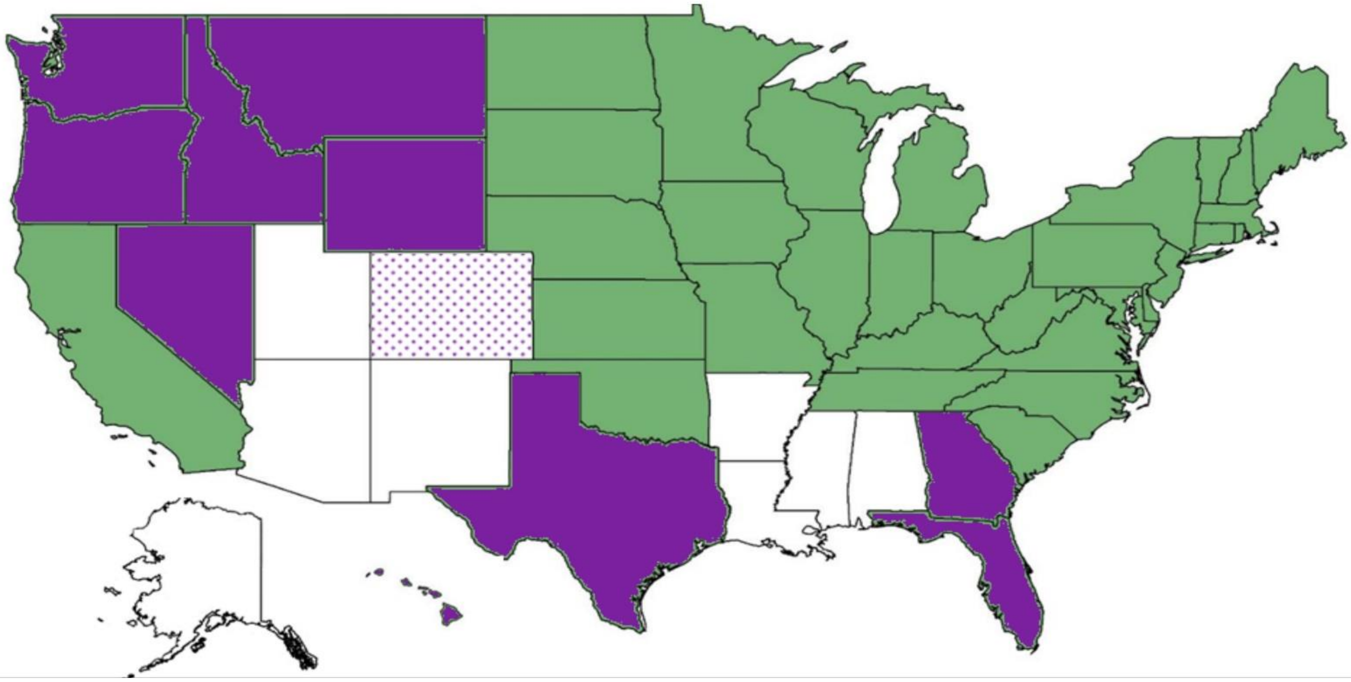


Figure 3. Geographic distribution of Diplodia shoot blight and canker pathogen in 2023. Previous known locations in 1981 (green shade). Recently described locations (purple shade). Recent unpublished discovery (purple dots).

Why is this native pathogen's geographic distribution expanding or what has changed? One potential explanation is the disease was present before, but changing climate conditions are causing the disease to express more frequently and severely. If something new and extensive shows up during a forest aerial detection survey, it gets noticed.

Literature Cited

Blodgett, J.T., Smith, D.R., and Stanosz, G.R. (2021) First report of Diplodia shoot blight and canker disease caused by Diplodia sapinea on ponderosa pine in WY, U.S.A. Plant Dis. 105:3289.

Peterson, G.W. (1981) Diplodia blight of pines. Forest Insect & Disease Leaflet 161. USA Department of Agriculture, Forest Service, State & Private Forestry; Washington, DC, USA.

Ghost canker of pines in southern California

Marcelo I. Bustamante1*, Shannon C. Lynch2, Karina Elfar[1], and Akif Eskalen[1]

Pinus eldarica, *P. halepensis* and *P. radiata* are important conifer species native to Mediterranean regions that are cultivated in the southwestern United States for landscaping (Phillips and Gladfelter, 1991; Chambel et al., 2013). Among them, Monterey pine (*P. radiata*) is native to restricted areas of California and Mexico, but it is extensively grown for timber production in other countries, especially in the Southern Hemisphere (Rogers, 2004). From 2018 to 2022, severe dieback and cankers have been detected on more than 30 mature pines of the three species within a 40-ha urban forest in Orange County, Southern California. Symptoms initiate on the lower portion of the canopy and advance into the crown, leading to quick dieback and, in some cases, to tree death (Figure 1A-B). Cross sections of affected branches revealed wedged cankers with irregular, indistinct margins, and cryptic discoloration, i.e., “ghost cankers” (Figure 1C-D). Pycnidia were observed on the surface of each bark scale of branches with advanced infections (Figure 1E). Two morphotypes of Botryosphaeriaceae colonies (*n* = 34 isolates) were recovered consistently from more than 90% of the symptomatic pines. Two isolates per morphotype were grown on pistachio leaf agar (Chen et al., 2014) for 14 days to induce pycnidia formation. Conidia (*n* = 50) were hyaline, thin-walled and fusoid to ellipsoidal in shape, ranging from 16.1 to 27.9 (22.6) × 5.4 to 8.2 (6.8) µm for the first morphotype and 11.5 to 20.4 (16.3) × 4.8 to 8.6 (6.3) µm for the second morphotype. The rDNA internal transcribed spacer (ITS), beta-tubulin (*tub2*), and translation elongation factor 1-alpha (*tef1-α*) partial gene regions were amplified and sequenced using the primers ITS5/ITS4 (White et al., 1990), Bt2a/Bt2b (Glass and Donaldson, 1995), and EF1-728F/EF1-986R (Carbone and Kohn, 1999), respectively. A multi-locus phylogenetic analysis (Figure 2) revealed that isolates UCD9433 and UCD10439 clustered with the ex-type strain of *Neofusicoccum mediterraneum* (CBS:113083), and isolates UCD9161 and UCD9434 grouped with *N. parvum* (CMW:9081). Sequences were submitted to GenBank (nos. OP535391 to OP535394 for ITS, OP561946 to OP561949 for *tef1-α*, and OP561950 to OP561953 for *tub2*). Pathogenicity tests were performed with above-mentioned isolates on 20-mm-diameter healthy branches of mature Monterey pines (*n* = 10, 14 years old) located in a research field at UC Davis. Isolates were grown for 7 days on potato dextrose agar and inoculated in the internode area by removing a 5-mm-diameter disk of the bark with a sterile cork borer and placing a 5-mm-diameter mycelial plug. Controls were mock-inoculated with sterile agar plugs, and the experiment was performed twice. After three months, inoculations resulted in vascular lesions that ranged from 20.6 to 49.7 (32.7) mm with *N. mediterraneum* and from 13.5 to 71.0 (33.6) mm with *N. parvum*, and the same pathogens were reisolated (70 to 100% recovery). Controls remained symptomless and no botryosphaeriaceous colonies were recovered (Figure 1F). Both *N. mediterraneum* and *N. parvum* are polyphagous pathogens associated with multiple woody plant hosts (Phillips et al., 2013). Previously, only *N. parvum* has been associated with pine cankers in Iran, however, the pine species was not indicated (Abdollahzadeh et al., 2013). The detection of these pathogens in urban forests raises concerns of potential spillover events to other forest and agricultural hosts in Southern California. To our knowledge, this is the first report of *N. mediterraneum and N. parvum* causing Pine Ghost Canker on *P. eldarica*, *P. halepensis* and *P. radiata* (Bustamante et al. 2023).

---

[1]University of California, Department of Plant Pathology; Davis, CA, USA
[2]State University of New York, College of Environmental Science and Forestry; Syracuse, NY, USA
*mibustamante@ucdavis.edu

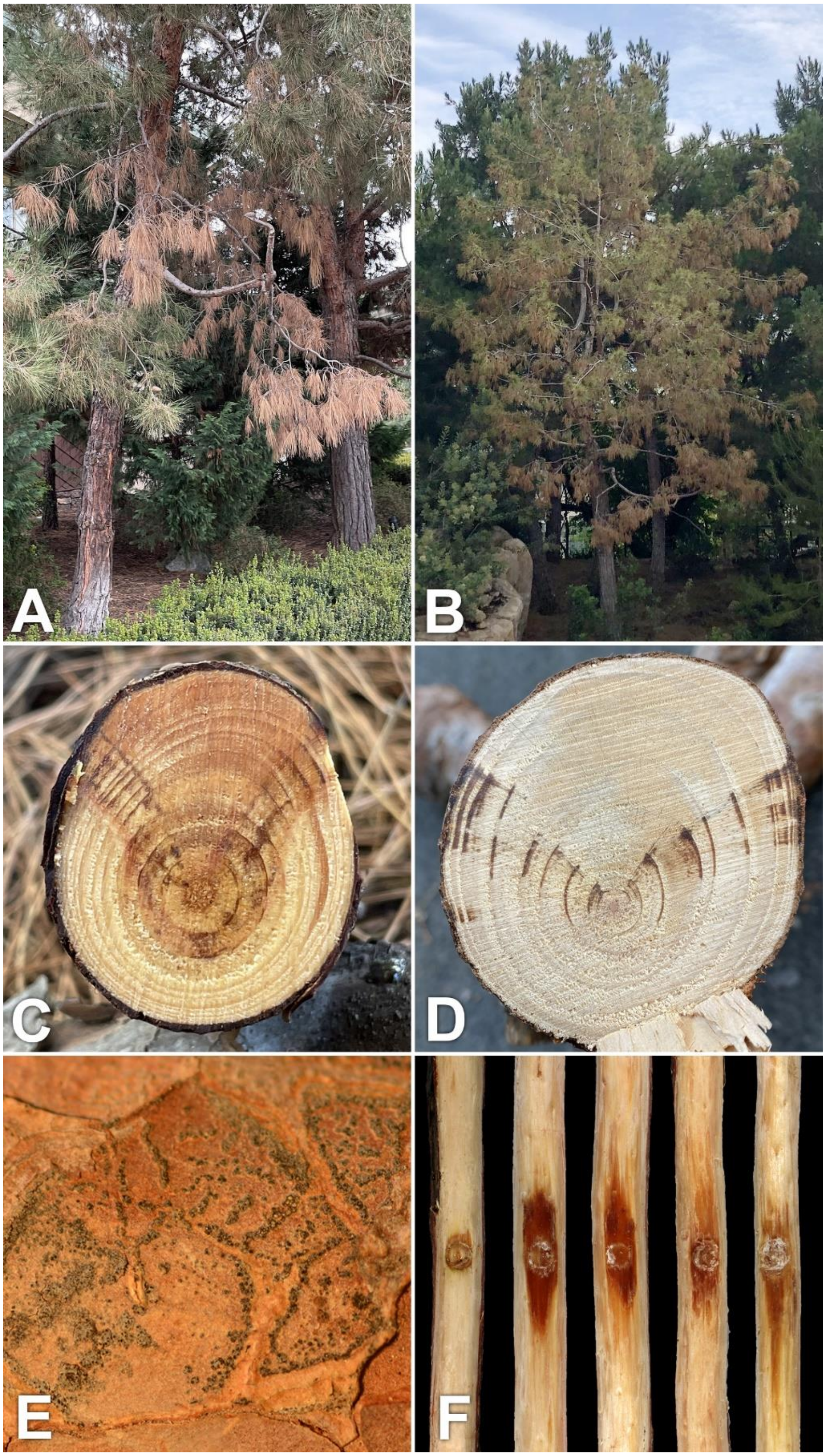


Figure 1: Symptoms and signs of pine ghost canker in Southern California, and pathogenicity test of causal agents. A-B. Branch canker and dieback on *Pinus eldarica*, respectively. C-D. 'Ghost cankers' in cross sections of affected branches. E. Pycnidia on the surface of the bark. F. Pathogenicity test showing the control, inoculations with *Neofusicoccum mediterraneum* UCD9433, *N. mediterraneum* UCD10439, *N. parvum* UCD9161, and *N. parvum* UCD9434, from left to right.

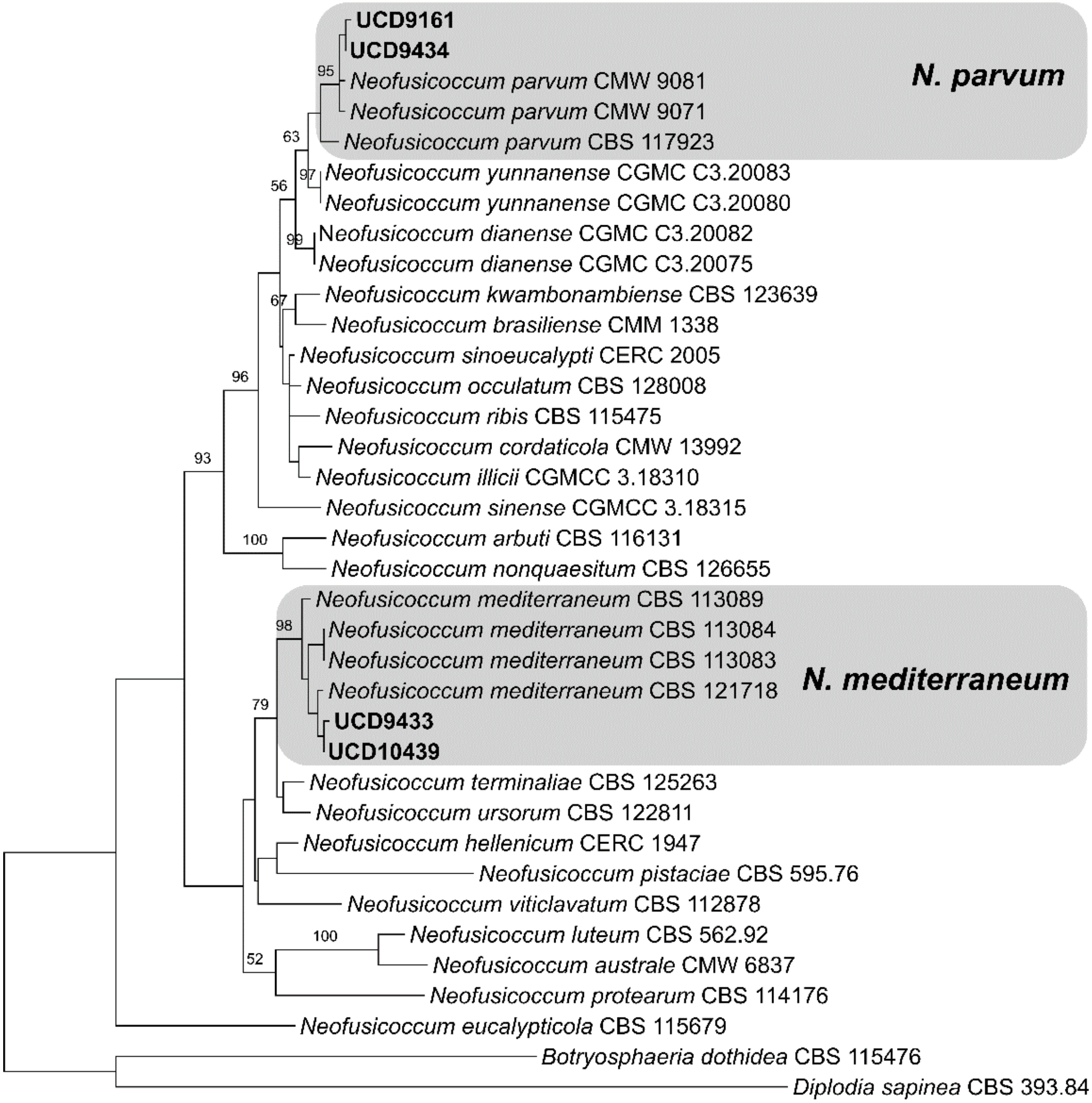


Figure 2: Most parsimonious phylogenetic analysis of selected isolates of *Neofusicoccum mediterraneum* and *N. parvum* affecting *Pinus eldarica*, *P. halepensis* and *P. radiata* in Southern California compared to strains of closely related species of Botryosphaeriaceae. The tree was inferred from a combined data set consisting of sequences of the rDNA internal transcribed spacer (ITS), and partial fragments of the beta-tubulin (*tub2*) and the translation elongation factor 1-alpha (*tef1*) genes. Numbers above branches represent non-parametric bootstrap values from 1,000 replicates. *Botryosphaeria dothidea* (CBS 115476) and *Diplodia sapinea* (CBS 393.84) were used as outgroups.

Literature Cited

Abdollahzadeh, J., Zare, R., and Phillips, A. J. L. 2013. Phylogeny and taxonomy of *Botryosphaeria* and *Neofusicoccum* species in Iran, with description of *Botryosphaeria scharifii* sp. nov. Mycologia 105:210-220. https://doi.org/10.3852/12-107

Bustamante, M.I., Lynch, S.C., Elfar, K., Kabashima, J., Wood, R., Neault, H.F., Rauhe, M.B., Crain, J., Lopez, J.A., Penicks, A., Mojica, H., Atkinson, M.D., Shogren, C., Arreguin, M., Chiang, C.F., Wells, S.I., Alarcon, K.S., Eskalen, A. 2023. First report of *Neofusicoccum mediterraneum* and *Neofusicoccum parvum* causing pine ghost canker on *Pinus* spp. in Southern California. Plant Disease 107(7): 2236. https://doi.org/10.1094/PDIS-09-22-2076-PDN

Chambel, M. R., Climent, J., Pichot, C., and Ducci, F. 2013. Mediterranean pines (*Pinus halepensis* Mill. and *brutia* Ten.). Page 229 in: Forest Tree Breeding in Europe. Springer, Dordrecht, the Netherlands.

Chen, S. F., Morgan, D. P., Hasey, J. K., Anderson, K., and Michailides, T. J. 2014. Phylogeny, morphology, distribution, and pathogenicity of Botryosphaeriaceae and Diaporthaceae from English walnut in California. **Fungal Divers.** 67:157. https://doi.org/10.1094/pdis-07-13-0706-re

Phillips, G. C., and Gladfelter, H. J. 1991. Eldarica pine, Afghan pine (*Pinus eldarica* Medw.). Pages 269-287. In: Bajaj, Y.P.S. (ed). Biotechnology in Agriculture and Forestry 16. Springer-Verlag Berlin Heidelberg GmbH.

Phillips, A. J. L., Alves, A., Abdollahzadeh, J., Slippers, B., Wingfield, M. J., Groenewald, J. Z., and Crous, P. W. 2013. The *Botryosphaeriaceae*: genera and species known from culture. Stud. Mycol. 76:51–167. https://doi.org/10.3114/sim0021

Rogers, D. L. 2004. In situ genetic conservation of a naturally restricted and commercially widespread species, *Pinus radiata.* For. Ecol. Manag. 197:311–322. https://doi.org/10.1016/j.foreco.2004.05.022

Posters

Moderator: Patrick Bennett

Enjoying a meal between sessions. (Photo: Kristen Chadwick)

Influence of fire on native microbial communities in forest soils associated with the fungal pathogen *Armillaria solidipes*

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

The virulent root disease pathogen *Armillaria solidipes* causes a white rot of conifers in the western USA, leading to tree mortality and altering forest structure. Few effective methods are available for managing Armillaria root disease on the landscape scale. While previous studies have indicated the potential for the soil microbial community, including biological control agents, to influence the disease activity of *A. solidipes*, these communities will likely be impacted by increasingly common wildfires in these forest ecosystems. This research aims to determine the potential influence of varying degrees of wildfire severity on native microbial communities in forest soils associated with *A. solidipes*. In Fall 2022, soil samples were collected from the base of 15 western white pine (*Pinus monticola*) and 15 Douglas-fir (*Pseudotsuga menziesii*) trees in northern Idaho, one year after a wildfire occurred at variable severity across the area. Fungal and bacterial species that potentially act as biological controls for *A. solidipes* were isolated from the soil samples and established in pure culture. Preliminary results from dual culture confrontation tests have identified five fungal species and five bacterial species that are effective at restricting the growth of *A. solidipes in vitro*, including multiple *Trichoderma* spp. and *Bacillus* spp. Results from the tagged-amplicon sequencing of the rDNA ITS2 region of fungal DNA and 16S V4-V5 region of bacterial DNA have revealed differences in the richness and alpha diversity of bacterial communities among different levels of fire severity, with unburned soils having higher richness and diversity than burned sites. In contrast, no significant changes in fungal community richness and diversity were observed at 1 year post fire, which suggests either a lack of change following fire or a rapid recovery to pre-fire conditions. However, changes were observed in the relative abundance of some bacterial and fungal families following fire. For example, the bacterial family Enterobacteriaceae, which has previously been associated with *A. solidipes*, was more abundant in soils from less severely burned areas. Additionally, a proliferation of Suillaceae, a family of ectomycorrhizal fungi that can benefit tree health, was found in soils of low-severity burns when compared with both soils from high-severity burns and unburned sites. While further research is required to determine which taxa are important for promoting or suppressing the disease-causing activity of *A. solidipes*, these results suggest the potential for low-severity fires to be part of a management strategy for Armillaria root disease. In general, understanding how fire influences the soil microbial communities in areas where *A. solidipes* is prevalent can promote the development of more effective management strategies for Armillaria root disease.

---

[1] Colorado State University, Department of Agricultural Biology, Fort Collins, CO, USA
[2] USDA Forest Service, Rocky Mountain Research Station, Moscow, ID, USA
[3] USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR, USA
[4] USDA Forest Service, Nez Perce-Clearwater National Forest, Clarkston, WA, USA
*Ada.Fitz_Axen@colostate.edu

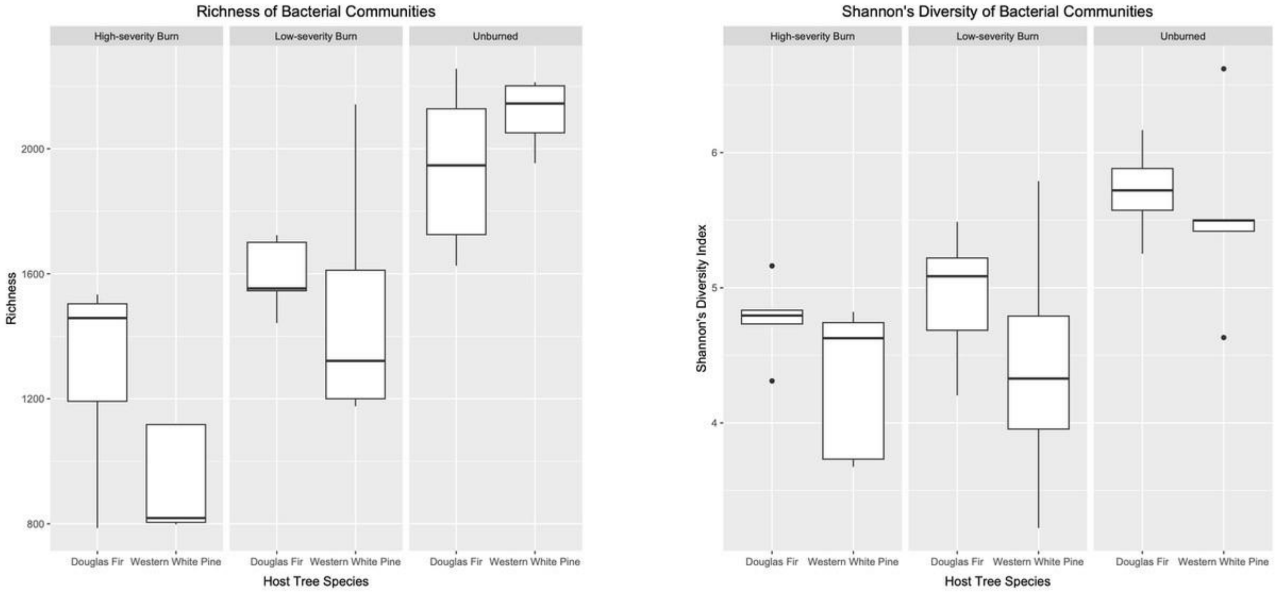


Figure 1: Changes in the richness and alpha diversity, as measured by Shannon’s diversity index, of soil bacterial communities with differing levels of fire severity.

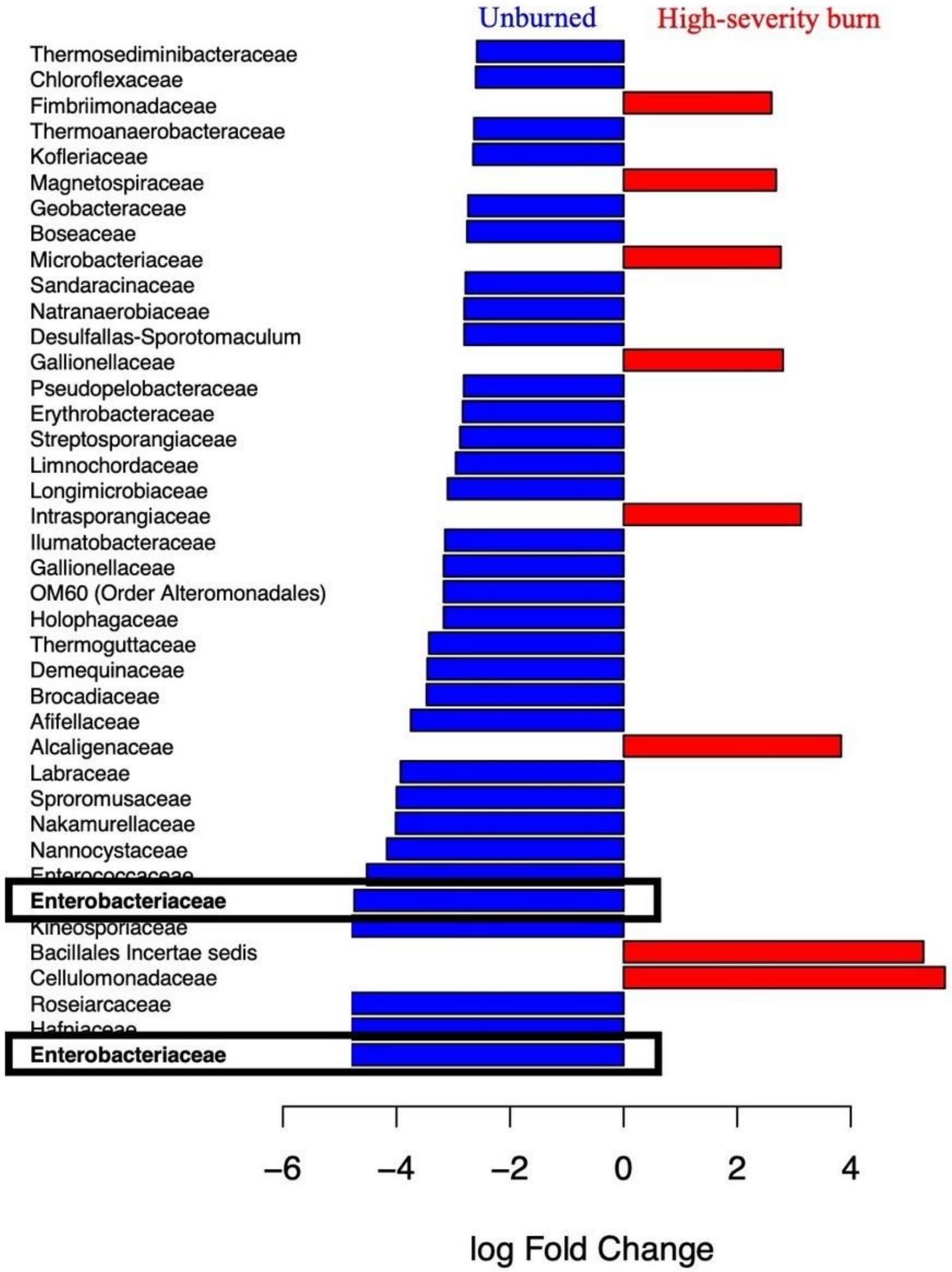


Figure 2: Log-fold change graph indicating bacterial families driving significant differences between soil microbial communities in unburned (blue) and high-severity burn (red) sites. The bacterial family Enterobacteriaceae (bold), which has been previously associated with the microbial community of *Armillaria solidipes*, is more prolific in soil microbial communities of unburned sites.

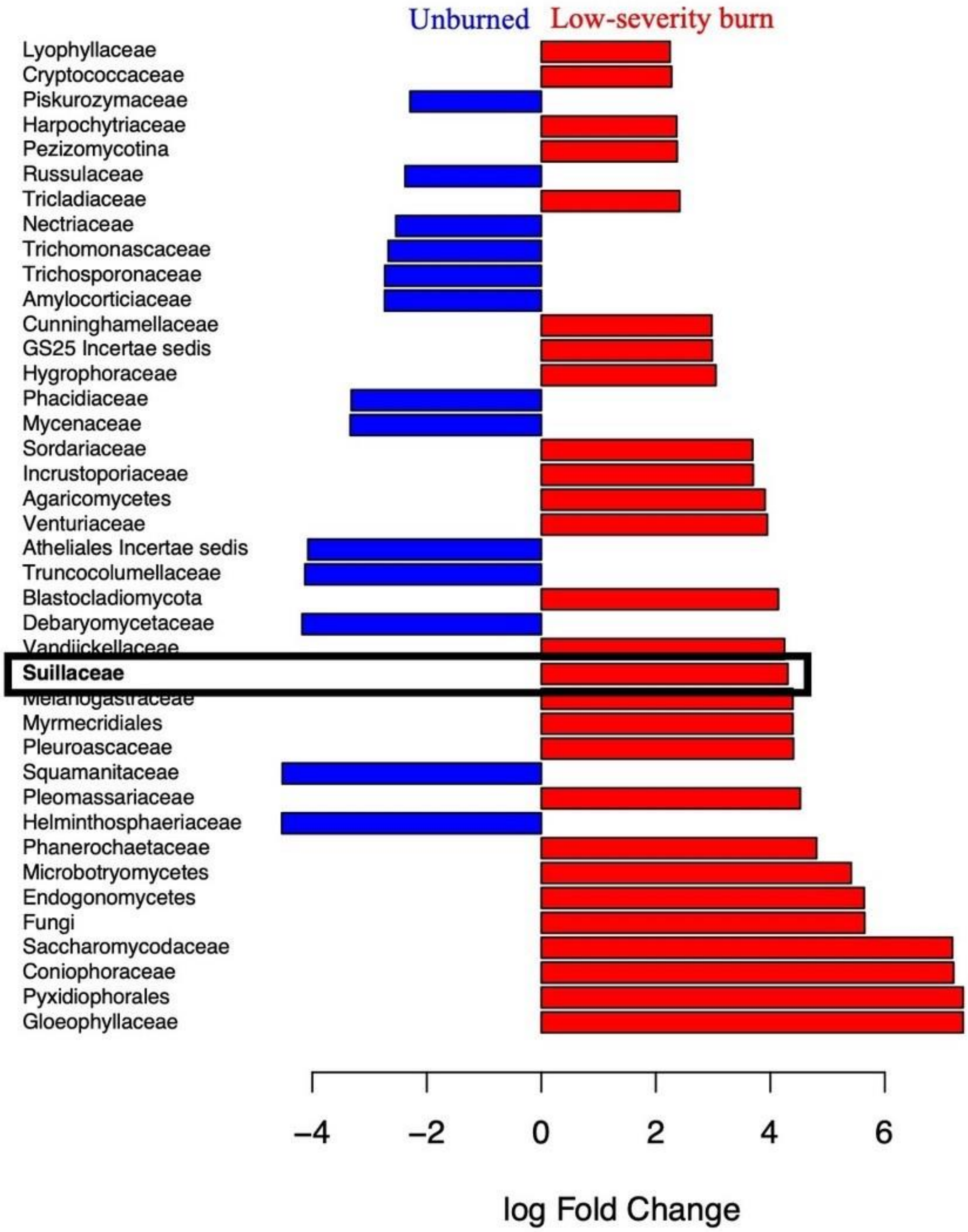


Figure 3: Log-fold change graph indicating fungal families driving significant differences between unburned (blue) and low-severity burn (red) microbial communities. Suillaceae (bold), a family of beneficial ectomycorrhizal fungi, is more abundant in soils from low-severity burn sites.

Aerial spore sampling to assess white pine blister rust risk in western white pine (*Pinus monticola*) and whitebark pine (*P. albicaulis*) stands at Priest River Experimental Forest in northern Idaho

Patrick I. Bennett[1]*, Jason Reinhardt[1], Hannah Basham[1], Nicole Mutchler[1], Christy Cleaver[2], John W. Hanna[1], Ned B. Klopfenstein[1], and Jane E. Stewart[3]

Introduction

Cronartium ribicola is an invasive forest pathogen that causes white pine blister rust, which threatens the health and productivity of five-needled white pines including iconic species, such as western white pine (WWP; *Pinus monticola*) and whitebark pine (WBP; *P. albicaulis*) in western North America. The pathogen has invaded most of the natural ranges of WWP and WBP and has dramatically altered forest composition and structure across the landscape (Neuenschwander et al. 1999). In recent decades, efforts to increase resilience of forest landscapes have led to a renewed interest in restoring WWP as a component of mesic and early seral forest ecosystems in the Northern Rockies, where WWP is a keystone species (Chmura et al. 2011, Bollenbacher et al. 2014). The widespread distribution of *C. ribicola* presents a challenge to these restoration efforts, even with the increased use of blister rust-resistant planting stock. In higher elevation ecosystems, *C. ribicola*, fire, beetles, and climate change threaten the existence of WBP in its role as a foundational and keystone species (Tomback et al. 2016). However, a better understanding of the factors affecting the growth and development of *C. ribicola* and its infection processes is needed to guide both management and conservation efforts of WWP and WBP.

The complex life cycle of *C. ribicola* requires two separate hosts, a primary/aecial host (e.g., white pine) and an alternate/telial host (e.g., *Ribes*, *Castilleja*, and *Pedicularis*). Basidiospores produced on the alternate host(s) can initiate an infection on white pine needles, aeciospores produced on stems and branches of infected white pines can only initiate infections on the alternate host(s), and urediniospores produced on the alternate hosts can only initiate subsequent infections on the alternate hosts, leading to an increase in inoculum potential (Zambino 2010). The risk of infection and disease development is strongly associated with inoculum (i.e., spore) abundance, environmental conditions, and topography (Zambino 2010). Assuming that a susceptible host is present in a conducive environment, the probability of infection is directly related to the amount of *C. ribicola* inoculum present.

Objectives

The objectives of this study are to 1) develop protocols for detecting and quantifying aerial inoculum (i.e., spores) of *C. ribicola*; and 2) incorporate environmental and topographic data to assess the risk of white pine blister rust in stands where planned management activities include restoration and/or conservation of five-needled white pines. These tools will support continued efforts by land managers to restore and conserve WWP and WBP in their native ecosystems.

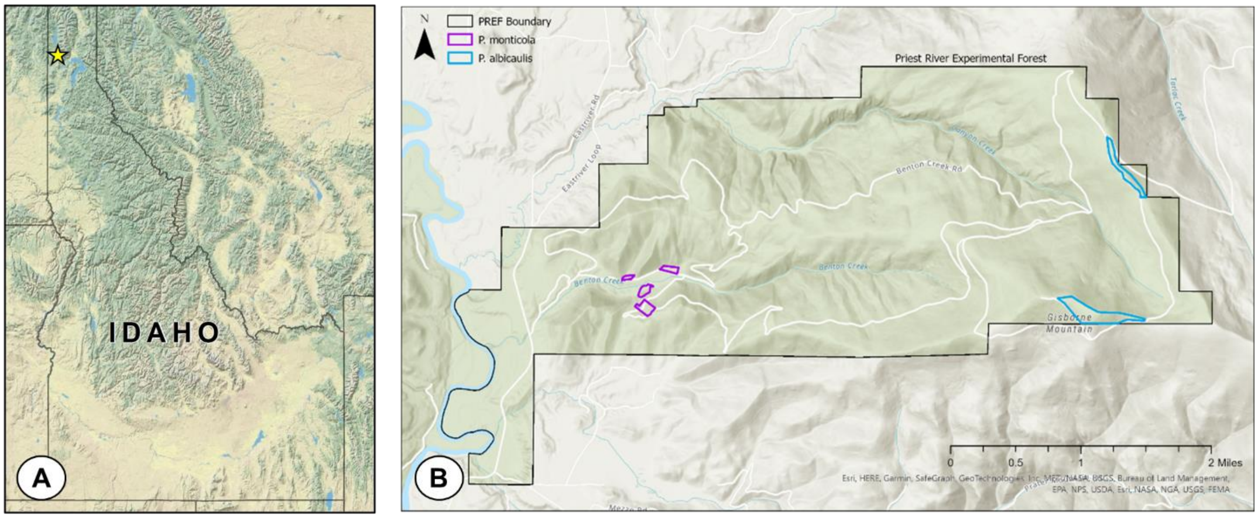
Methods

A pilot study was initiated at Priest River Experimental Forest (PREF) in northern Idaho, starting in 2023 (Figure 1A). *C. ribicola* spores were collected using a rotating-arm impaction sampling device based on a design by Dr. Walt Mahaffee (Oregon State University) (Figure 2). The spore traps are powered by a 12V battery with a small motor driving a rotating arm that holds glass slides coated with petroleum jelly. DNA will be extracted from the

---

[1]USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA
[2]USDA Forest Service, State, Private, and Tribal Forestry, Forest Health Protection, Northern Region; Coeur d'Alene, ID, USA
[3]Colorado State University, Department of Agricultural Biology; Fort Collins, CO, USA
*Patrick.Bennett@usda.gov

petroleum jelly recovered from glass slides, and *C. ribicola* inoculum density will be quantified via real-time polymerase chain reaction (qPCR) using *C. ribicola*-specific primers.



Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, Esri, NASA, NGA, USGS, FEMA

Figure 1: A) Map showing the location of Priest River Experimental Forest (PREF) in northern Idaho. B) Map showing study sites within PREF. Purple polygons represent sites in the western white pine forest type. Blue polygons represent sites in the whitebark pine forest type.

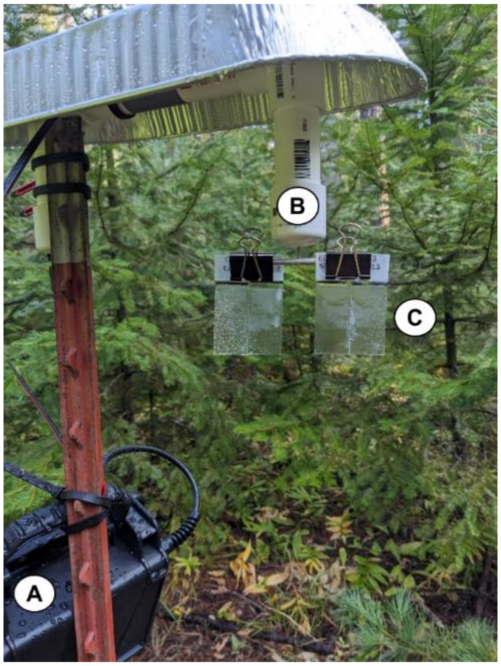


Figure 2: Mechanical spore trap (based on a design by Dr. Walt Mahaffee, Oregon State University). A) 12-Volt battery enclosed in a waterproof plastic case. B) Battery-powered spinning motor attached to an aluminum sampling arm. C) Rotating arm holding four glass slides coated with petroleum jelly that are attached using binder clips.

Spore traps were installed in four stands in 2023 – three in western white pine stands and one in a mixed whitebark pine stand on Gisborne Mountain [approx. elev. 1,700 m (5,600 ft)] (Figure 1B). The spore-trapping sites were arranged along an elevational gradient with variability in topography, microclimate, host abundance, and existing blister rust levels. Environmental factors, such as wind speed, wind direction, temperature, and relative humidity, are measured continually using weather stations in the selected stands, along with *C. ribicola* spore dispersal. Stands will be surveyed in conjunction with spore trapping to assess white pine blister rust incidence and severity in local populations of both the primary host (WWP or WBP) and alternate host (e.g., *Ribes*). This study will also leverage new and existing light detection and ranging (LiDAR) data for acquiring topography and vegetation information (Bright et al. 2020).

Ongoing Work and Future Directions

Data collection using the methods described above will continue over the next 2-4 years. These various data sources will be integrated and applied to develop models of local spore dispersal. A white pine blister rust risk assessment framework will be developed based on a combination of variables, such as *C. ribicola* inoculum density, environmental data, and site data (e.g., stand size/structure, stand age, species composition, site topography including slope, aspect, and elevation). This framework will allow for site-specific estimates of *C. ribicola* infection risk, which will serve as a decision-support tool for land managers in their restoration and/or conservation plans for WWP and/or WBP. Management decisions, such as project placement, unit boundaries, stand composition, planting density, pruning, and harvest parameters, will be informed by these risk assessments.

Acknowledgements

The authors thank Ashley Miller, Kelly Burns, and Paul Zambino for providing constructive feedback on the study design and methods, and Cameron Amos for assistance with processing slides in the Moscow laboratory. The authors also thank Dr. Walt Mahaffee for providing information and advice related to the constructing spore traps. Funding has been provided by USDA Forest Service, State, Private, and Tribal Forestry, Forest Health Protection Special Technology Development Program (STDP) R1-2023-02 and the Rocky Mountain Research Station, Forest and Woodland Ecosystems Program. Any 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.

Literature Cited

Bollenbacher, B. L.; Graham, R. T.; Reynolds, K. M. 2014. Regional forest landscape restoration priorities: Integrating historical conditions and an uncertain future in the Northern Rocky Mountains. Journal of Forestry, 112(5), 474–483.

Bright, B. C.; Hudak, A. T.; McCarley, R.T. 2020. Digital surface, terrain, and canopy height models for Priest River Experimental Forest in 2011. Fort Collins, CO: Forest Service Research Data Archive.

Chmura, D.J. et al. 2011. Forest responses to climate change in the northwestern United States: Ecophysiological foundations for adaptive management. Forest Ecology and Management, 261(7), 1121-1142.

Neuenschwander, L. F.; Byler, J. W.; Harvey, A. E.; McDonald, G. I.; Ortiz, D. S.; Osborne, H. L.; Snyder, G. C.; Zack, A. 1999. White pine in the American West: A vanishing species - can we save it Gen. Tech. Rep. RMRS-GTR-35. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 20 p.

Tomback, D. F.; Resler, L. M.; Keane, R. E.; Pansing, E. R.; Andrade, A. J.; Wagner, A. C. 2016. Community structure, biodiversity, and ecosystem services in treeline whitebark pine communities: Potential impacts from a non-native pathogen. Forests, 7(1), Article 1.

Zambino, P. J. 2010. Biology and pathology of *Ribes* and their implications for management of white pine blister rust. Forest Pathology, 40(3–4), 264–291.

Developing protocols for detecting and monitoring *Heterobasidion irregulare* in ponderosa pine stands

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 Kearns[6], and Matteo Garbelotto[7]

Introduction

Heterobasidion root disease causes growth loss and mortality in coniferous forests of the Northern Hemisphere (Garbelotto and Gonthier 2013). Two species of *Heterobasidion* are present in North America— *H. occidentale,* which primarily infects true fir (*Abies* spp.), hemlock (*Tsuga* spp.), spruce (*Picea* spp.), and Douglas-fir (*Pseudotsuga menziesii*), and *H. irregulare,* which primarily infects ponderosa pine (Garbelotto and Gonthier 2013, Lockman and Kearns 2016, Otrosina and Garbelotto 2010). These root pathogens spread long-distance via windborne spores, which may be deposited on the surfaces of cut stumps or wounds (Otrosina and Cobb 1989, Kliejunas 1989). Following successful colonization, *Heterobasidion* can spread from infected trees to healthy trees via root-to-root contact. Because freshly cut stumps represent the primary infection court for *H. irregulare* in ponderosa pine forests, disease incidence is related to management history. Larger stumps [> 30 cm (12 inches)] are more conducive to establishment and spread of disease (Otrosina and Cobb 1989, Kliejunas 1989). Once established, *Heterobasidion* can persist on a site for decades in the woody biomass of roots and stumps. Preventing the introduction and spread of *H. irregulare* is critical for managing ponderosa pine.

The risk of *H. irregulare* infection varies according to stump size (Kliejunas 1989, Lockman 2006), inoculum abundance (Gonthier et al. 2005), and other factors. Previous studies suggest that a spore deposition rate (DR) of 5 spores m^{-2} hr^{-1} is sufficient to initiate infection (Gonthier et al. 2005, Bérubé et al. 2017), and DR exceeding 10 spores m^{-2} hr^{-1} at the time of harvest significantly increases the risk of infection (Gonthier et al. 2005). Spore infections can be reduced or prevented by treating stumps with borate compounds. Although these treatments are effective (Nicolotti and Gonthier 2005, Pratt 2000, Pratt and Quill 1996), application adds extra cost and logistical complexity to timber harvest. Information regarding the abundance of *H. irregulare* spores and the spatial variation in inoculum densities will allow land managers to assess the relative risk of *H. irregulare* infection when prioritizing sites for stump treatments.

Objectives

The objectives of this study are to develop protocols for 1) monitoring aerial inoculum density and spore deposition rates of *H. irregulare* in ponderosa pine stands; and 2) applying existing molecular tools for detection and identification of *H. irregulare* in stumps and standing trees.

These detection and monitoring techniques will enable development of site-specific disease risk assessments based on *H. irregulare* inoculum availability and other factors. This information will guide prevention strategies for Heterobasidion root disease, such as post-harvest stump treatments and appropriate timing of harvest based on

---

[1]USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA
[2]USDA Forest Service, State, Private, and Tribal Forestry, Forest Health Protection, Pacific Northwest Region; Portland, OR, USA
[3]USDA Forest Service, State, Private, and Tribal Forestry, 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]University of California, Department of Environmental Science, Policy, & Management; Berkeley, CA, USA
*Patrick.Bennett@usda.gov

spatial and temporal variation in inoculum availability. This work will also support future studies investigating the ecology of *H. irregulare* in ponderosa pine stands in the Pacific and Inland Northwest.

Methods

For our pilot study, sampling was conducted in ponderosa pine stands in south-central Washington in October 2022. Sites were selected based on previous observations of symptoms in live trees (Figure 1a), as well as DNA-based identification of *H. irregulare* from basidiocarps present in stumps (Figure 1b) and spores deposited on wood disks. Both *H. irregulare* and *H. occidentale* are present in the study area. Five transects were established-two in each of two ponderosa pine stands (HB2 and HB5), and one in a dry lakebed approximately 500 m from the forest edge at Conboy Lake National Wildlife Refuge. Each transect consisted of three mechanical spore traps and four wood disk subplots placed 10 m apart.

Spore deposition rates (DR) were measured using the wood-disk exposure method (Rishbeth 1959) (Figure 2a). In each of the four wood-disk subplots, nine 100 mm petri dishes containing ponderosa pine disks were placed on the ground. Four of the disks in each subplot were exposed to the open air (i.e., lids were removed from the petri plates) for 24 hrs., another four disks were exposed for 72 hrs., and the final disk was left covered to serve as a control. This study design resulted in a total of 180 wood disks. The disks were incubated for 7-10 days at which time colonies of the asexual stage of *Heterobasidion* were counted. Each colony represented one viable spore. Isolates were sub-cultured and identified via PCR with taxon-specific primers (Shamoun et al. 2019). The proportion of each *Heterobasidion* species from each disk was used to calculate deposition rates (DR) for *H. irregulare* and *H. occidentale* (i.e., viable spores deposited m^{-2} hr^{-1}).

Wood shavings were extracted from five standing trees (two symptomatic, two asymptomatic, one dead) using a 30.5 cm (12 inch) drill bit and were collected in sterile petri dishes. Wood cores were also extracted from the four live trees using an increment borer. Increment cores and drill shavings were plated on selective media (2% malt agar with benomyl and streptomycin) (Worrall et al. 1991) for detection and identification of *Heterobasidion*. The presence of *H. irregulare* in fungal cultures and wood samples will be confirmed via PCR with taxon-specific primers (Shamoun et al. 2019).

Aerial inoculum was collected using rotating-arm spore impaction devices (aka rotorod) consisting of a battery-powered motor with rotating arm holding silicone-coated stainless-steel rods, based on a design by Dr. Walt Mahaffee (Oregon State University) (Figure 2b-c). The rods were collected and replaced with sterile rods every 24 hours for three days. Efforts are currently underway to extract DNA from the rods and quantify inoculum via real-time PCR (qPCR) using TaqMan assay with probes and primers specific for *H. irregulare* [13]. The results will be used to estimate aerial spore density (spores m^{-3} hr^{-1}).

Sampling will be conducted again in October 2023 at the same sites using similar methodology, except for the wood disk exposure times, which were reduced to include 4 hrs. and 24 hrs. treatments.

Preliminary Results and Conclusions

To date, 262 colonies sub-cultured from wood disks have been identified via PCR to determine the relative abundances of *H. occidentale* and *H. irregulare* on each disk. Overall, approximately 65% of the colonies were identified as *H. irregulare*. Within ponderosa pine stands, *H. irregulare* accounted for 75% of the colonies on wood disks but only 8% of the colonies on disks placed 500 m away from the forest. In pine stands (HB2 and HB5), DR for *H. irregulare* ranged from 0 to 23 spores m^{-2} hr^{-1} with an average of 10.8 spores m^{-2} hr^{-1}. Stand HB2 had a higher mean DR than stand HB5 and both had higher mean and maximum DR than the site 500 m away from the forest (CL; Figure 3), suggesting limited dispersal capabilities of *H. irregulare*. The estimated DR in ponderosa pine stands suggest that there may have been sufficient viable inoculum of *H. irregulare* present for stump infections to occur given the environmental conditions at the time that the study was conducted. Further studies are needed to determine whether routine stump treatments are warranted and logistically feasible in the study area.

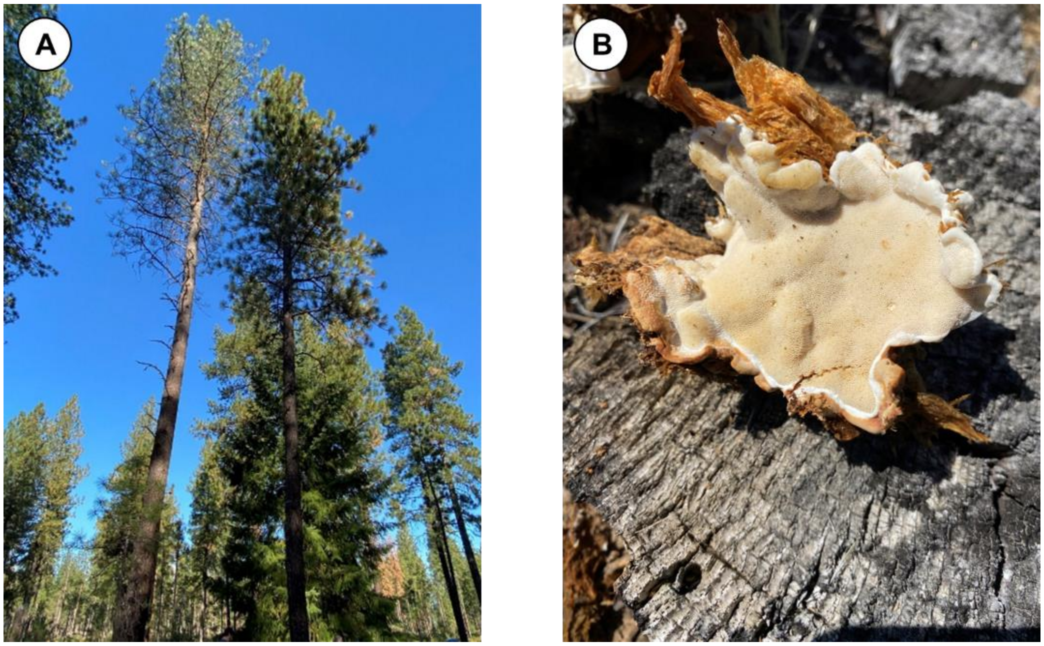


Figure 1: A) Ponderosa pine (*Pinus ponderosa*) at one of our study sites in south-central Washington. The tree on the left is showing some symptoms of root disease including a sparse crown and foliar discoloration, while the neighboring tree appears asymptomatic with a full crown and green needles. B) Fruiting body (basidiocarp) of *H. irregulare* collected from a ponderosa pine stump in one of our study sites in south-central Washington.

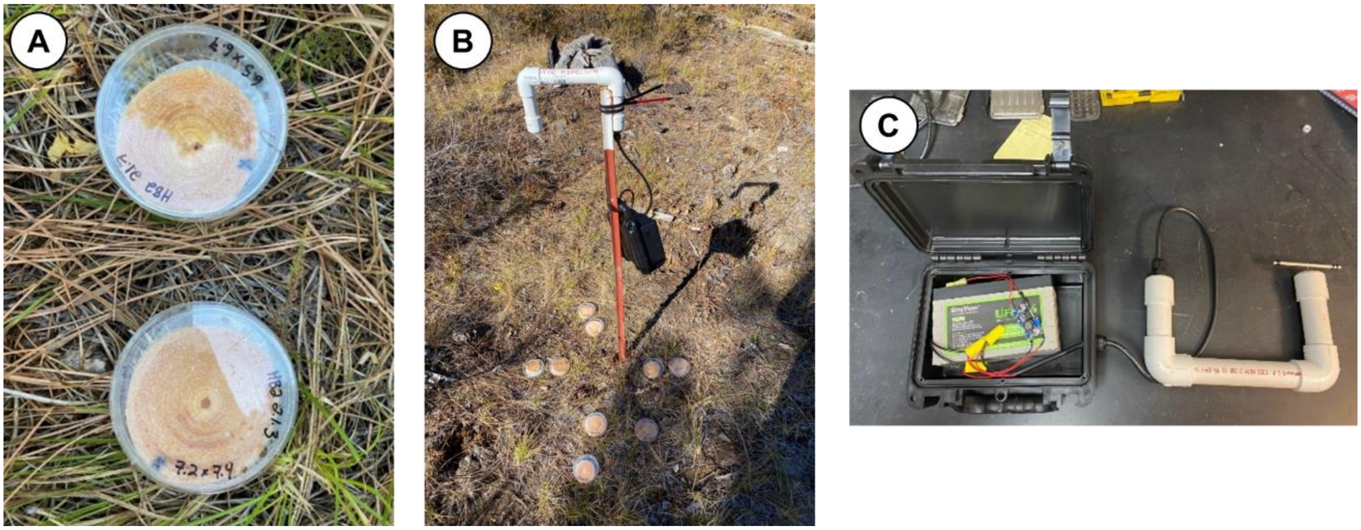


Figure 2: A) Ponderosa pine wood disks in Petri dishes used for measuring spore deposition rates of Heterobasidion. B) Spore-sampling plot with mechanical spore trap mounted on a T-post and wood disks arranged on the ground below. C) Mechanical spore-trap design. Traps are powered by a 12v battery and a small spinning motor. An aluminum rotating arm is attached to the motor and holds two stainless steel rods, which are coated with silicone vacuum grease before being deployed.

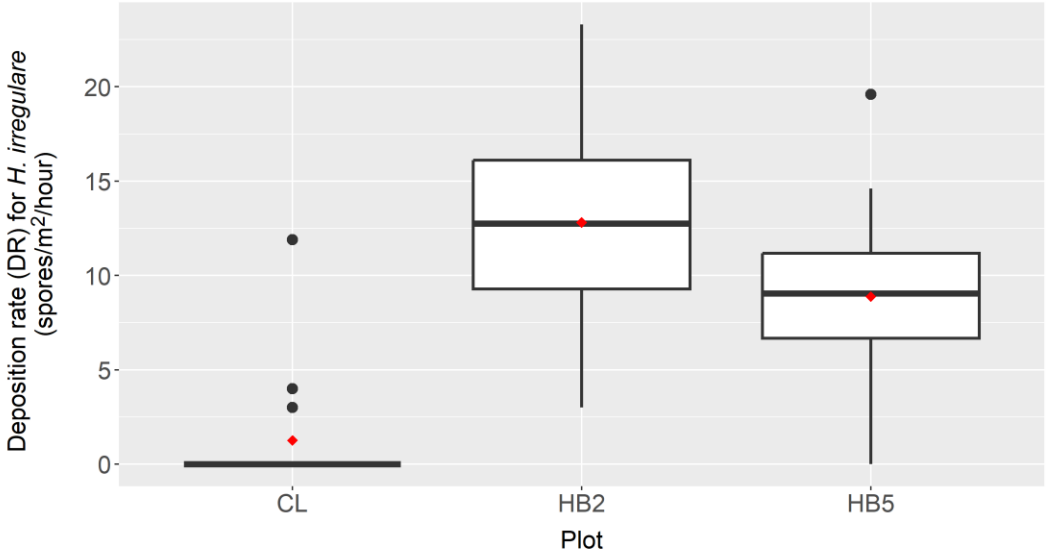


Figure 3: Boxplot showing estimated spore deposition rates (DR; spores m-2 hr-1) for *Heterobasidion irregulare* on ponderosa pine wood disks exposed for 72 hrs. in three plots in south-central Washington during October 2022. CL = Conboy Lake (500 m from forest edge). HB2 and HB5 represent plots within two ponderosa pine stands where the presence of *H. irregulare* has been documented. The bold horizontal lines in the center of each box represent the median DR, while the red points represent mean DR for each group. The black points are outliers. N = 16 disks for CL and 32 disks each for HB2 and HB5.

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 authors also thank Dr. Walt Mahaffee (Oregon State University) for providing information and advice regarding the construction and deployment of mechanical spore traps. Funding for this project is provided by U.S. Forest Service, Forest Health Protection, Special Technology Development Program (STDP) grant R6-2022-01 and Rocky Mountain Research Station Forest and Woodland Ecosystems (FWE) Program.

Literature Cited

Bérubé, J.A.; Potvin, A.; Stewart, D. 2017. Importance of local and long-distance *Heterobasidion irregulare* aerial basidiospore dispersal for future infection centres in thinned red pine plantations in Quebec. The Forestry Chronicle. 93(3): 241–245.

Garbelotto, M., & Gonthier, P. 2013. Biology, epidemiology, and control of *Heterobasidion* species worldwide. Annual Review of Phytopathology. 51(1): 39–59.

Gonthier, P.; Garbelotto, M.M.; Nicolotti, G. 2005. Seasonal patterns of spore deposition of *Heterobasidion* species in four forests of the western Alps. Phytopathology. 95(7): 759–767.

Kliejunas, J.T. 1989. Borax stump treatment for control of Annosus root disease in the eastside pine type forests of northeastern California. pp. 159-166. In: Otrosina, W.J.; Scharpf, R.F., tech. coords. Research and management of Annosus root disease (*Heterobasidion annosum*) in western North America; symposium proceedings; 1989 April 18–21; Monterey, CA. Gen. Tech. Rep. PSW-GTR-116. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 159-166.

Lamarche, J.; Potvin, A.; Stewart, D.; Blais, M.; Pelletier, G.; Shamoun, S. F.; Hamelin, R. C.; Tanguay, P. (2016). Real-time PCR assays for the detection of *Heterobasidion irregulare*, *H. occidentale, H. annosum* sensu stricto and the *Heterobasidion annosum* complex. Forest Pathology. 47(2): e12321.

Lockman, I. B. 2006. Annosus Root Disease: P-type ecology and management. In: *Forest insect and disease management guide for the northern and central Rocky Mountains.* USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection. p. 14.

Lockman, I. Blakey; Kearns, Holly S.J., eds. 2016. Forest root diseases across the United States. Gen. Tech. Rep. RMRS-GTR-342. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 55 p.

Nicolotti, G., & Gonthier, P. 2005. Stump treatment against *Heterobasidion* with *Phlebiopsis gigantea* and some chemicals in *Picea abies* stands in the western Alps. Forest Pathology, 35(5), 365–374.

Otrosina, W. J., & Garbelotto, M. 2010. *Heterobasidion occidentale* sp. nov. and *Heterobasidion irregulare* nom. nov.: A disposition of North American *Heterobasidion* biological species. Fungal Biology. 114(1): 16–25.

Otrosina, W.J.; Cobb, F.W., Jr. 1989. Biology, ecology and epidemiology of *Heterobasidion annosum*. In: Otrosina, W.J.; Scharpf, R.F., tech. coords. Research and management of Annosus root disease (*Heterobasidion annosum*) in western North America; symposium proceedings; 1989 April 18–21; Monterey, CA. Gen. Tech. Rep. PSW-GTR-116. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 26–33.

Pratt, J. E. 2000. Effect of inoculum density and borate concentration in a stump treatment trial against *Heterobasidion annosum*. Forest Pathology. 30(5): 277–283.

Pratt, J. E., & Quill, K. 1996. A trial of disodium octaborate tetrahydrate for the control of *Heterobasidion annosum*. European Journal of Forest Pathology, 26(6), 297–305.

Rishbeth, J. 1959. Dispersal of *Fomes annosus* Fr. and *Peniophora gigantea* (Fr.) massee. Transactions of the British Mycological Society. 42(2): 243–260.

Shamoun, S.F.; Hammett, C.; Sumampong, G.; Li, X. and others 2019. New taxon-specific *Heterobasidion* PCR primers detect and differentiate North American *Heterobasidion* spp. in various substrates and led to the discovery of *Heterobasidion irregulare* in British Columbia, Canada. Pathogens. 8(3): 156.

Worrall, J.J. 1991. Media for Selective Isolation of Hymenomycetes. Mycologia. 83(3): 296–302.

Washington State Swiss needle cast update

Rachel Brooks[1]*, Dan Omdal[1], Isaac Davis[1], Glenn Kohler[1], Justin Hof[2], Marty Kimbrel[3], and Connie Okasaki[4]

Swiss needle cast (SNC) is a foliar disease of Douglas-fir often associated with Pacific Northwest coastal forests. In May 2022, an aerial survey covering 2.0 million acres was flown to map the distribution of discolored Douglas-fir trees typically associated with SNC in coastal Washington. Acreage of mapped symptomatic Douglas-fir was within range of measurements taken in previous years. In support of the aerial survey, 96 ground locations across the same geographic area were assessed in spring 2021 and 2022. SNC severity and needle retention were estimated at each location and found to be similar or lower to numbers measured in previous years. Additionally, during the same time period, 32 ground plots were surveyed in the NW Region in an area where monitoring had not occurred before. Measurements at these sites were significantly higher than those measured along the coast during the same time period. The correlation between SNC severity and needle retention was not significant in all locations and years except for the NW Region in 2022. This lack of consistent correlation may indicate other factors in addition to SNC are driving needle retention.

Literature Cited

Kincaid, T.M., Olsen, A.R., and Weber, M.H. 2019. Spsurvey: Spatial survey design and analysis. R package version 4.1.0. https://crian.r-project.org/web/packages/spsurvey/citation.html

Ramsey, A., Omdal, D., Dozic, A., Kohler, G., Hof, J., and M. Kimbrel. 2018. Coastal Washington Swiss Needle Cast Aerial and Ground Survey. Washington Department of Natural Resources. https://www.dnr.wa.gov/publications/rp_2018_swiss_needle_cast_report.pdf

Robertson, B.L., Brown, J.A., McDonald, T. and Jaksons, P. 2013. BAS: Balanced acceptance sampling of natural resources. Biometrics, 69(3) 776 - 784. https://doi.org/10.1111/biom.12059

Shaw, D.C., Ritóková, G., Lan, Y., Mainwarning, D.B., Russo, A., Comeleo, R., Navarro, S., Norlander, D., and Smith, B. Persistence of the Swiss needle cast outbreak in Oregon coastal Douglas-fir and new insights from research and monitoring. Journal of Forestry, 1 – 15. https://doi.org/10.1093/jofore/fvab011

Ritóková, G., Shaw, D.C., and Mainwaring, D. 2022. Silvicultural decision guide for Swiss needle cast in coastal Oregon and Washington. Oregon State University Extension Service. EM 9352. https://extension.oregonstate.edu/pub/em-9352

---

[1] Washington State Department of Natural Resources, Forest Resilience, Olympia, WA, USA
[2] USDA Forest Service, Pacific Northwest Region, State & Private Forestry, Portland, OR, USA
[3] Washington State Department of Fish and Wildlife, Olympia, WA, USA
[4] University of Washington, Seattle, WA USA
*rachel.brooks@dnr.wa.gov

Sporulation of *Phytopthora ramorum* in response to weather conditions and host herbicide treatment in southwest Oregon

Steph Chase[1]*, Adam Carson[1], Hannah Suli[1], Kelsey Søndreli[1], Nathan Bearden[1], Biz Stamm[1], and Jared LeBoldus[1,2]

Sporulation of *Phytopthora ramorum* was measured over the course of one year throughout a network of 29 plots in southwest coastal Oregon. Plot overstories were predominantly tanoak, and all tanoaks in a subset of plots (n =15) were treated with herbicide. Bucket baits were used to monitor canopy drip for sporulation, and comparisons between treatments were made using weather variables as a covariates. Sporulation was correlated with wet weather conditions, including rain, leaf, wetness, and relative humidity. Herbicide treatments were not effective for preventing or slowing the spread of SOD, and were found to increase sporulation for 10 months following treatment. Treated sites produced more bucket bait positives than untreated sites in both the early (months 0-4) and late (months 5-11) sampling periods (p=0.040 and p=0.020, respectively).

Figure 1: Photos of a bucket bait (left) and a weather tower (right).

---

[1] Oregon State University, Department of Botany and Plant Pathology, Corvallis, OR, USA
[2] Oregon State University, Forest, Engineering, Resources and Management Department, Corvallis, OR, USA
*chasest@oregonstate.edu

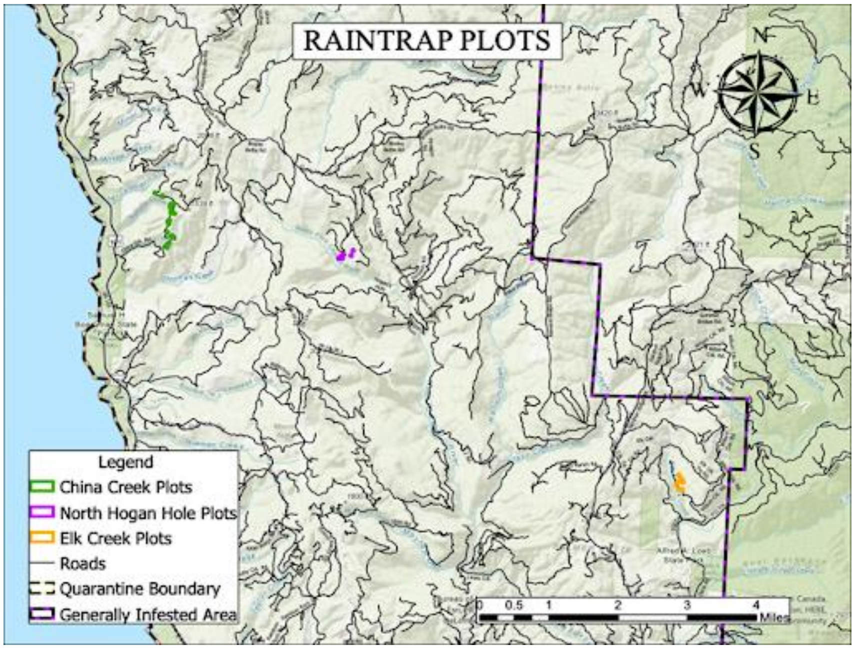


Figure 2: A map of plot locations.

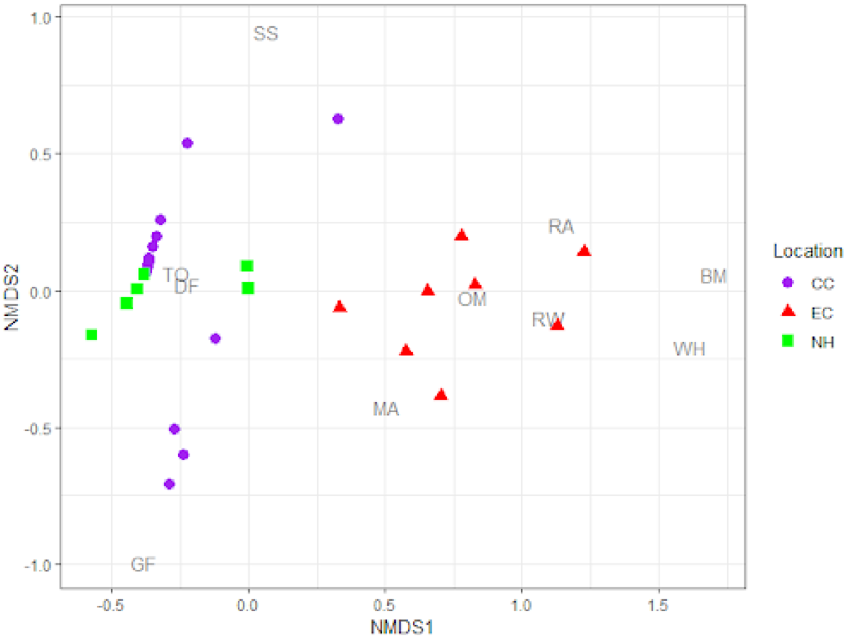


Figure 3: An NMS of plot ordinated in species space. Points represent individual plots and point shape and color corresponds to location. Tree species are abbreviated to two characters. TO = tanoak, DF = Douglas-fir, GF = grand fir, OM = Oregon myrtle, RA = red alder, BM = bigleaf maple, RW = redwood, WH = western hemlock, MA = Pacific madrone, SS = Sitka spruce.

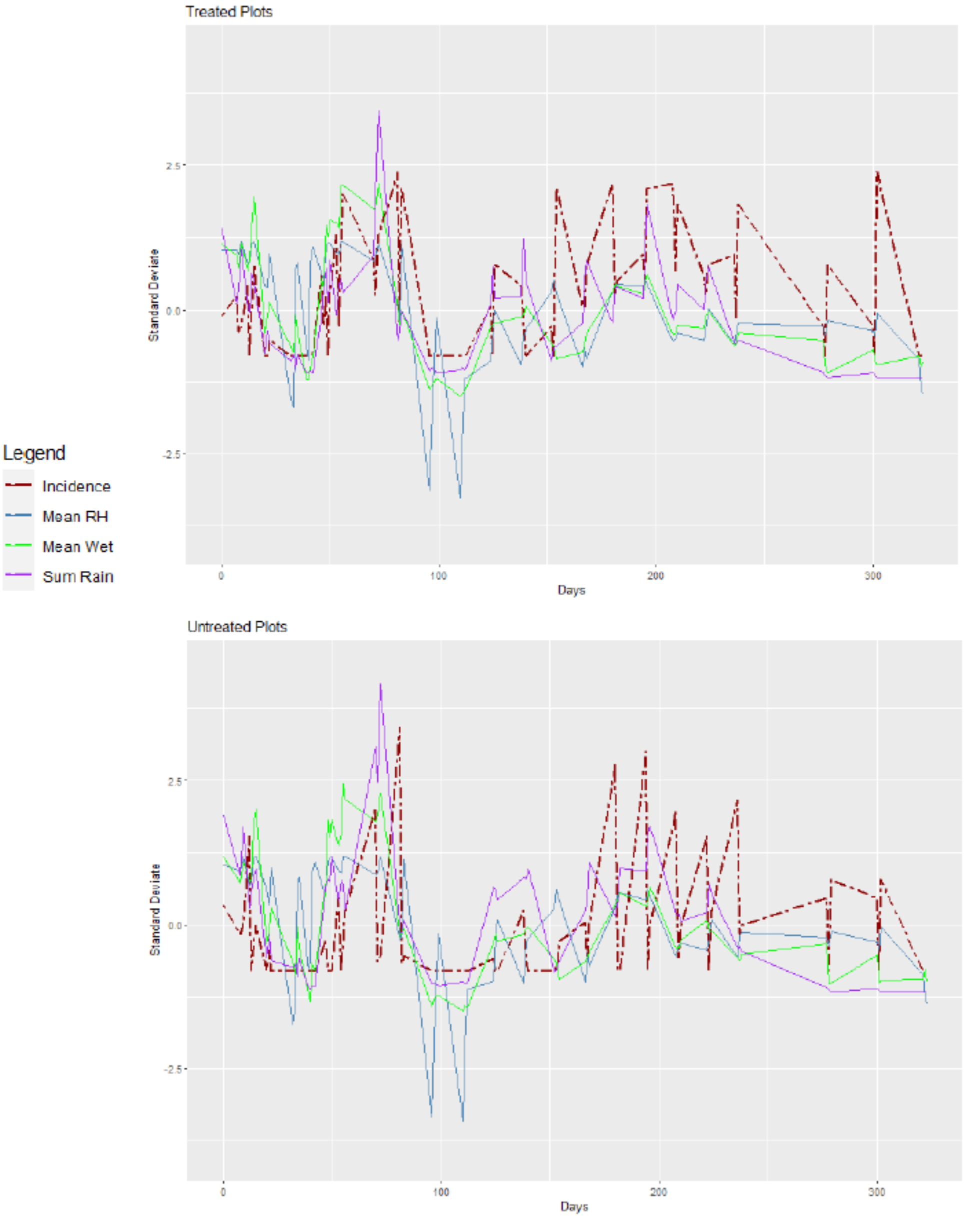


Figure 4: Time series plots of sporulation (incidence out of 9 leaves) and weather variables in treated plots and untreated plots. Variables were relativized by standard deviate. Days range from 10/26/21 to 9/15/22.

Foliar fungal communities of Pacific madrone (*Arbutus menziesii*) in Washington and Oregon

Marianne Elliott[1]*, Gary Chastagner[1], and Richard Sniezko[2]

Pacific madrone (*Arbutus menziesii* Pursh., Ericaceae) occurs from coastal BC, Canada to Southern CA, USA. Recent vegetation survey (CVS) data of 22 species on Forest Service lands show decline of madrone at levels comparable to western white pine and whitebark pine (Lintz et al. 2016). Range-wide common garden tests partially funded by FHP were established in 2011-2012 to investigate relative contributions of biotic and abiotic stresses to Pacific madrone decline. The common garden sites have different climate conditions and show variable mortality and leaf blight severity. While monitoring surveys document the extent of diseases and pests, common gardens can identify how and why causes and severity of health problems vary across large geographic ranges, including genetic variation among seed sources (Bullington et al. 2018).

Foliar blight and leaf spot on madrone (Figure 1) can be very severe in some years and locations (Figure 2), with most of the foliage on the tree being symptomatic and, in some cases, leading to mortality of the terminal buds. Many fungi have been identified from symptomatic foliage but it is unclear which ones are associated with these symptoms and which are endophytes, or decomposers associated with senescent foliage. In this project we collected foliar samples from families HC2 (Happy Camp, CA, high leaf blight ratings in previous surveys) and OR1 (Cornelius, OR, low blight ratings) from the four US common garden sites (SO, SF, PH, PV, Figure 3) for identification of fungal pathogens and endophytes. Samples were collected in June 2021 from current year and newly emerging foliage on 8 trees per site. Two methods were used to identify fungi present in foliage, metabarcoding (PacBio long read sequencing, Runnel et al. 2022) and identification using morphological and culture methods, followed by Sanger sequencing of pure cultures. For both methods, the ITS region of the ribosomal DNA was amplified using primers ITS6 (GAAGGTGAAGTCGTAACAAGG) and ITS4 (TCCTCCGCTTATTGATATGC).

Figure 1: A madrone tree in Washington with severe leaf blight involving the entire canopy in May, 2011.

---

[1] Washington State University, Puyallup Research and Extension Center; Puyallup WA 98371
[2] Dorena Genetic Resource Center, USDA Forest Service; Cottage Grove, OR 97424
*melliott2@wsu.edu

Figure 2: Leaf blight (yellow arrow) and leaf spot (red arrows) on current year madrone foliage and leaf spot (red arrow) on newly emerging foliage at the PV common garden site.

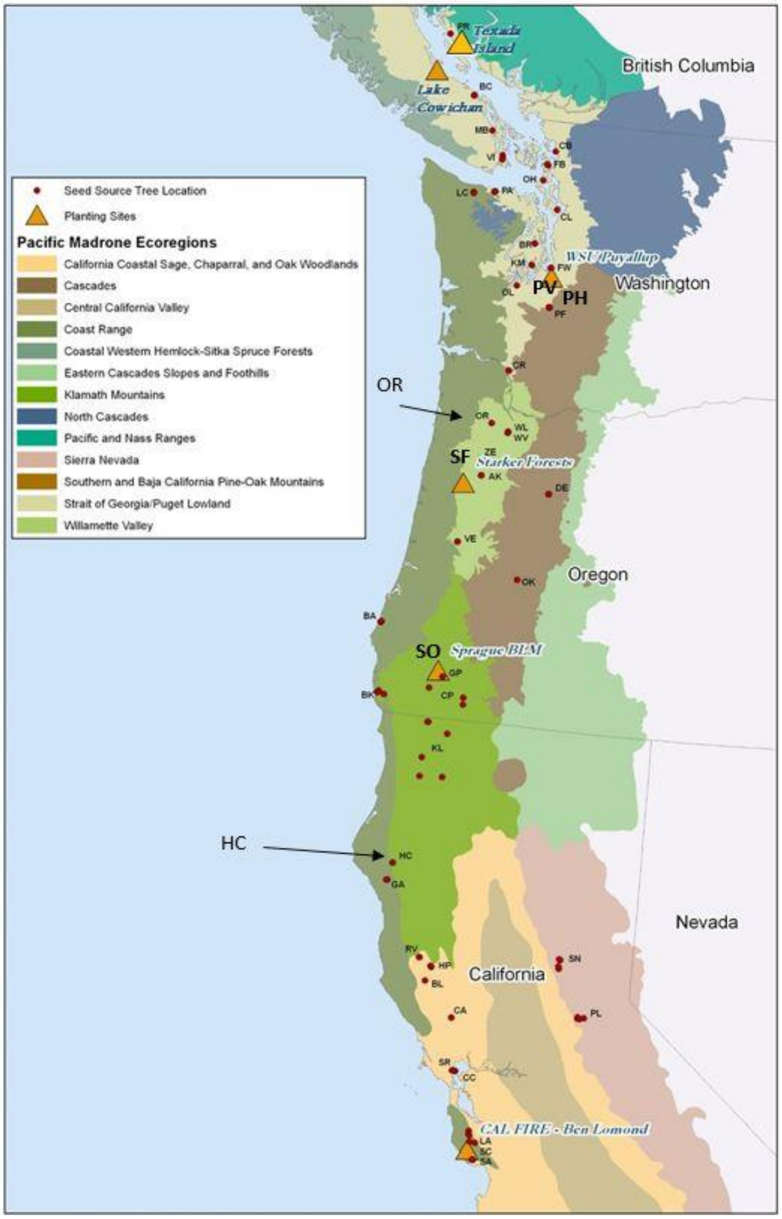


Figure 3: Locations of the six madrone common garden sites. Madrones at the four sites in WA and OR (PV, PH, SF, SO) were sampled in this project. Foliage from two families (OR and HC, arrows) was collected in June 2021.

Initial examination of the data indicates that fungal communities are similar at the three northernmost sites (PV, PH, and SF) and different at the southernmost site (SO) (Figure 4). Fewer fungi were present in newly emerging foliage than in current year foliage at all sites. There was no difference in fungal communities between samples taken from the high (HC2) and low (OR1) blight families at the two Washington sites (PH and PV) and at the central Oregon site (SF), but there were some differences between families at the southern Oregon (SO) site. This trend will be explored further, including the effect of seasonal differences in foliar fungi at a given site. There was some overlap between species isolated into culture and those identified by metabarcoding. However, some species such as those in the Rhytismataceae and Mycosphaerellaceae that may be slow-growing or not culturable, were present in large numbers in the metabarcoded samples but were not isolated into culture. Based on signs, symptoms, and examination of fruiting structures, leaf spot is most likely caused by a species of *Mycosphaerella* or *Chuppomyces* (Mycosphaerellaceae), and the tar spot at SO is likely caused by a species of *Coccomyces* (Rhytismataceae) (Figure 5). It is unclear which organism is primarily responsible for the leaf blight commonly seen at the two WA sites (PH and PV). Fungi in the Phacidiaceae (*Phacidiopycnis* and *Allantophomopsis*) and Diaporthales (*Diaporthe* and *Phomopsis*) have been isolated from leaf blight symptoms and were also present in the metabarcoded samples. *Phacidiopycnis washingtonensis* has previously been shown to be pathogenic on Pacific madrone (Elliott et al. 2014).

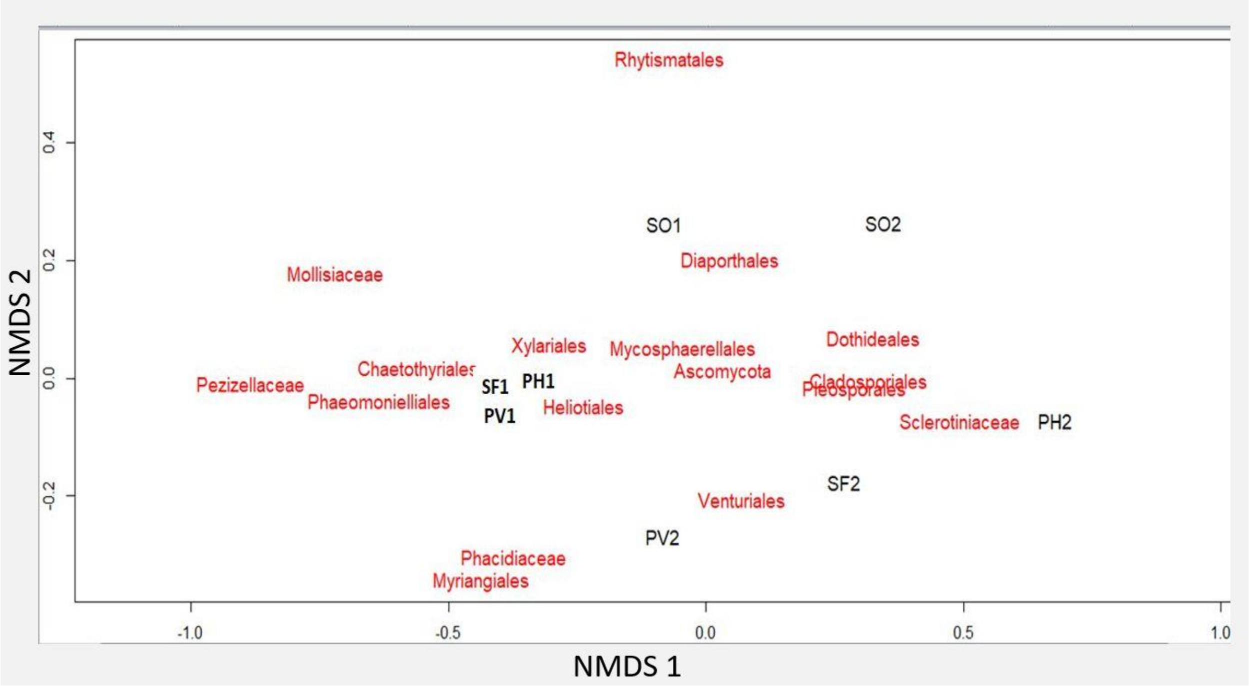


Figure 4: Non-metric multidimensional scaling (NMDS) for fungal communities in Pacific madrone foliage from the four US common garden sites (PV, PH, SF, SO). One year old and emerging foliage were sampled, indicated by 1 (current year foliage) or 2 (newly emerging foliage). Orders and families of ascomycete fungi with the highest frequency of occurrence are shown.

Figure 5: Underside of madrone leaf from the southern Oregon site (SO) with lesions and fruiting bodies of a tar spot fungus (*Coccomyces* sp.)

Acknowledgements

Funding support from USFS Evaluation Monitoring WC-EM-18-02 Agreement 20-CA-11062765-709, McIntire Stennis WNP0009 Project, and from Cal Van Zee. We also acknowledge WSDA Plant Pathology/Molecular Diagnostics lab and staff from WSU and USFS labs for technical assistance.

Literature Cited

Bullington, L.S., Lekberg, Y., Sniezko, R. and Larkin, B., 2018. The influence of genetics, defensive chemistry and the fungal microbiome on disease outcome in whitebark pine trees. *Molecular plant pathology*, *19*(8), pp.1847-1858.

Elliott, M., Chastagner, G.A., Coats, K.P., Sikdar, P. and Xiao, C.L., 2014. First report of a new leaf blight caused by *Phacidiopycnis washingtonensis* on Pacific madrone in western Washington and Oregon. *Plant Disease*, *98*(12), pp.1741-1741.

Lintz, H.E., Gray, A.N., Yost, A., Sniezko, R., Woodall, C., Reilly, M., Hutten, K. and Elliott, M., 2016. Quantifying density-independent mortality of temperate tree species. *Ecological indicators*, *66*, pp.1-9.

Runnel, K., Abarenkov, K., Copoț, O., Mikryukov, V., Kõljalg, U., Saar, I. and Tedersoo, L., 2022. DNA barcoding of fungal specimens using PacBio long-read high-throughput sequencing. *Molecular Ecology Resources*, *22*(8), pp.2871-2879.

Detecting biological invasions with sentinel plantings at ports and urban points of dispersal in Washington State

Marianne Elliott[1]*, Joseph Hulbert[1], Todd Murray[1], and Gary Chastagner[1]

Ports of commerce are important bottlenecks in biological invasion pathways (McCullough et al. 2006). Monitoring plants near ports promotes the early detection of forest pests and pathogens, but surveillance capacity is limited and novel invasions can be undetected. When an introduction occurs, detecting the pest or pathogen before it establishes and spreads is critical for limiting its potential impacts on forests in the United States.

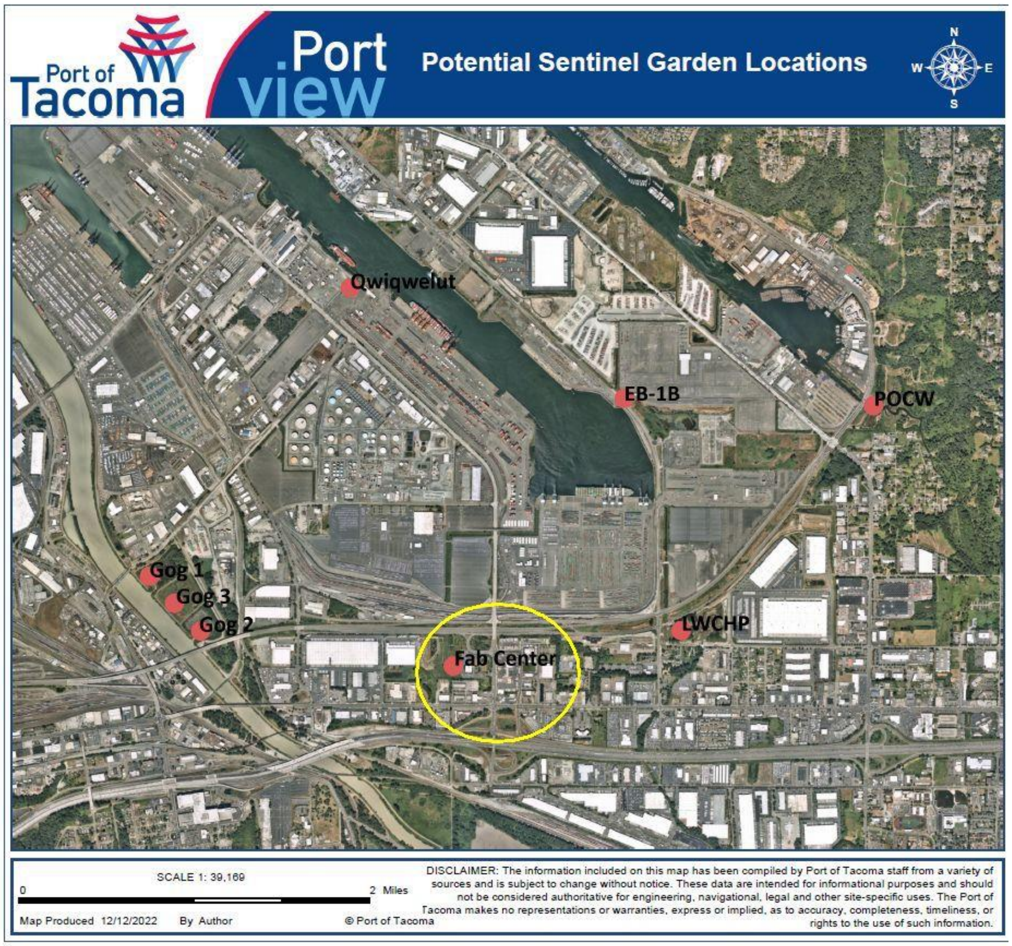
Washington state has many ports of entry, including major seaports in Seattle and Tacoma. Each year, high risk materials such as live plants, wood products, solid wood packing material, and other protected structures for hitchhiking pests travel through these ports. These ports have been and continue to be possible sources of new introductions because they receive high-risk materials from diverse sources, including many countries in Asia. Seattle and Tacoma are also widely surrounded by forest ecosystems with moderate climates suitable for many pests and pathogens. However, because they are located near urban population centers, there is great opportunity for engaging urban communities in biosurveillance to add capacity for early detection of new pests and pathogens (Hulbert et al. 2017).

Starting at the Port of Tacoma, WSU is establishing plantings of important northwest trees and shrubs to monitor for the potential arrival of invasive forest pests and diseases (Figure 1). The Port of Tacoma identified eight potential sites for the sentinel garden (Figures 2 and 3). In addition to the Port of Tacoma, an existing sentinel garden site at the City of Tacoma Green Waste Transfer Station will be expanded as part of this project. A sentinel garden which will be primarily used for training and educational purposes will also be established at the WSU Puyallup Research and Extension Center (WSU-PREC).

Figure 1: Aerial view of the Port of Tacoma (photo source: Tacoma News Tribune)

---

[1] Washington State University, Puyallup Research and Extension Center, Puyallup, WA, USA
*melliott2@wsu.edu



DISCLAIMER: The information included on this map has been compiled by Port of Tacoma staff from a variety of sources and is subject to change without notice. These data are intended for informational purposes and should not be considered authoritative for engineering, navigational, legal and other site-specific uses. The Port of Tacoma makes no representations or warranties, express or implied, as to accuracy, completeness, timeliness, or rights to the use of such information.

Figure 2: Aerial photo of proposed sites for a sentinel garden at the Port of Tacoma, WA. A 1-acre site at the circled “Fab Center” was selected for establishment of the garden.

Figure 3: Plants at other sites, such as the nearby LWCHP restoration site, will potentially also be monitored.

Stakeholders were asked to determine priority plants that will be included in the Port and WSU-PREC planting sites. The goal was to have economically, culturally, and ecologically regionally important species in the plantings. Respondents prioritized and suggested plant species to include in the plantings. These responses were ranked and weighted to score each species. In addition, there was space for host plants not on the survey list to be suggested. Survey responses for high priority insect pests and plant pathogens to be monitored in the sentinel gardens, and their primary forest hosts are presented in Tables 1 and 2. Some trees such as *Prunus* spp. and *Malus* spp. are also important agricultural hosts in WA.

Table 1: High priority insect pests and their primary hosts identified by stakeholders in the survey for monitoring in the sentinel gardens.

Insect Pests	Primary Hosts
Coleoptera	
Ambrosia beetles	
Mediterranean oak borer (Xyleborus monographus)	Oaks
Exotic bark beetles	
Emerald ash borer (Agrilus planipennis)	Ash
Asian longhorn borer (Anoplophora glabripennis)	Hardwoods
Citrus longhorn beetle (Anoplophora chinensis)	Citrus, apple, poplar, willow
Monochamus spp.	Conifers
Longhorned beetles (Callidiellum/Callidium spp.)	Conifers
Red-necked longhorn beetle (Aromia bungii)	Prunus spp.
Hemiptera	
Scales, aphids, and other sucking insects	Many woody hosts
Elongate hemlock scale (Fiorinia externa)	Conifers (hemlock, fir, spruce)
Spotted Lanternfly (Lycorma delicatula)	Tree of Heaven, many other secondary hosts
Brown marmorated stink bug (Halyomorpha halys)	Malus and Prunus
Lepidoptera	
Spongy moth (Lymantria dispar)	Hardwoods

Table 2: High priority plant pathogens and their primary hosts identified by stakeholders in the survey for monitoring in the sentinel gardens. Some of these pathogens are already present in WA and others, such as ash dieback (*Hymenoscyphus fraxineus*) are not.

Pathogens	Primary Hosts	Insect vectored
Bacterial pathogens	Oaks, Horse chestnut (Aesculus hippocastanum)	x
Candidatus Phytoplasma	Many hosts	x
Oomycetes		
Phytophthora spp.	Larch	
Phytophthora alni	Alders	
Phytophthora kernoviae	Many woody hosts	
Phytopthora ramorum	Many woody hosts	
Phytopthora cinnamomi	Many woody hosts	

Fungi		
Laurel wilt (Raffaelea spp.)	Oaks, Lauraceae	x
Ash dieback (Hymenoscyphus fraxineus)	Ash	
Oak wilt (Bretziella fagacearum)	Oaks	x
Sooty bark disease (Cryptostroma corticale)	Maples	
Dutch elm disease (Ophiostoma novo-ulmi)	Elms	x
Nematodes		x
Beech leaf disease (Litylenchus crenatae)	Beech	

The WSU-PREC sentinel garden will be used as a training site for workshops and demonstrations. The gardens near the port and transfer station will be priority monitoring sites for staff and partners. Community scientists will be engaged to monitor vegetation (including mature trees) nearby and beyond priority gardens.

Plantings will be monitored for signs and symptoms of pests and diseases. In collaboration with WSDA, insect traps (e.g. Lindgren funnel traps) will also be installed and screened at each site. A combination of morphometric and molecular approaches will be used to confirm the identity of pathogens causing disease on symptomatic plants (Munck and Bonello 2018). Partnerships will be leveraged for pest ID or diagnostics where needed.

The overall goals of this project are to establish sentinel plantings and develop educational programming for communities near Tacoma, then expand the approaches to other port cities in the Pacific Northwest. Major objectives to achieve these goals include: 1) establishing and demonstrating a sentinel planting approach, 2) conducting general surveys and sampling for exotic insects and diseases, including non-regulated species, 3) incorporating education and community science in monitoring, and 4) measuring the immediate and longer-term impacts of outreach on the effectiveness of early detection.

Acknowledgements

Funding provided by USDA Forest Service International Programs; McIntire Stennis WNP0009 Project.

Special thanks to those who answered the survey and the Port of Tacoma for making potential sites available for the project, as well as the support from WSDA, WA Invasive Species Council, and the City of Tacoma.

Literature Cited

Hulbert, J.M., Agne, M.C., Burgess, T.I., Roets, F. and Wingfield, M.J., 2017. Urban environments provide opportunities for early detections of Phytophthora invasions. *Biological invasions*, *19*, pp.3629-3644.

McCullough, D.G., Work, T.T., Cavey, J.F., Liebhold, A.M. and Marshall, D., 2006. Interceptions of nonindigenous plant pests at US ports of entry and border crossings over a 17-year period. *Biological invasions*, *8*, pp.611-630.

Munck, I.A. and Bonello, P., 2018. Modern approaches for early detection of forest pathogens are sorely needed in the United States. *Forest Pathology*, *48*(5), p.e12445.

Identification of the sooty bark pathogen (*Cryptostroma corticale*) from hosts in multiple states

Marianne Elliott[1]*, Joseph Hulbert[1], Collin Marshall[1], and Gary Chastagner[1]

Sooty bark disease of maple, caused by the fungus *Cryptostroma corticale*, has emerged as a forest health concern due to the number of new reports, its recovery from novel hosts, and its risk to human health. In 2020 Seattle Parks and Recreation detected *C. corticale* from unhealthy living trees in the Seattle metropolitan area with confirmation by sequencing from Bartlett Tree Research Laboratories and the WSU Puyallup (WSUP) laboratory. The term 'sooty bark disease' refers to the mats of black fungal spores produced by this pathogen within the bark of infected trees. These fruiting bodies develop on dead or dying portions of the tree, where the bark blisters and then the top layer of the bark flakes off and exposes the dark brown, gray, or black fruiting bodies (Figure 1). These discolored patches, which produce spores, may appear dusty (when large numbers of spores are being actively released) or solid and firm. Over time the fruiting bodies can become lighter in color. While rare, when some people inhale spores of *Cryptostroma corticale*, a hypersensitivity reaction called Maple Bark Disease may occur that affects their respiratory system. Internal staining from sooty bark disease may be observed after felling symptomatic trees or branches (Figure 2). However, internal staining of wood can be a symptom of infection by several other pathogens.

---

[1]Washington State University, Puyallup Research and Extension Center; Puyallup, WA, USA
*melliott2@wsu.edu

Figure 1: Fruiting bodies of *C. corticale* exposed after bark sloughed off on declining/dead stems of bigleaf maple.

Figure 2: Stained wood in trees with sooty bark symptoms. Staining can also be caused by other pathogens.

A total of 351 samples were processed by WSU in 2021 and 2022. Overall, 67% of the samples were positive for *C. corticale* using nested PCR (Kelnarová et al. 2017). Raising awareness about the issue through outreach activities resulted in the submission of samples from tree professionals in the cities throughout the northwest and many other states. Samples have been confirmed PCR positive from nine states and 20 broadleaf host genera. In addition to nested PCR, diagnostic methods included isolation into culture, and observation of spores from symptomatic host material on some samples.

Isolation of *C. corticale* into culture was attempted on approximately half of the submitted samples and has been focused on samples from new hosts and locations so that cultures are available for further study, including population genetic studies and completing Koch's Postulates. Symptomatic bark, wood, or asymptomatic cores were surface sterilized and plated onto potato-dextrose agar amended with streptomycin and chloramphenicol. Fast-growing colonies resembling *C. corticale* were isolated onto PDA plates and identity of the fungus was confirmed with sequencing the ITS region. Recovery of *C. corticale* was low (16%), possibly due to the presence of competing fungi such as *Trichoderma* spp. in the substrate. Other fungi such as *Diplodia* spp. and a closely related, undescribed *Biscogniauxia* species were also present. Selected isolates were placed into the WSU culture collection.

Recent PCR results have identified diverse, potentially new hosts including bigleaf maple, red maple, Pacific dogwood and horse chestnut, with a wide distribution across North America. Although Koch's postulates need to be completed, all hosts are novel reports for the state of Washington, and there are no reports of this pathogen on many of these hosts within the literature. Drought stress has been shown to increase the virulence of *C. corticale* in maple trees in Europe. Given the increasing frequency of hot, dry summers in many areas, more research into the potential impacts and link between the continued emergence of this disease and anticipated longer and hotter summer droughts is needed. To obtain a better understanding of the geographic and host range for sooty bark disease, a project on iNaturalist has been established for reporting observations:

https://www.inaturalist.org/projects/sooty-bark-disease-watch

Acknowledgements

Funding provided by USDA Forest Service: Region 6 Emerging Pest Investigation: Survey and Detection Program; WA DNR Community Forestry Assistance Program; McIntire Stennis WNP0009 Project.

A special thanks to the organizations and individuals who helped support this work by submitting suspected sooty bark disease samples.

Literature Cited

Kelnarová I, Černý K, Zahradník D, Koukol O (2017) Widespread latent infection of *Cryptostroma corticale* in asymptomatic *Acer pseudoplatanus* as a risk for urban plantations. Forest Pathology 47:e12344. https://doi.org/10.1111/efp.12344

Brooks, R., Hulbert, J., Elliott, M., Omdal, D., and Chastagner, G. 2022. Sooty bark disease diagnostic guide. FS325E, WSU Extension. https://pubs.extension.wsu.edu/sooty-bark-disease-diagnostic-guide

Using TLS to quantify the spread of root disease in California's Sierra Nevada Mountains

Alexander Flores[1]*, Elliott Smeds[1], Richard Cobb[2], and Lisa Patrick Bentley[1]

Introduction

This research focuses on Heterobasidion spp., common fungal root pathogens of conifers, known for their global prevalence and impact on forest ecosystems. The spread of these pathogens occurs through root contact or spore dispersal, resulting in the formation of gaps in affected areas. These gaps, indicative of disease severity over a 50-year period, are the focal point of our study within the Plumas National Forest, specifically targeting H. irregulare (Figure 1). Advancements in terrestrial remote sensing, particularly Terrestrial Lidar Scanning (TLS), offer a novel approach to understanding H. irregulare gap patterns. While aerial lidar data has traditionally been employed for measuring forest canopies, TLS enables the capture of explicit 3D imagery, providing insights into changes from ground to canopy levels. Our experimental approach involves using TLS scans on H. irregulare infected and non-infected plots, comparing structural characteristics to discern alterations at varying distances from the plot center through concentric circles.

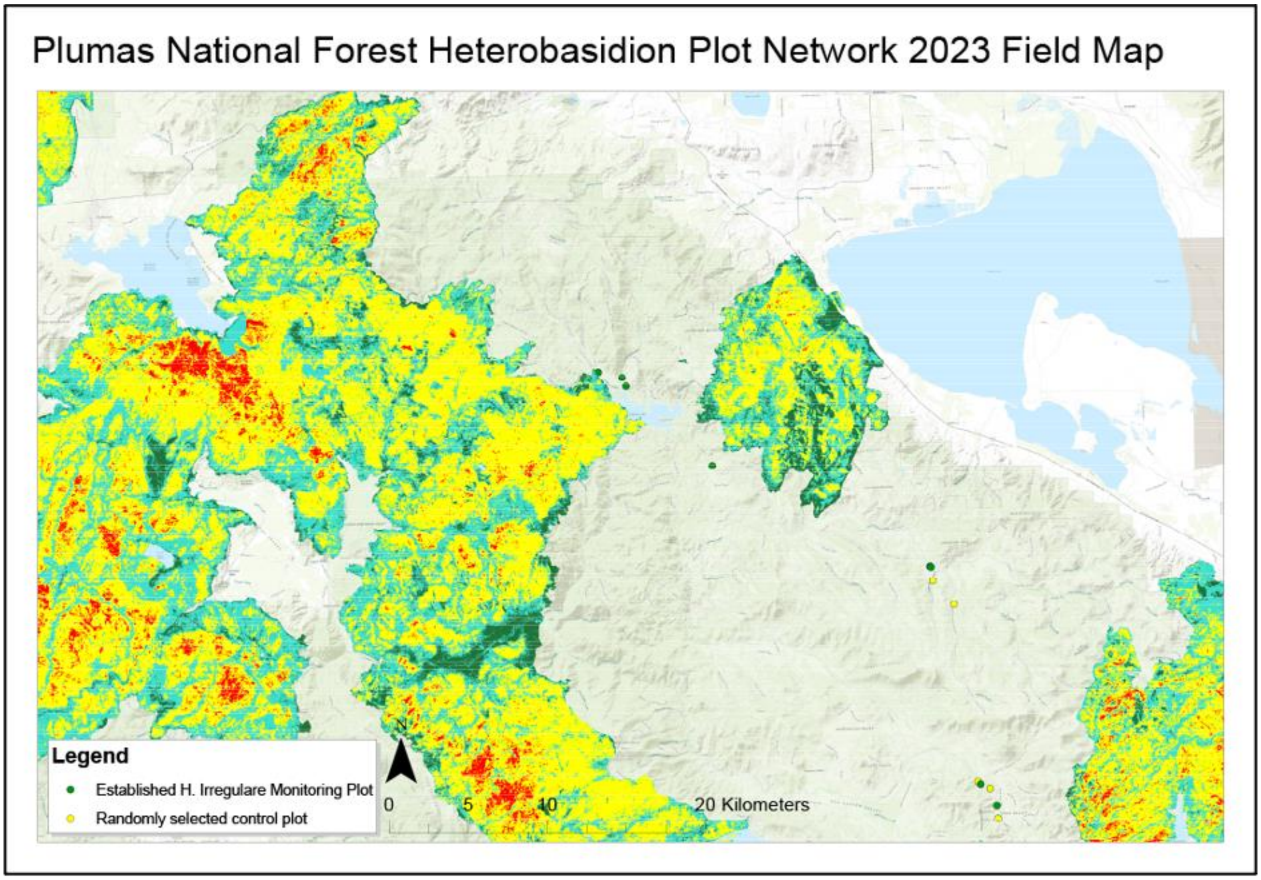


Figure 1: Map of Plumas National Forest with Dixie fire footprint and *Heterobasidion* monitoring plots.

Use of Terrestrial Laser Scanning (TLS) in Forestry

The conversion of TLS point cloud data into volumetric pixels, or voxels, allows for a quantitative analysis of structural differences between infected and non-infected plots. The proof of concept is illustrated through the

---

[1] Sonoma State University; Rohnert Park, CA, USA
[2] Cal Poly,Natural Resources Management & Environmental Sciences; San Luis Obispo, CA, USA
*floredavid@sonoma.edu

analysis of point clouds from Saddle Mountain Open Space Preserve in Sonoma County, CA, utilizing a concentric clipping method. Although these plots were not specifically designed to capture disease effects over time, the method showcases the potential of identifying Heterobasidion disease gaps through the measurement of voxel occupancy, as depicted in Figure 2.

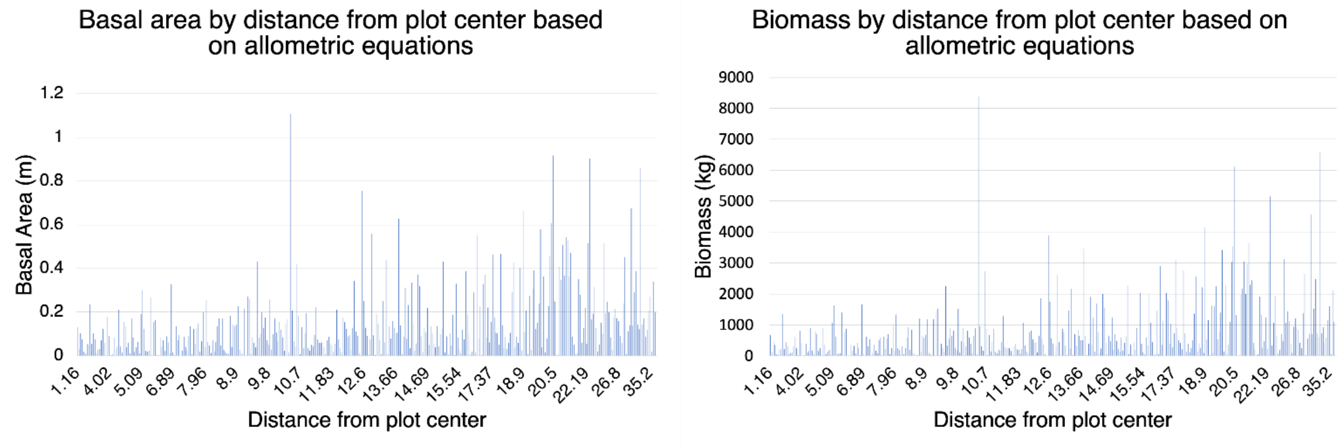


Figure 2: Tree basal area and biomass outward from *Heterobasidion* monitoring plot centers.

Future Applications of TLS in

To ascertain inflection points in disease spread, data collected from previous measurements serve as a baseline for identifying changes in tree density, basal area, and biomass (Figure 3). These metrics inform the voxel occupancy analysis, contributing to a comprehensive understanding of how H. irregulare impacts the forest structure over time. The integration of TLS and voxel occupancy analysis holds promise for identifying and monitoring the extent of Heterobasidion disease gaps in conifer forests, providing valuable insights for effective forest management and conservation efforts.

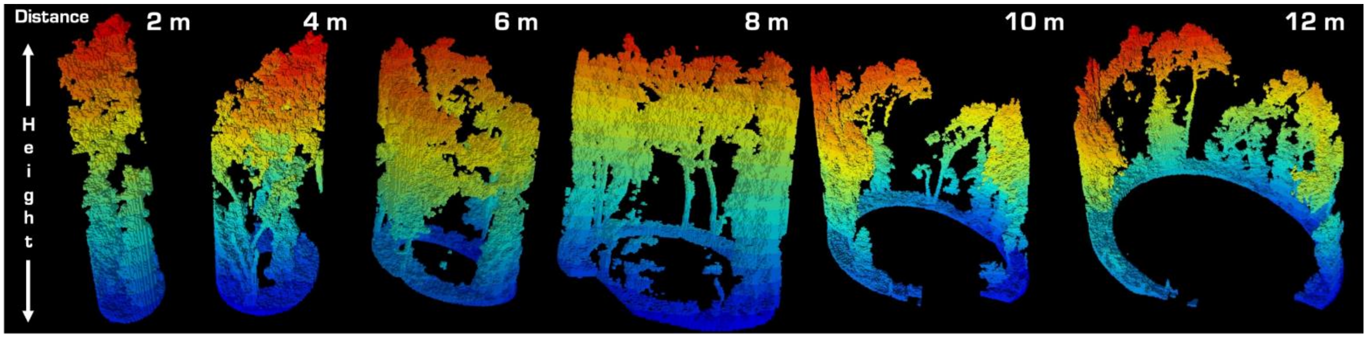


Figure 3: Voxelized LiDAR scan of a 12 meter monitoring plot at Saddle Mountain Open Space Preserve in Sonoma County, CA .

Does biotech disturb a tree's microbiome?

Michael I. Gordon[1]*, Steven H. Strauss[1,3], Jared M. LeBoldus[2], and Posy E. Busby[2]

Sphaerulina musiva is now in the northwestern United States where little natural resistance to Sphaerulina stem canker exists amongst native black cottonwoods. Resistance could be rapidly engineered with an emerging biotechnology known as 'HIGS' or host-induced gene silencing. HIGS is a transgenic crop protection strategy that uses conserved RNA interference (RNAi) pathways to target essential genes of pathogens or pests. HIGS is thought to be highly specific to the targeted organism due to the mechanism of RNAi. For HIGS to be effective, RNA signals from the host must be taken up by the target organism. Given that uptake of HIGS silencing RNAs is not limited to the target organism, HIGS must be designed carefully to avoid non-target effects on beneficial organisms that may ingest silencing RNAs. Although HIGS has been demonstrated as effective in several pathosystems, to our knowledge, the specificity of HIGS against a fungal pathogen has never been evaluated empirically in a field trial. We were curious if HIGS in *Populus trichocarpa* against *S. musiva* would have any non-target effects on the fungal microbiome as determined by ITS metabarcoding methods. We were specifically interested in non-target effects on foliar endophytes, some of which are beneficial antagonists and moderators of disease —unintended impacts against which might cause negative consequences for overall tree health. Our experimental design also allowed us to see if the biotech methods themselves used to create HIGS transgenics—transformation, regeneration, and use of antibiotic markers and selection—had any effect on fungal community composition. Our results show that sterile micropropagation derived trees grown in a greenhouse are largely uncolonized after 50 days. Once established in the field, fungal communities are nearly as diverse as well-established trees after one season of growth. HIGS against *S. musiva* lacked a detectable effect on the composition of non-target foliar fungal communities of trees grown at field site where the target pathogen was not present. This result provides evidence that HIGS can be applied safely without risk to non-target fungi. Neither regeneration from single cells nor expression of selectable markers affected fungal communities either, suggesting that standard plant biotech methods are likely to have no lasting impact on the assembly of healthy fungal leaf microbiomes in *P. trichocarpa* once deployed to the field.

---

[1] Oregon State University, Molecular and Cellular Biology; Corvallis, OR, USA
[2] Oregon State University, Botany and Plant Pathology; Corvallis, OR, USA
[3] Oregon State University, Forest Ecosystems and Society; Corvallis, OR, USA
*michael.gordon@oregonstate.edu

Bioclimatic modeling of *Armillaria altimontana* in western North America

John W. Hanna[1]*, Mee-Sook Kim[2], Patrick I. Bennett[1], Geral I. McDonald[1], and Ned B. Klopfenstein[1]

Introduction

Relatively little is known about the ecology and distribution of *Armillaria altimontana* compared with some other *Armillaria* species in North America. After first being recognized as an unnamed North American Biological Species X based on mating tests (Anderson and Ullrich 1979), *A. altimontana* was subsequently formally described by Brazee et al. (2012). While *A. altimontana* is occasionally found as a pathogen causing Armillaria root disease, it is often only found in a saprophytic state as rhizomorphs on diverse coniferous and broad-leaved trees and shrubs. A previous study suggests that *A. altimontana* found in this saprophytic state may also function as an *in situ* biological control agent for Armillaria root disease caused by *A. solidipes* (Warwell et al. 2019). Subsequent studies have compared the *A. solidipes* and *A. altimontana* genomes and their associated soil microbiomes (microbial communities) to gain insights into their ecological functions (Ibarra Caballero et al. 2023). *Armillaria altimontana* occurs widely across the northwestern USA to southern British Columbia, Canada (Figure 1A). Efforts are underway to better understand the ecology and distribution of *A. altimontana*. Recently, bioclimatic modeling using MaxEnt (Maximum Entropy) have been used to model suitable climate for forest pathogens and their hosts (e.g., Klopfenstein et al. 2009, Stewart et al. 2017, Hanna et al. 2020, Kim et al. 2021, Kim et al. 2023). These models can be projected for different future time periods, using a combination of emissions scenarios and global circulation models, to predict suitable habitat (potential distribution) for a species under future-climate scenarios. Such information provides valuable insights into geographic regions where *A. altimontana* is predicted to potentially occur under various climate scenarios, which can guide forest management in decisions to promote desirable outcomes for forest ecosystems in the future.

Objectives

The objectives of this project are to (i) use survey data to evaluate and refine bioclimatic models for predicting the suitable climate space (the geographic area that is climatically suitable for a species' survival) for *A. altimontana*; and (ii) project this information to future time periods under different climate scenarios to better understand influences of changing climates on *A. altimontana* and associated microbes that may represent an important management tool to help protect forest ecosystems against Armillaria root disease caused by *A. solidipes*.

Methods

For this study, MaxEnt bioclimatic modeling (Phillips et al. 2006) was coupled with 139 GPS locations of DNA sequence-confirmed *A. altimontana*, collected from basidiocarps, wood samples, mycelial fans, and rhizomorphs, to produce models that predict its suitable climate space/potential distribution (Figure 1A, Figure 2A-D). MaxEnt bioclimatic modeling and evaluation methods largely followed the protocol of Kim et al. (2021, 2023), in which WorldClim version 2.1 (Fick and Hijmans, 2017) provided 19 bioclimatic variables that were used in the species distribution model for *A. altimontana* under the contemporary (1970–2000) time period (Figure 1B). The model was computed from 20 replicate runs using cross-validation and scored an average area under curve (AUC) score of 0.978 with a standard deviation of 0.010. An AUC score of 1 represents a perfect model, while values below 0.5 are worse than random.

---

[1] USDA Forest Service, RMRS; Moscow, ID, USA
[2] USDA Forest Service, PNWRS; Corvallis, OR, USA
*john.w.hanna@usda.gov

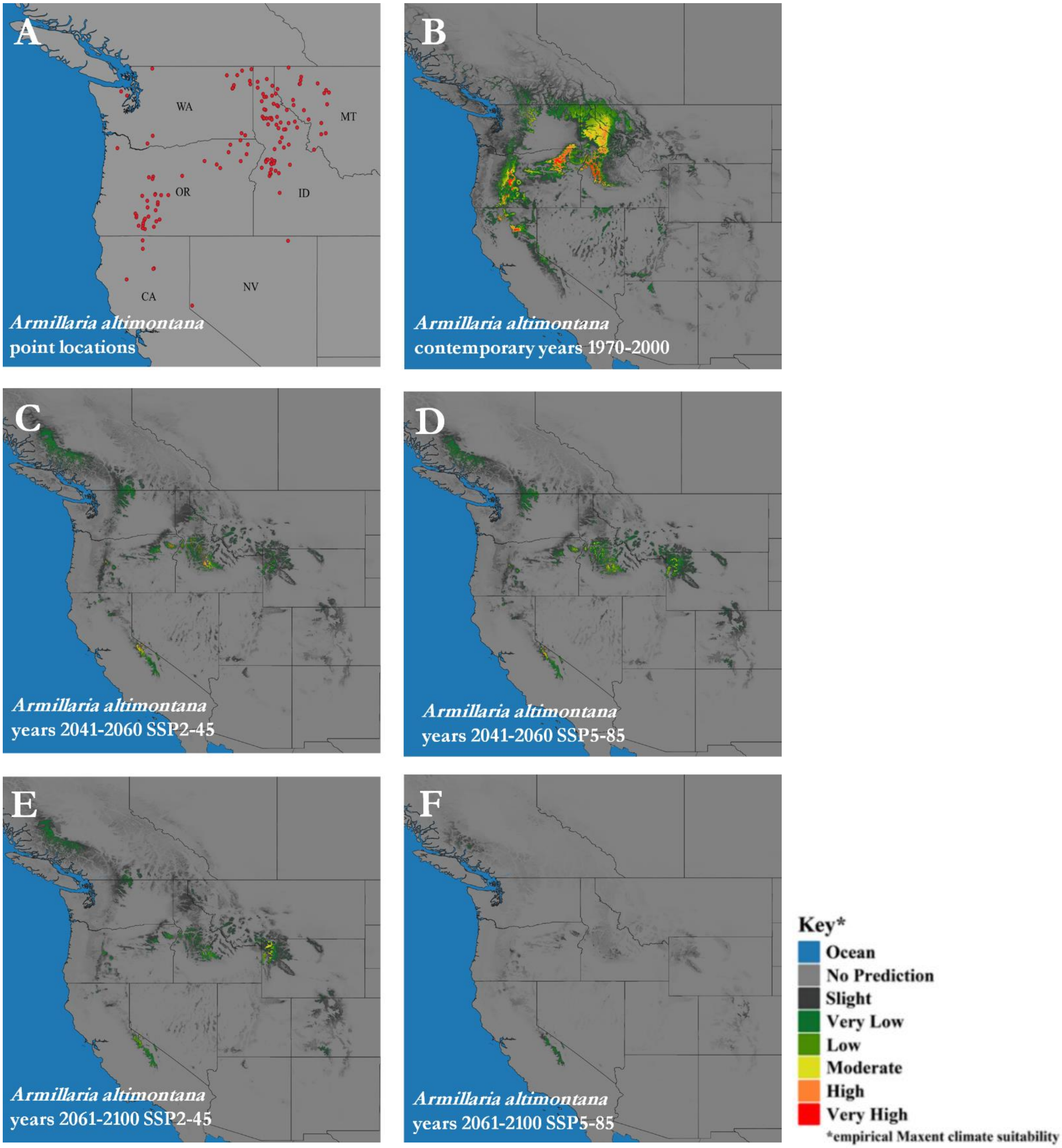


Figure 1A-F: A: *Armillaria altimontana* GPS point locations used for the models, where the presence of *A. altimontana* has been confirmed using DNA-based identification methods. B: Contemporary bioclimatic prediction model for the years 1970–2000. C-F: Bioclimatic predictive distribution models based on two future climate emissions scenarios (SSP2-45 and SSP5-85) and projected for two future time periods (years 2041–2060 and years 2061–2100) using 30-sec resolution (~1 km) CMIP6 downscaled data (WorldClim v2.1). Derived from Kim et al. (2023).

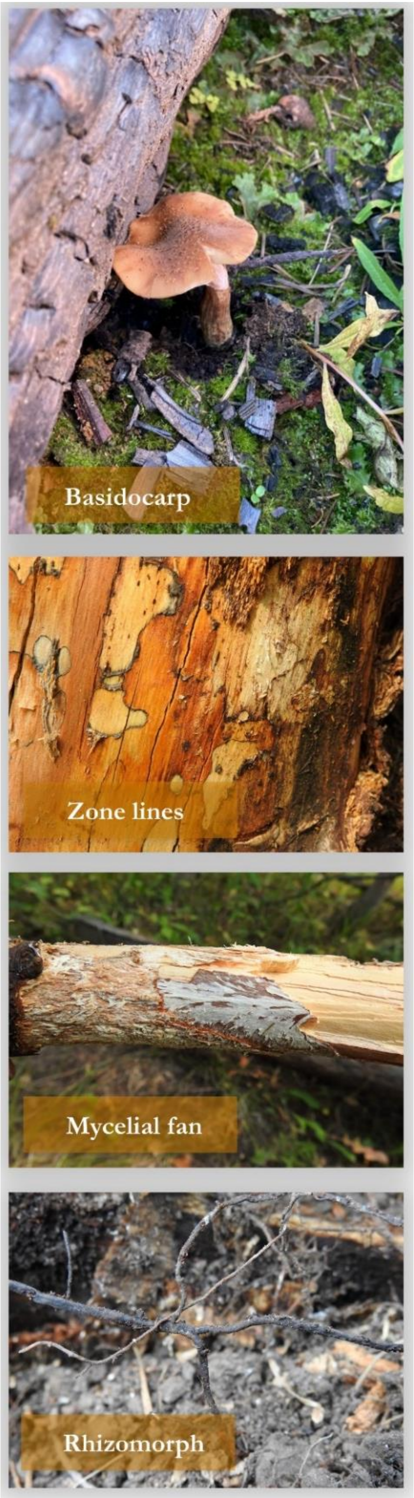


Figure 2: Signs of *Armillaria altimontana*. Derived from Kim et al. (2023).

Predictive distribution models based on future-climate scenarios were also projected for two future time periods (years 2041–2060 and years 2061–2100) using 30-second (ca, 1-km) resolution CMIP6 downscaled data (WorldClim v2.1) (Figure 1C-E). Two different Shared Socioeconomic Pathways (SSPs) were paired with the "Canadian Ocean Ecosystem model" (CanESM5-CanOE) GCM (Christian et al. 2022). In general, five SSPs narratives describe the broad socioeconomic trends that could shape future society, and we applied two scenarios: SSP2-4.5 ("middle of the road" world, where trends do not shift markedly from historical patterns) and SSP5-8.5 ("fossil-fueled development" that follows path of rapid and unconstrained growth in economic output and fossil fuel-based energy use) (Figure 3).

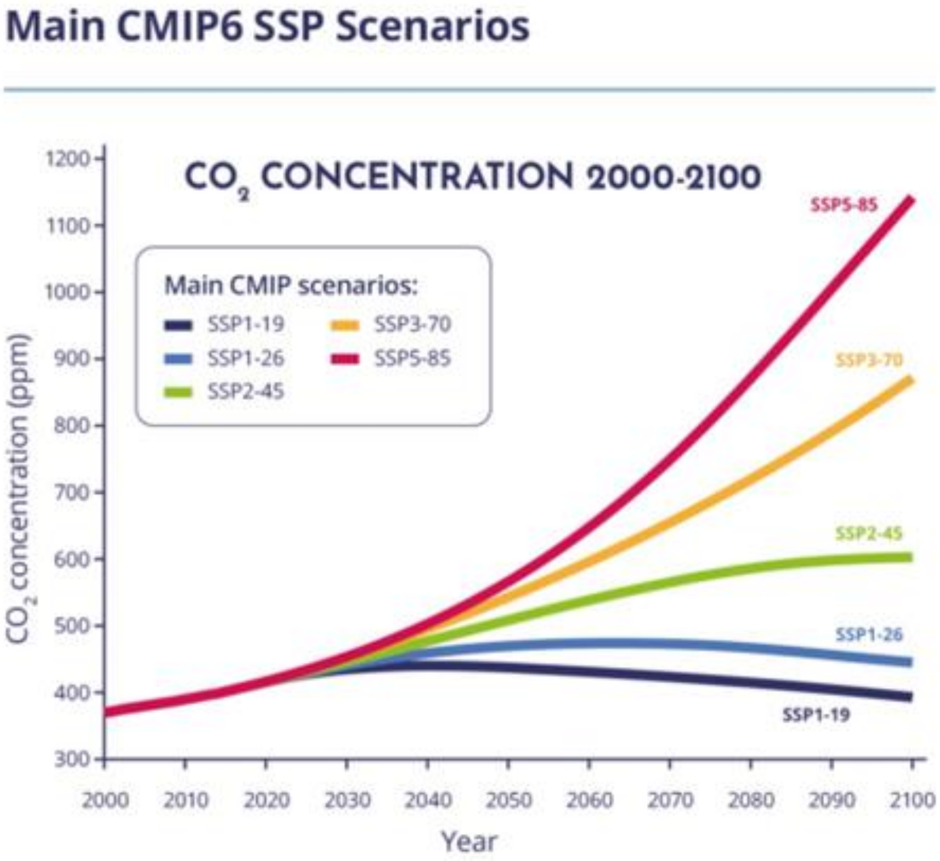


Figure 3: Comparison of CMIP6 SSP emissions scenarios. SSP2-45 (some carbon mitigation and a declining population) and SSP5-85 ("business as usual" scenario) were used for this study. From: "CONSTRAIN (2020) ZERO IN ON: A new generation of climate models, COVID-19 and the Paris Agreement," by D. Rosen, A. Nauels, K.B. Tokarska, C. McKenna, C.-F. Schleussner, J. Rogelj, and P. Forster, 2020, The CONSTRAIN Project Annual Report 2020, DOI:10.5281/zenodo.4282461. CC BY 4.0.

Results and discussion

The contemporary prediction from the MaxEnt bioclimatic models (Figure 1B) largely concur with the *A. altimontana* occurrence data found from surveys (Figure 1A). These predictions show a high probability of suitable climate space (potential distribution) for *A. altimontana* in diverse geographic areas, such as northwestern Montana, northern Idaho, northeastern Washington, northeastern Oregon, and the Oregon Cascade Mountains of the USA, and southern British Columbia, Canada. Interestingly, the projected range of *A. altimontana* overlaps the range of western white pine (*Pinus monticola*) in many areas. Based on the overlapping ranges and the mutualistic ecology of *A. altimontana* and western white pine, we hypothesize that these two ecosystem components may have a long co-evolutionary history; however, more in-depth studies are needed to examine this hypothesis. The results of the future models indicate that *A. altimontana* may have a substantially reduced range in the future, if the predicted models of future climate come to fruition (Figures 1C-F). Unfortunately, this trend parallels the predictions of many host species as well (Rehfeldt et al. 2006, Rehfeldt et al. 2009, Hanna et al. 2016, Kim et al. 2021). Climate mitigation measures must be a top priority to sustain future healthy forest ecosystems that have any resemblance to those of the present and past.

As previous work has demonstrated, *A. altimontana* can potentially function as an *in situ* biological control agent against Armillaria root disease caused by *A. solidipes* (Warwell et al. 2019). However, many questions remain about how to enhance biological control activities of *A. altimontana*. For the purposes of this discussion, widespread inoculation of forests with *A. altimontana* is deemed impractical, and the ecological requirements of *A. altimontana* must also be considered. Instead, activities to encourage *in situ* biological control of Armillaria root disease should focus on areas where *A. altimontana* (and associated beneficial microbes) and the pathogen (*A. solidipes*) already co-occur. First, surveys are needed to determine the geographic distribution and climatic/environmental requirements of the putative biocontrol agent (*A. altimontana*) and the Armillaria root disease pathogen (*A. solidipes*) for identifying areas/sites where the putative biocontrol agent(s) and pathogen naturally co-occur. Second, the ecological conditions where *A. altimontana* functions as a biological control agent must be better characterized. Third, the influence of interacting microbes and other ecosystem components must be better understood (e.g., Ibarra Caballero et al. 2023). With this information, management techniques can be developed to encourage *A. altimontana* and other beneficial microbes in sites where they co-occur with the pathogenic *A. solidipes*. Examples of management methods that should be evaluated for increasing biological control of Armillaria root disease include minimizing site disturbances, increasing organic matter in the soil, adjusting soil pH, increasing vegetation that serves as hosts for *A. altimontana* but not *A. solidipes* (e.g., hardwoods and shrubs), using prescribed burning, or other activities that could favor *A. altimontana* and/or suppress *A. solidipes*. Although more studies are needed to unleash the full potential of *in situ* biological control for Armillaria root disease by *A. altimontana* and associated microbes, the benefits of such studies are warranted because of the extensive mortality and growth loss associated with Armillaria root disease, which subsequently exacerbates climate change.

One long-term goal of studies toward understanding ecological interactions of *A. altimontana* is the development of novel, ecologically friendly approaches for forest management to reduce Armillaria root disease and increase forest productivity (C sequestration) and sustainability. Such studies can help determine which management activities (e.g., prescribed fire, organic matter retention, soil pH adjustments, favoring/planting appropriate tree species, thinning, etc.) will promote beneficial functions of *A. altimontana* and associated microbes, while decreasing detrimental activities of *A. solidipes* or other forest root pathogens, while also preparing for climate change.

Acknowledgements

This project was partially funded by USDA Forest Service (FS) State, Private, and Tribal Forestry, Forest Health Protection, Special Technology Development Program (R1-2020-02) and USDA FS R&D Rocky Mountain Research Station and Pacific Northwest Research Station. The authors would also like to thank M.V. Warwell, S.M. Ashiglar, J.B Donley, A. Smith, B.M. Lalande, and J.E. Stewart for their support on this project. 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.

Literature Cited

Anderson, J.B.; Ullrich, R.C. 1979. Biological Species of *Armillaria mellea* in North America. Mycologia 71: 402-414. http://www.jstor.org/stable/3759160

Brazee, N.J.; Ortiz-Santana, B.; Banik, M.T.; Lindner, D.L. 2012. *Armillaria altimontana*, a new species from the western interior of North America. Mycologia 104: 1200-1205. DOI: 10.3852/11-409

Christian, J.R.; Denman, K.L.; Hayashida, H.; Holdsworth, A.M.; Lee, W.G.; Riche, O.G.J.; Shao, A.E.; Steiner, N.; Swart, N.C. 2022. Ocean biogeochemistry in the Canadian Earth System Model version 5.0.3:CanESM5 and CanESM5-CanOE. Geoscientific Model Development 15(11): 4393-4424.

Fick, S. E.; Hijmans, R. J. 2017. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37: 4302–4315. doi: 10.1002/joc.5086

Hanna, J.W.; Smith, A.L.; Maffei, H.M.; Kim, M.-S.; Klopfenstein, N.B. 2009. Survey of *Armillaria* spp. in the Oregon East Cascades: Baseline data for predicting climatic influences on Armillaria Root Disease. pp. 53-59 in: Baker, F.A.; Jamieson, C.; Palacios, P., comps. Proceedings of the 56th Western International Forest Disease Work Conference; 2008 October 27-31; Missoula, MT. Logan, UT: Utah State University, Dept. of Wildland Resources. https://www.fs.usda.gov/rm/pubs_other/rmrs_2008_hanna_j002.pdf

Hanna, J.W.; Warwell, M.V.; Maffei, H.; Fairweather, M.L.; Blodgett, J.T.; Zambino, P.J.; Worrall, J.; Burns, K.S.; Jacobs, J.J.; Ashiglar, S.M.; Lundquist, J.E.; Kim, M.-S.; Ross-Davis, A.L.; Hoffman, C.; Mathiasen, R.; Hofstetter, R.; Shaw, J.D.; Pitman, E.W.I.; Nelson, E.V.; McDonald, G.I.; Cleary, M.R.; Brar, S.; Richardson, B.A.; Klopfenstein, N.B. 2016. Bioclimatic modeling predicts potential distribution of *Armillaria solidipes* and *Pseudotsuga menziesii* (Douglas-fir) under contemporary and changing climates in the interior western U.S.A. pp. 117-123 in: Ramsey, A.; Palacios, P., compilers. Proceedings of the 63rd annual Western International Forest Disease Work Conference. 21-25 September 2015, Newport, OR, USA. https://www.fs.usda.gov/rm/pubs_journals/2016/rmrs_2016_hanna_j001.pdf

Hanna, J.W.; Warwell, M.V.; Sitz, R.A.; Guyon, J.C.; Hebertson, E.G.; Saavedra, A.L.; Blodgett, J.T.; Kim, M.-S.; Stewart, J.E.; Ashiglar, S.M.; McDonald, G.I.; Klopfenstein, N.B. 2020. Toward DNA-based and bioclimatic modeling tools to identify *Armillaria* pathogens, predict host/pathogen distributions, and manage Armillaria Root Disease in the Intermountain Region (USA) under changing environments. pp.177-182 in: Reynolds, G.J.; Wilhelmi, N.P.; Palacios, P., comps. Proceedings of the 66th Western International Forest Disease Work Conference; 3-7 June 2019; Estes Park, CO. www.wifdwc.org https://www.fs.usda.gov/rm/pubs_journals/2020/rmrs_2020_hanna_j001.pdf

Ibarra Caballero, J.; Lalande, B.M.; Hanna, J.W.; Klopfenstein, N.B.; Kim, M.S.; Stewart, J.E. 2023. Genomic comparisons of two *Armillaria* species with different ecological behaviors and their associated soil microbial communities. Microbial Ecology 85: 708-729. https://www.fs.usda.gov/rm/pubs_journals/2022/rmrs_2022_caballero_j001.pdf

Kim, M.-S.; Hanna, J.W.; Stewart, J.E.; Warwell, M.V.; McDonald, G.I.; Klopfenstein, N.B. 2021. Predicting present and future suitable climate spaces (potential distributions) of and Armillaria root disease pathogen (*Armillaria solidipes*) and its host, Douglas-fir (*Pseudotsuga menziesii*), under changing climates. Frontiers in Forests and Global Change 4: 740994. https://www.fs.usda.gov/rm/pubs_journals/2021/rmrs_2021_kim_m001.pdf

Kim, M,-S.; Hanna, J.W.; McDonald, G.I.; Klopfenstein, N.B. 2023. *Armillaria altimontana* in North America: Biology and ecology. Journal of Fungi 9: 904. https://www.fs.usda.gov/rm/pubs_journals/2023/rmrs_2023_kim_m002.pdf

Klopfenstein, N.B.; Kim, M.-S.; Hanna, J.W.; Richardson, B.A.; Lundquist, J.E. 2009. Approaches to predicting potential impacts of climate change on forest disease: an example with Armillaria root disease. Res. Pap. RMRS-RP-76. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 10 p. https://www.fs.usda.gov/rm/pubs/rmrs_rp076.pdf

Phillips, S. J.; Anderson, R. P.; Schapire, R. E. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190, 231–259. doi: 10.1016/j.ecolmodel.2005.03.026

Rehfeldt, G.E.; Crookston, N.L.; Warwell, M.V.; Evans, J.S. 2006: Empirical analyses of plant-climate relationships for the western United States. *International Journal of Plant Sciences*167: 1123-1150.

Rehfeldt, G.E.; Ferguson, D.E.; Crookston, N.L. 2009. Aspen, climate, and sudden decline in western USA. Forest *Ecology and Management*258: 2353-2364.

Rosen, D.; Nauels, A.; Tokarska, K.B.; McKenna, C.; Schleussner, C.-F.; Rogelj, J.; Forster, P. 2020. CONSTRAIN (2020) ZERO IN ON: A new generation of climate models, COVID-19 and the Paris Agreement. The CONSTRAIN Project Annual Report 2020, DOI:10.5281/zenodo.4282461

Stewart, J.E.; Ross-Davis, A.L.; Graça, R.N.; Alfenas, A.C.; Peever, T.L.; Hanna, J.W.; Uchida, J.Y.; Hauff, R.D.; Kadooka, C.Y.; Kim M.-S.; Cannon, P.G.; Namba, S.; Simeto, S.; Pérez, C.A.; Rayamajhi, M.B.; Lodge, D.J.; Arguedas, M.; Medel-Ortiz, R.; López-Ramirez, M.A.; Tennant, P.; Glen, M.; Machado, P.S.; McTaggart, A.R.; Carnegie, A.J.; Klopfenstein, N.B. 2017. Genetic diversity of the myrtle rust pathogen (*Austropuccinia psidii*) in the Americas and Hawaii: Global implications for invasive threat assessments. Forest Pathology 48 (1): e12378. https://www.fs.usda.gov/nrs/pubs/jrnl/2017/nrs_2017_stewart-j_001.pdf

Warwell, M.V.; McDonald, G.I.; Hanna, J.W.; Kim, M.-S.; Lalande, B.M.; Stewart, J.E.; Klopfenstein, N.B. 2019. *Armillaria altimontana* is associated with healthy western white pine (*Pinus monticola*) planted in northern Idaho: Potential *in situ* biological control of the Armillaria root disease pathogen, *A. solidipes*. Forests 10(4): 294. https://www.fs.usda.gov/rm/pubs_journals/2019/rmrs_2019_warwell_m002.pdf

Ongoing surveys for *Armillaria* 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], Phil G. Cannon[9], and Ned B. Klopfenstein[1]

Introduction

Armillaria root disease (ARD) is among the largest causes of mortality and lost productivity in forests of the western USA (Lockman and Kearns 2016, Kim et al. 2022). In some forest areas of western North America, growth/volume losses between 16-55% have been attributed to ARD (Filip and Goheen 1984; Cruickshank 2011). Damage from ARD is expected to increase under climate change and extreme weather events (e.g., drought, temperature), because host tree stress can predispose trees to ARD (Klopfenstein et al 2009; Kim et al. 2021; Murray and Leslie 2021). Furthermore, ARD may predispose trees to beetle attack or other pathogenic fungi (e.g., Kulhavy et al. 1984, Tkacz and Schmitz 1986, Williams et al. 1986).

Studies suggest that *Armillaria* species play an important role in driving the structure and successional trajectories of California forests by reducing the abundance of tree species with higher susceptibility to ARD, while favoring more resistant or tolerant species (Hawkins and Henkel 2011). Currently, little is known about which *Armillaria* species are involved in these ecological processes in California or whether interactions occur among multiple *Armillaria* species. Wide-ranging *Armillaria* surveys using DNA-based identification methods have not been conducted in California since the early 2000s (e.g., Baumgartner and Rizzo 2001), when four *Armillaria* species were found to occur: *A. mellea*, *A. gallica*, *A. nabsnona*, and *A. altimontana* (as North American biological species X; Brazee et al. 2012). In recent decades, more reliable DNA-based methods have been developed for identifying *Armillaria* species, which can distinguish closely related *Armillaria* species, such as *A. gallica* and *A. sinapina* (Kim et al. 2006, Hanna et al. 2007, Ross-Davis et al. 2012, Klopfenstein et al. 2017).

Data from iNaturalist suggests that *Armillaria* is likely more abundant and widespread in California than previously known (Figure 1, iNaturalist 2023). However, the iNaturalist data have not been confirmed and likely contain some misidentified species. For example, iNaturalist reports list four species (*A. sinapina*, *A. ostoyae*, *A. novae-zelandiae,* and *A. borealis*) that have not yet been confirmed in scientific literature to exist in California, and few records (if any) use DNA-based identification (Figure 2, iNaturalist 2023). The report of *A. ostoyae* likely refers to *A. solidipes*, which was formerly known as North American *A. ostoyae*; however, *A. solidipes* has not yet been confirmed in California. Two other species (*A. novae-zelandiae* and *A. borealis*) have not yet been reported in North America using DNA sequence-confirmed identification, and these species would represent invasive species, if confirmed. As a complicating factor, some *Armillaria* species have been recognized as morphologically indistinguishable using microscopic and macroscopic observations. Also, for the purpose of bioclimatic modeling of *Armillaria* spp., iNaturalist data appear to have significant sampling bias associated with populated areas (Figure 3, iNaturalist 2023). Furthermore, preliminary surveys indicate that ARD is perhaps increasing in California

---

[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; Vallejo, CA, USA
*john.w.hanna@usda.gov

(Figure 4), especially in the context of increased climate-induced stress on trees due to relatively rapid shifts in climate and extreme weather events. For these reasons, new *Armillaria* surveys are needed in California that combine accurate location information (e.g, GPS coordinates) with DNA-based identification.

Figure 1: Range of *Armillaria* species in California based on 9,887 iNaturalist occurrence records.

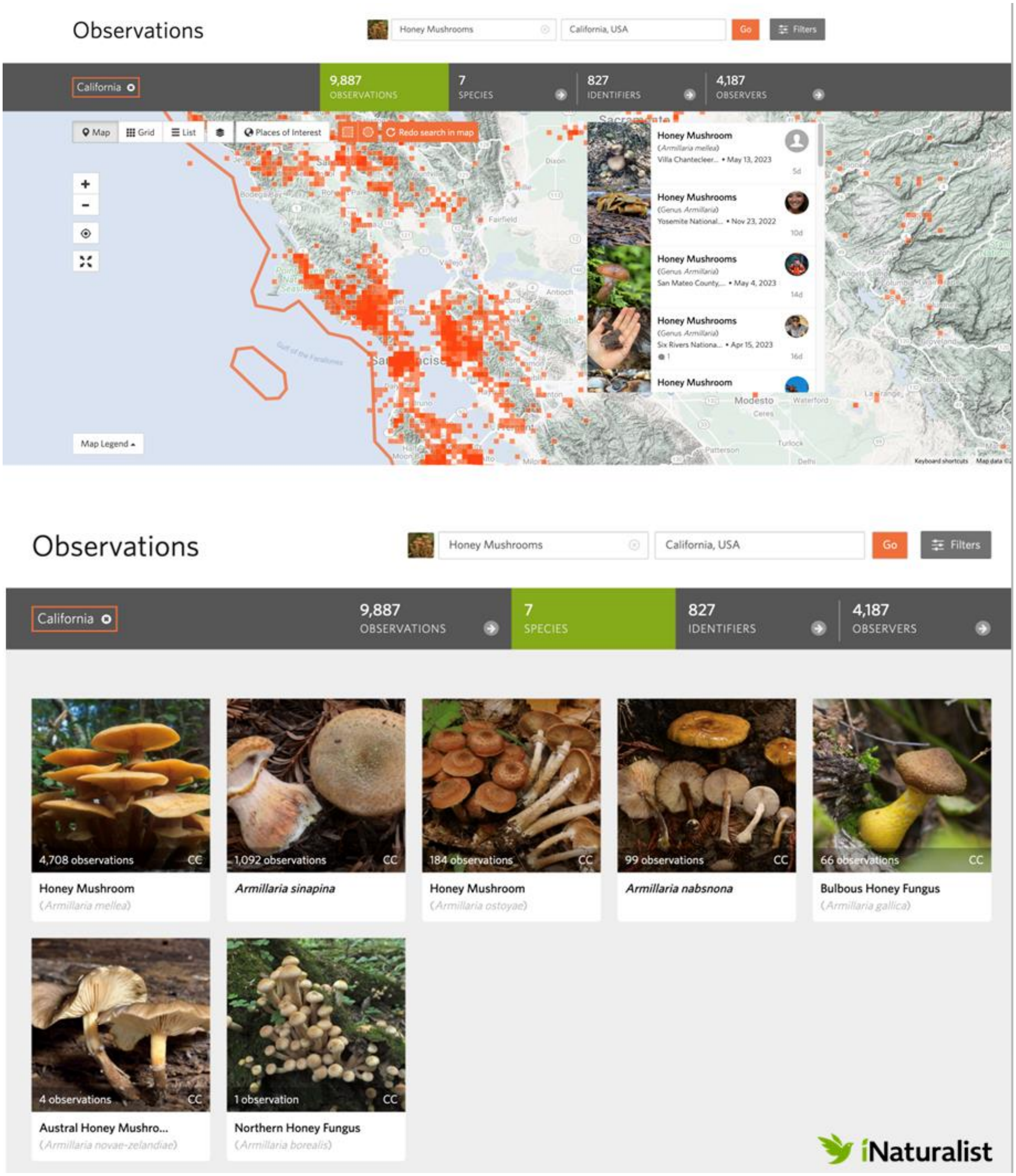


Figure 2: Example of *Armillaria* species data for California from iNaturalist.

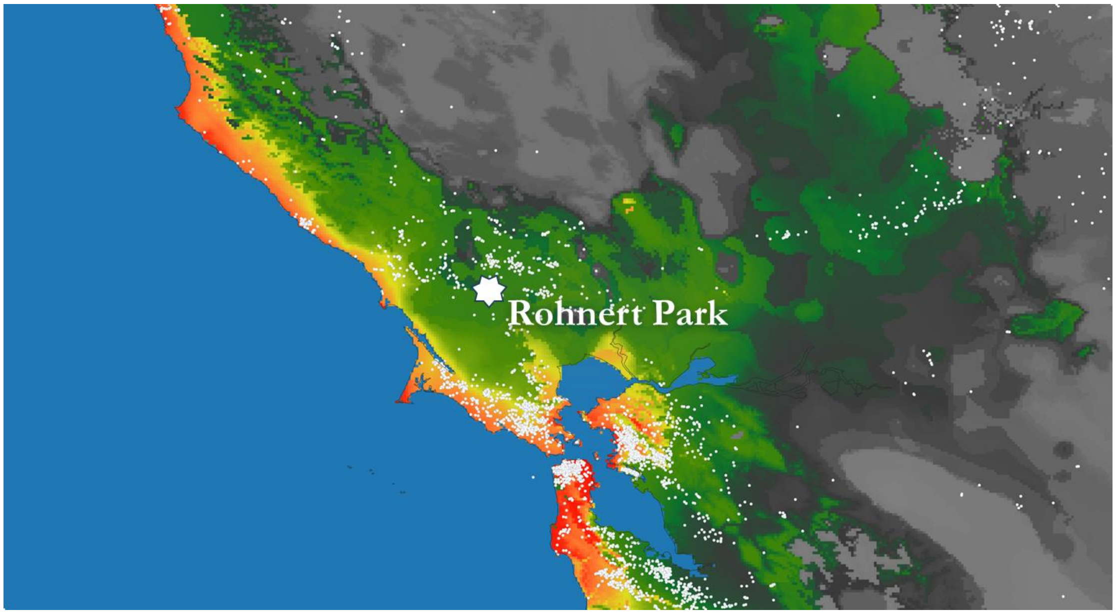


Figure 3: Example contemporary bioclimatic model for all *Armillaria* spp. centered on Rohnert Park, California, based on unconfirmed occurrence records from iNaturalist records (white dots). Darkest gray represents predicted suitable climate space, with light green, yellow, orange, and red indicating increased probabilities of climate suitability, respectively. Note the significant amount of sampling bias in populated areas.

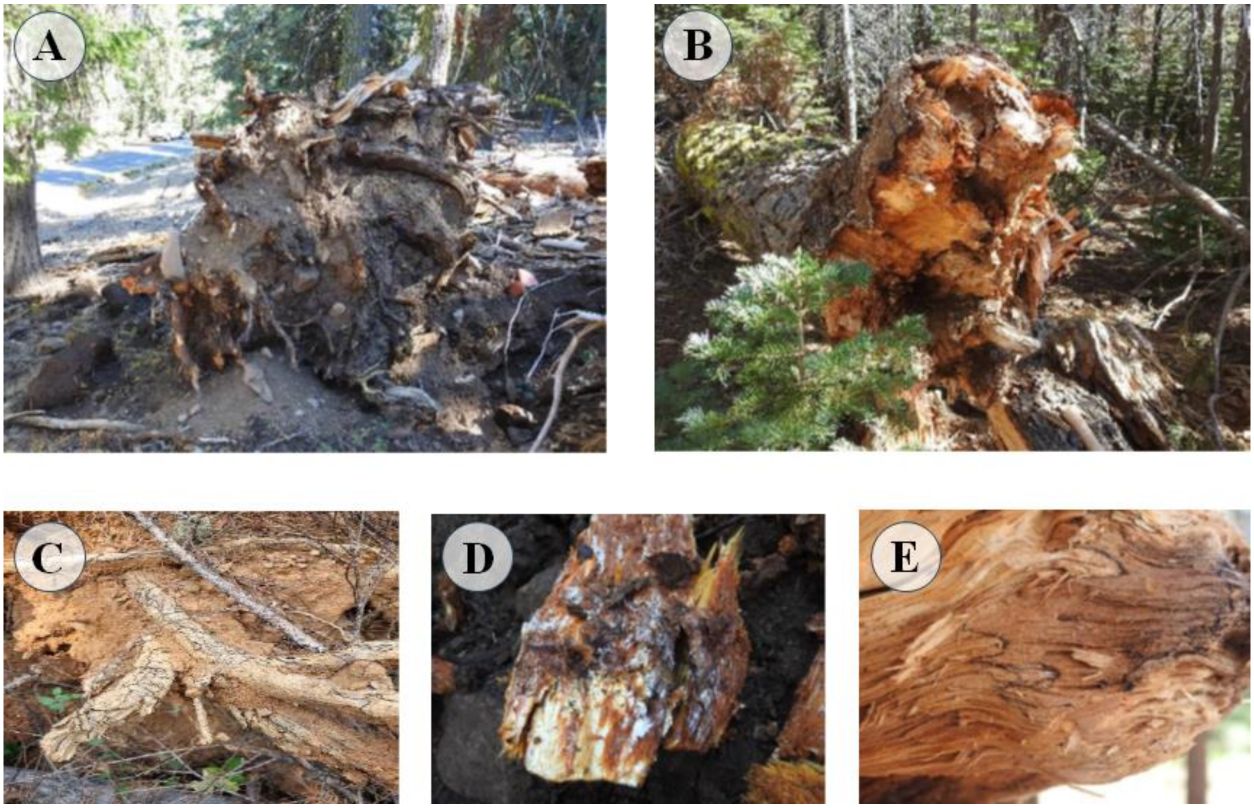


Figure 4A-E: 4A: Windthrown *Abies concolor* with Armillaria root disease in Klamath National Forest and 4B: Latour State Forest; 4C: Rhizomorphs from unidentified *Armillaria* spp. on windthrown tree in forest associated with the Karuk Tribe (Six Rivers National Forest) in northwestern California; 4D: Mycelial fan and rhizomorphs associated with Armillaria root disease of *A. concolor* in Kamath National Forest; and 4E: wood rot with zone lines associated with Armillaria root disease of *A. concolor* in Latour State Forest.

Objectives

The objectives of this project are to (i) conduct collections/surveys across diverse forest areas in California from which *Armillaria* will be isolated, cultured, and identified using DNA sequences; (ii) use *Armillaria* occurrence data to evaluate and refine bioclimatic models for predicting the present and future suitable climate space (the geographic area that is climatically suitable for a particular species' survival) for representative *Armillaria* species in California (if sufficient occurrence points are identified for the species); and (iii) produce predictive maps from the bioclimatic models to inform forest manager decisions in relation to ARD. These models can be compared to parallel bioclimatic models of important forest host species within the region. Any new *Armillaria* species/host combinations within California will be documented.

To supplement under-represented areas, additional *Armillaria* surveys/collections are needed across California (Figure 1). We ask collaborators to help survey for *Armillaria* within these areas and send us *Armillaria* samples (e.g., mycelial fans on live trees indicating disease activity, rhizomorphs, fruiting bodies) along with GPS information, associated host/environmental information, and photos.

Methods

DNA sequence-based diagnostics will be conducted to identify *Armillaria* species collected from diverse areas across California. Primary root systems and butts of trees and shrubs will be examined, and samples (i.e., rhizomorphs, mycelial fans, rotten wood, fruiting bodies) of *Armillaria* spp. will be collected along with precise location and associated host/environmental data. Cultured *Armillaria* isolates from each site will be identified using DNA sequencing (e.g., Kim et al. 2006, Hanna et al. 2007, Ross-Davis et al. 2012, Klopfenstein et al. 2017). Sampling locations will initially be selected based on local knowledge of areas with ARD from USDA Forest Service, other forest health professionals (e.g., CAL FIRE), and iNaturalist records of interest. Some targeted sampling will be based on preliminary models generated from surrounding regions, previous collections, and underrepresented areas that appear likely to support *Armillaria* spp.

Armillaria survey data will be integrated into a bioclimatic model to predict suitable climate space across California and adjacent regions. A bioclimatic model, such as MaxEnt (Phillips et al. 2006), will be used to determine which climatic factors are associated with the occurrence of *Armillaria* spp. across the landscape. Future distributions of suitable climate space for *Armillaria* will be predicted based on various Global Circulation Models and greenhouse gas-emission scenarios (Klopfenstein et al. 2009, Hanna et al. 2016, Kim et al. 2021, 2023), and compared with contemporary/future suitable climate spaces for major host-tree species, which have already been predicted (Rehfeldt et al. 2006). In addition, predictions will be updated with improved climate surfaces, as available. In general, potential distribution of suitable climate for ARD pathogens will be predicted, with increased risk for disease in areas where the climate is suitable for ARD pathogens to occur, but the tree host is climatically maladapted.

Expected Outcomes and Benefits

At the completion of these studies, we expect to have a much clearer picture of 1) which *Armillaria* species are present in California, 2) the present and predicted future ranges of major *Armillaria* species in California, and 3) areas in California where forest management should consider and/or address ARD. Resulting products and information from these studies will be made available to diverse groups, ranging from forest health professionals to amateur mycologists. Both contemporary and future bioclimatic model predictions will be made available via publications, presentations, on-site workshops, and/or online websites.

Acknowledgements

This project is supported by USDA-Forest Service, State and Private 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.

Literature Cited

Baumgartner, K.; Rizzo, D.M. 2001. Distribution of *Armillaria* species in California. Mycologia 93: 821-830.

Burdsall, H.H. Jr.; Volk, T.J. 2008. *Armillaria solidipes*, an older name for the fungus called *Armillaria ostoyae*. North American Fungi 3: 261-267

Brazee, N.J.; Ortiz-Santana, B.; Banik, M.T.; Linder, D.L. 2012. *Armillaria altimontana*, a new species from the western interior of North America. Mycologia 104: 1200-1205.

Cruickshank, M.G. 2011. Yield reduction in spruce infected with *Armillaria solidipes* in the southern interior of British Columbia. Forest Pathology 41: 425-428.

Filip, G.M.; Goheen, D.J. 1984. Root diseases cause severe mortality in white and grand fir stands of the Pacific Northwest. Forest Sci. 30: 138-142.

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. doi:10.1371/

Hanna, J.W.; Klopfenstein, N.B.; Kim, M.-S.; McDonald, G.I.; Moore, J.A. 2007. Phylogeographic patterns of *Armillaria ostoyae* in the western United States. Forest Pathol. 37: 192-216.

Hanna, J.W.; Warwell, M.V.; Maffei, H.; Fairweather, M.L.; Blodgett, J.T.; Zambino, P.J.; Worrall, J.; Burns, K.S.; Jacobs, J.J.; Ashiglar, S.M.; Lundquist, J.E.; Kim, M.-S.; Ross-Davis, A.L.; Hoffman, C.; Mathiasen, R.; Hofstetter, R.; Shaw, J.D.; Pitman, E.W.I.; Nelson, E.V.; McDonald, G.I.; Cleary, M.R.; Brar, S.; Richardson, B.A.; Klopfenstein, N.B. 2016. Bioclimatic modeling predicts potential distribution of *Armillaria solidipes* and *Pseudotsuga menziesii* (Douglas-fir) under contemporary and changing climates in the interior western U.S.A. pp. 117-123 in: Ramsey, A.; Palacios, P., compilers. Proceedings of the 63rd annual Western International Forest Disease Work Conference. 21-25 September 2015, Newport, OR, USA.

Hawkins, A.E.; Henkel, T.W. 2011. Native forest pathogens facilitate persistence of Douglas-fir in old-growth forests of northwestern California. Can. J. for. Res. 41: 1256-1266.

iNaturalist. 2023. Avalilable from http://www.inaturalist.org Last Accessed [05/22/2023]

Kim, M.-S.; Klopfenstein, N.B.; Hanna, J.W.; McDonald, G.I. 2006. Characterization of North American *Armillaria* species: genetic relationships determined by ribosomal DNA sequences and AFLP markers. Forest Pathol. 36: 145–164.

Kim, M.-S.; Hanna, J.W.; Stewart, J.E.; Warwell, M.V.; Klopfenstein, N.B. 2021. Predicting present and future suitable climate spaces (potential distributions) of and Armillaria root disease pathogen (*Armillaria solidipes*) and its host, Douglas-fir (*Pseudotsuga menziesii*), under changing climates. Frontiers in Forests and Global Change 4: 740994. doi: 10.3389/ffgc.2021.740994

Kim, M.-S.; Heinzelmann, R.; Labbé, F.; Ota, Y.; Elías-Román, R.D.; Pildain, M.B.; Stewart, J.E.; Woodward, S.; Klopfenstein, N.B. 2022. Armillaria root diseases of diverse trees in wide-spread global regions. Pp. 361-378 in: Asiegbu, F.O.; Andriy Kovalchuk, A. eds., Forest Microbiology Forest Tree Health, Volume 2, Academic Press (Elsevier), London, chapter 20. https://www.fs.usda.gov/treesearch/pubs/64635

Kim, M.-S.; Hanna, J.W.; McDonald, G.I.; Klopfenstein, N.B. 2023. *Armillaria altimontana* in North America: Biology and ecology. Journal of Fungi 9: 904 (17 p). https://www.fs.usda.gov/rm/pubs_journals/2023/rmrs_2023_kim_m002.pdf

Klopfenstein, N.B.; Kim, M.-S.; Hanna, J.W.; Richardson, B.A.; Lundquist, J.W. 2009. Approaches to predicting potential impacts of climate change on forest disease: An example with Armillaria root disease. Research Paper RMRS-RP-76. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO. 10 p.

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.; Rigling, D.; Prospero, S.; Tsykun, T.; Bérubé, J.A.; Stefani, F.O.P.; Jafarpour, S.; Antonín, V.; Tomšovský, M.; McDonald, G.I.; Woodward, S.; 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: 75-91.

Kulhavy, D.L.; Partridge, A.D.; Stark, R.W. 1984. Root diseases and blister rust associated with bark beetles (Coleoptera: Scolytidae) in western white pine in Idaho. Environmental Entomology 13: 813-817.

Lockman, I.B.; Kearns, H.S.J., eds. 2016. Forest root diseases across the United States. Gen. Tech. Rep. RMRS-GTR-342. U.S. Dept. of Agriculture, Forest Service, RMRS, Ogden, UT, USA. 55p.

Murray, M.P., Leslie, A., 2021. Climate, radial growth, and mortality associated with conifer regeneration infected by root disease (*Armillaria ostoyae*). For. Chron. 97, 43-51. https://doi.org/10.5558/tfc2021-006Phillips, S.J.; Anderson, R.P.; Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecol. Model. 190: 231-259.

Redhead, S.A.; Bérubé, J.A.; 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: 1770-1771.

Rehfeldt, G.E.; Crookston, N.L.; Warwell, M.V.; Evans, J.S. 2006. Empirical analyses of plant-climate relationships for the western United States. Int. J. Plant Sci. 167: 1123-1150.

Ross-Davis, A.L.; Hanna, J.W.; Kim, M.-S.; Klopfenstein, N.B. 2012. Advances toward DNA-based identification and phylogeny of North American *Armillaria* species using elongation factor-1 alpha gene. Mycoscience 53: 161-165.

Tkacz, B.M.; Schmitz, R.F. 1986. Endemic mountain pine beetle population with lodgepole pine infected by Armillaria root disease in Utah. U.S. Dept. of Agriculture, Forest Service, Intermountain Research Station, Research Note INT-353. Ogden, UT, USA. 7 p.

Williams, R.E.; C. G. Shaw, C.G. III; Wargo, P.M.; Sites, W.H. 1986. Armillaria Root Disease. USDA-Forest Service. Forest Insect & Disease Leaflet 78.

Updated bioclimatic modeling of *Armillaria solidipes* in the Intermountain Region (USA)

John W. Hanna[1]*, Patrick I. Bennett[1], Maria Newcomb[2], Mee-Sook Kim[3], and Ned B. Klopfenstein[1]

Introduction

Armillaria root disease is one of the leading causes of growth loss and mortality in coniferous forests of the western USA (Lockman and Kearns 2016; Kim et al. 2022). In 2019, a collaborative project was started to learn more about Armillaria root disease in the Intermountain Region (USDA Forest Service Region 4). Recent surveys suggested that Armillaria root disease was increasing on trees in Utah, particularly at higher elevations than was previously observed (John Guyon, per. comm.). Previous and subsequent surveys using DNA-based identification revealed that *A. solidipes* (formerly known as North American *A. ostoyae*) was the predominant cause of Armillaria root disease in Utah (McDonald 1999, Hanna unpublished data). Earlier modeling efforts produced preliminary predictions of the geographic distribution of suitable climate for *A. solidipes* in the Intermountain Region of the USA (Hanna et al. 2021, Kim et al. 2021). These earlier models were limited due to COVID-19-related delays in field surveys and lack of availability of higher resolution bioclimatic grids. Currently, the higher resolution CMIP6 (Coupled Model Intercomparison Project Phase 6) bioclimatic grids are available at 30-second (ca. 1-km) resolution and additional locations of DNA-confirmed *A. solidipes* have been determined. Refined models are presented based on the newly available information. Information from this project will provide insights for improving other existing bioclimatic models and/or developing new models for *Armillaria*, other forest pathogens, and/or forest hosts in other regions of western North America. These tools can inform forest managers about how climate change might influence the spatial distribution of suitable climate for this Armillaria root disease pathogen and its hosts, which is an important consideration for forest management in the Intermountain Region.

Objectives

The objectives of this project are to (i) update and refine *A. solidipes* bioclimatic models specific to the Intermountain Region [Forest Service Intermountain Region (Region 4)]. Improvements over previous models (Kim et al. 2021) include additional confirmed locations (increased from 19 to 28) of *A. solidipes* and higher resolution grids [from 2.5-minute (ca. 4-km) resolution to 30-second (ca. 1-km) resolution]; (ii) compare these specific regional models (Figures 1B-F) using 28-point locations to the western North American model from Kim et al. (2021; Figure 2) that used 382-point locations (363 locations outside of the Intermountain Region); and (iii) model the potential future distribution of suitable climate space for *A. solidipes* in the Intermountain Region under climate-change scenarios (based on historic climate suitability), interpret results, and provide access for forest managers to use these data for forest planning.

---

[1] USDA Forest Service, RMRS; Moscow, ID, USA
[2] USDA Forest Service, FHP Region 1; Missoula, MT, USA
[3] USDA Forest Service, PNWRS; Corvallis, OR, USA
*john.w.hanna@usda.gov

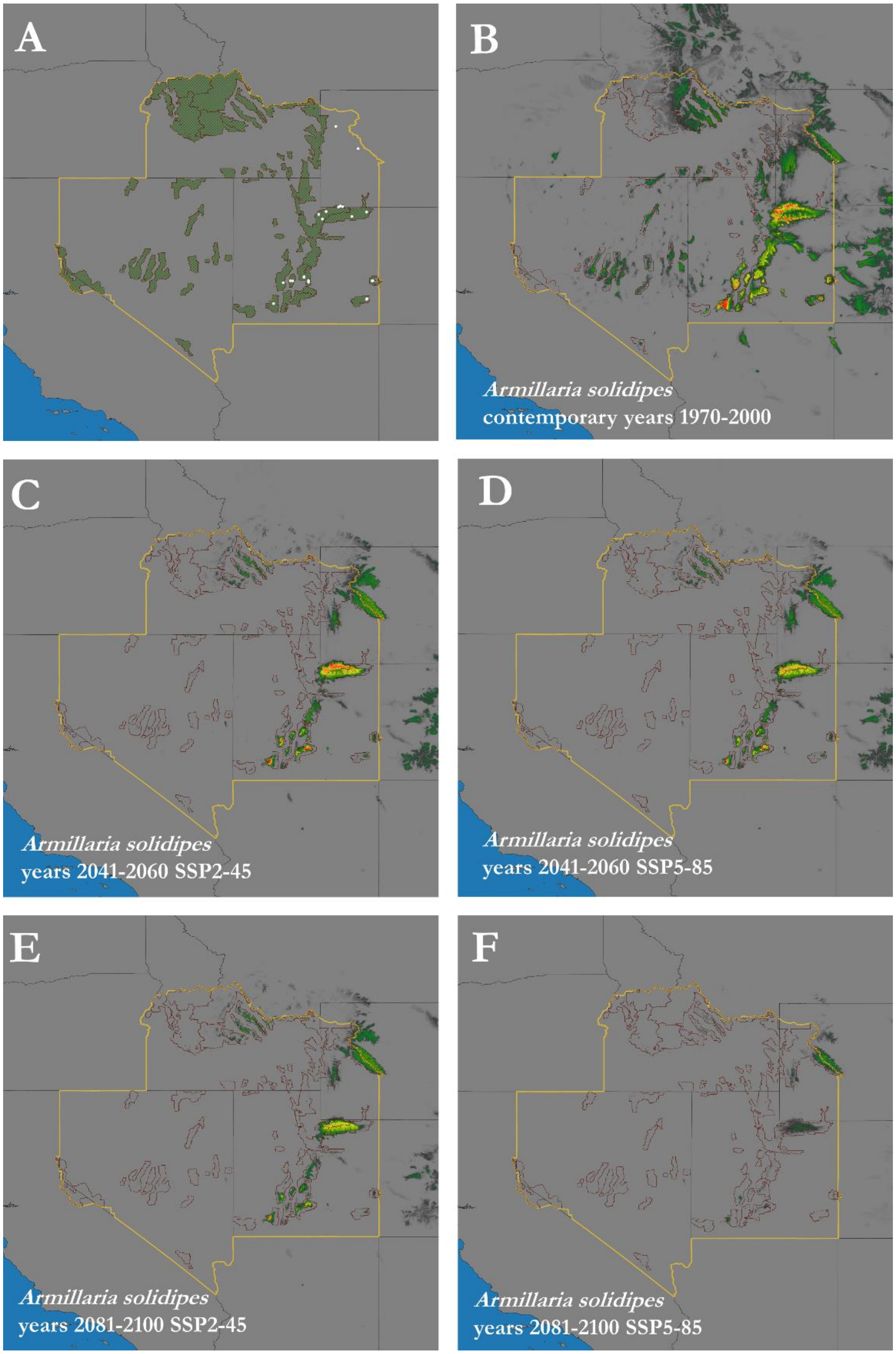


Figure 1: A: *Armillaria solidipes* GPS point locations used for the models. B: Contemporary bioclimatic prediction model for the years 1970-2000. C-F: Bioclimatic predictive distribution models based on two future climate emissions scenarios (SSP2-45 and SSP5-85) and projected for two future time periods (years 2041-2060 and years

2061-2100) using 30-sec resolution (~1km) CMIP6 downscaled data (WorldClim v2.1).

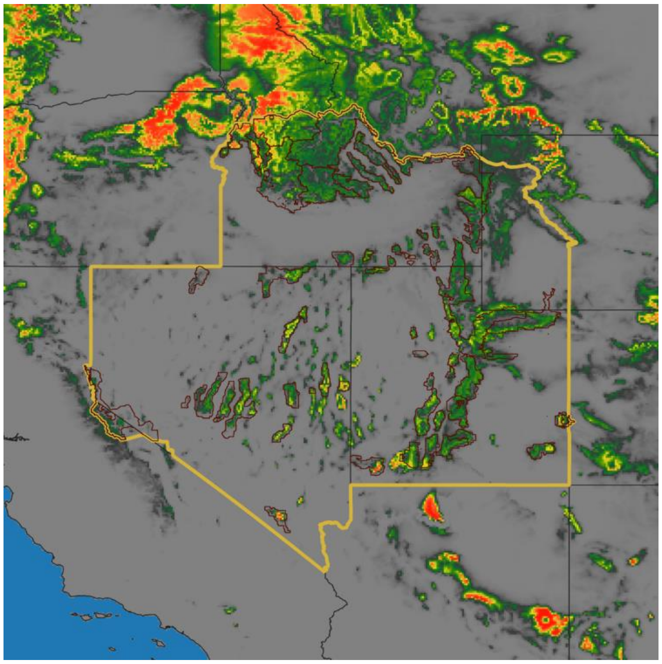
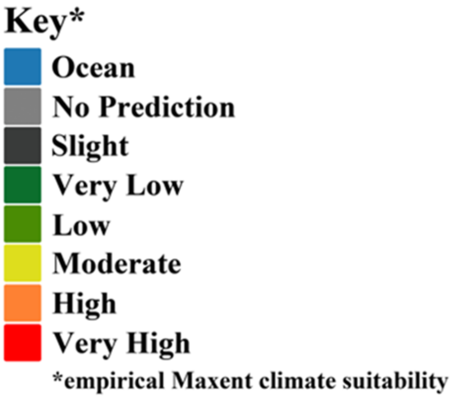


Figure 2: Contemporary *Armillaria solidipes* bioclimatic prediction model from Kim et al. (2021) based on 382 *A. solidipes* point locations across western North America overlayed onto the Intermountain Region.



Key for Figures 1 and 2: Yellow lines on maps indicate the Intermountain Region boundary (Forest Service region 4) and the burgundy lines [surrounding green polygons (USDA forest lands) in Figure 1A] indicate USDA forest boundaries. White dots in Figure 1A indicate point locations used for the Maxent modeling.

Methods

We built upon the methods, data, and lessons from previous studies (Kim et al. 2006, Klopfenstein et al. 2009, Ross-Davis et al. 2012, Hanna et al. 2016, Hanna et al. 2021, Kim et al. 2021, 2023) to improve *A. solidipes* models for the Intermountain Region. Maximum Entropy (MaxEnt) bioclimatic modeling (Phillips et al. 2006) was used with 19 bioclimate grids from WorldClim version 2.1 (Fick and Hijmans 2017) coupled with 28 GPS occurrence locations for *A. solidipes* confirmed via DNA sequencing (Figure 1A). A contemporary model was produced based on climate data from 1970–2000 (Figure 1B). The model was computed from 20 replicate runs using cross-validation.

Predictive distribution models based on future-climate scenarios were also projected for two future time periods (years 2041-2060 and years 2061-2100) using 30-second (ca. 1-km) resolution CMIP6 downscaled data (WorldClim v2.1). Two different Shared Socioeconomic Pathways (SSPs), detailing expected future CO_2 concentrations, were paired with the "Canadian Ocean Ecosystem model" (CanESM5-CanOE) global climate model (GCM) (Christian et al. 2022). In general, five SSPs narratives describe the broad socioeconomic trends that could shape future society, and we used two scenarios: SSP2-45 (a "middle of the road" future, where trends do not shift markedly from historical patterns) and SSP5-85 (a "fossil-fueled development" future, which follows a path of rapid and unconstrained growth in economic output and fossil fuel-based energy use) (Figure 3).

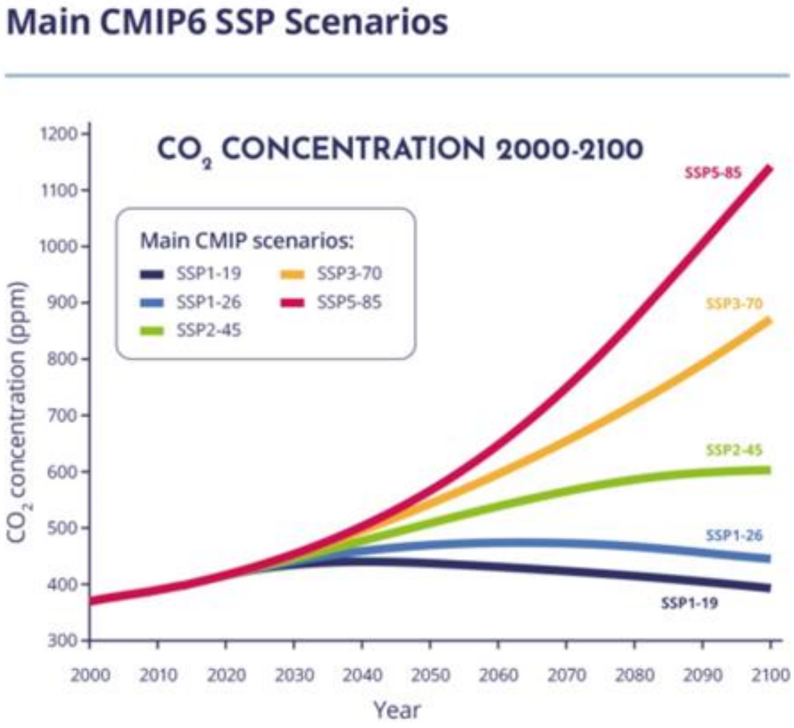


Figure 3: Comparison of CMIP6 SSP emissions scenarios. SSP2-45 (some carbon mitigation and a declining population) and SSP5-85 ("business as usual" scenario) were used for this study. From: "CONSTRAIN (2020) ZERO IN ON: A new generation of climate models, COVID-19 and the Paris Agreement," by D. Rosen, A. Nauels, K.B. Tokarska, C. McKenna, C.-F. Schleussner, J. Rogelj, and P. Forster, 2020, The CONSTRAIN Project Annual Report 2020, DOI:10.5281/zenodo.4282461. CC BY 4.0.

Results and Discussion

For the contemporary predictive model, the climate variables Max Temperature of Warmest Month (bio5 = 52.1) and Precipitation Seasonality (bio15 = 41.4) had the highest permutation-importance values. The model was scored an average area-under-curve (AUC) score of 0.97 with a standard deviation of 0.098. An AUC score of 1 represents a perfect model, while AUC scores below 0.5 are considered worse than random.

The results of the bioclimatic models for the Intermountain Region show predicted declines in overall climate suitability for *A. solidipes* within the region. These predictions correspond with other previous predictions for host species in the region (Rehfeldt et al. 2006, Rehfeldt et al. 2009, Hanna et al. 2015, Kim et al. 2021, 2023). As the climate warms, the predicted trend is for species' suitable climate space to shift northward and/or higher in elevation where optimal climate exists for species survival; however, climates may continue warming to a point where even the highest elevations in a region are too warm for a species' survival. Since the contemporary model shows historic climate data from 1970-2000, it seems likely that some shifts in climate suitability for *A. solidipes* have already occurred, as evident from observed field reports (John Guyon, per. comm.). For example, *A. solidipes* was not found during additional surveys within areas predicted to have some climate suitability in Nevada and southern Idaho according to the contemporary model. These preliminary observations raise the possibility that the climate suitability in some of these areas may already be closer to the 2041-2060 model than the contemporary model.

Another interesting aspect from this study is the comparison of these Intermountain Region-specific models (Figures 1B-1F) to western North America model from Kim et al. (2021; Figure 2) that was developed using *A. solidipes* locations throughout western North America. The contemporary "all locations" western North America model (Figure 2) shows distinctly different predictions for *A. solidipes* in the Intermountain Region than the Intermountain Region-specific model that solely uses Intermountain Region point locations. Previous studies have shown genetic variation within *A. solidipes* that may correspond to distinct subspecies or populations within *A. solidipes* (Hanna 2005, Hanna et al. 2007). If such genetic differences represent distinct groups within *A. solidipes*, these groups have perhaps evolved with distinct adaptations to climate. Population genetic studies of *A. solidipes* in western North America are needed to investigate this hypothesis. If distinct genetic groups of *A. solidipes* are found, they could be modeled separately to improve the bioclimatic model predictions for *A. solidipes* in western North America, while also identifying threats associated with movement of these genetic groups under contemporary and projected future climates.

Products from this project will guide forest management by providing decision-support tools that predict potential distribution of suitable climate for Armillaria root disease under present and future climate scenarios. Management recommendations will offer strategies to reduce Armillaria root disease for projected future climates based on climatic adaptation of tree species in relation to *Armillaria*. These decision-support tools will provide guidance for field units for project planning, NEPA documents, and forest plan revisions. This information can also be incorporated into National Disease Risk maps, which will help develop appropriate disease management protocols. In addition, this project can be readily adapted to other important forest pathogens (endemic and invasive).

Acknowledgments

This project was partially funded by the USDA Forest Service (FS), Forest Health Protection (FHP), Special Technology Development Program (e.g., STDP-R4-2019-01, STDP-R1-2020-02, STDP-R5-2023-01), USDA FS, State, Private, and Tribal Forestry, FHP Region 4; USDA FS, Research and Development, Pacific Northwest Research Station and Rocky Mountain Research Station. The authors also thank J.C. Guyon, E.G. Hebertson, J.T. Blodgett, M.V. Warwell, S.M. Ashiglar, G. I. McDonald, J.B Donley, R.A. Sitz, and J.E. Stewart for their contributions to this project. 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.

Literature Cited

Christian, J.R.; Denman, K.L.; Hayashida, H.; Holdsworth, A.M.; Lee, W.G.; Riche, O.G.J.; Shao, A.E.; Steiner, N.; Swart, N.C. 2022. Ocean biogeochemistry in the Canadian Earth System Model version 5.0.3:CanESM5 and CanESM5-CanOE. Geoscientific Model Development 15(11): 4393-4424.

Fick, S. E.; Hijmans, R. J. 2017. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. Int. J. Climatol. 37: 4302–4315. doi: 10.1002/joc.5086

Hanna, J. W., 2005: *Armillaria ostoyae*: genetic characterization and distribution in the western United States. MS Thesis. University of Idaho, Moscow, ID, USA.116 pp.

Hanna, J.W.; Klopfenstein, N.B.; Kim, M.-S.; McDonald, G.I.; Moore, J.A. 2007. Phylogeographic patterns of *Armillaria ostoyae* in the western United States. Forest Pathol. 37: 192-216.

Hanna, J.W.; Warwell, M.V.; Maffei, H.; Fairweather, M.L.; Blodgett, J.T.; Zambino, P.J.; Worrall, J.; Burns, K.S.; Jacobs, J.J.; Ashiglar, S.M.; Lundquist, J.E.; Kim, M.-S.; Ross-Davis, A.L.; Hoffman, C.; Mathiasen, R.; Hofstetter, R.; Shaw, J.D.; Pitman, E.W.I.; Nelson, E.V.; McDonald, G.I.; Cleary, M.R.; Brar, S.; Richardson, B.A.; Klopfenstein, N.B. 2016. Bioclimatic modeling predicts potential distribution of *Armillaria solidipes* and *Pseudotsuga menziesii* (Douglas-fir) under contemporary and changing climates in the interior western U.S.A. pp. 117-123 in: Ramsey, A.; Palacios, P., compilers. Proceedings of the 63rd annual Western International Forest Disease Work Conference. 21-25 September 2015, Newport, OR, USA.

Hanna, J.W.; Kim, M.-S.; Klopfenstein, N.B. 2021. Predicting potential distribution of the Armillaria root disease pathogen, *Armillaria solidipes*, within the Intermountain Region of the United States. Annual meeting of the American Phytopathology Society, held as online virtual meeting, 2-6 August 2021.

Kim, M.-S.; Klopfenstein, N.B.; Hanna, J.W.; McDonald, G.I. 2006. Characterization of North American *Armillaria* species: genetic relationships determined by ribosomal DNA sequences and AFLP markers. Forest Pathol. 36: 145–164.

Kim, M.-S.; Hanna, J.W.; Stewart, J.E.; Warwell, M.V.; McDonald, G.I.; Klopfenstein, N.B. 2021. Predicting present and future suitable climate spaces (potential distributions) of an Armillaria root disease pathogen (*Armillaria solidipes*) and its host, Douglas-fir (*Pseudotsuga menziesii*), under changing climates. Frontiers in Forests and Global Change 4: 740994. https://www.fs.usda.gov/rm/pubs_journals/2021/rmrs_2021_kim_m001.pdf

Kim, M.-S.; Heinzelmann, R.; Labbé, F.; Ota, Y.; Elías-Román, R.D.; Pildain, M.B.; Stewart, J.E.; Woodward, S.; Klopfenstein, N.B. 2022. Armillaria root diseases of diverse trees in wide-spread global regions. pp. 361-378 in: Asiegbu, F.O.; Kovalchuk, A. eds., Forest Microbiology Forest Tree Health, Volume 2, Academic Press (Elsevier), London, chapter 20. https://www.fs.usda.gov/rm/pubs_journals/2022/rmrs_2022_kim_m002.pdf

Kim, M,-S.; Hanna, J.W.; McDonald, G.I.; Klopfenstein, N.B. 2023. *Armillaria altimontana* in North America: Biology and ecology. Journal of Fungi 9: 904. https://www.fs.usda.gov/rm/pubs_journals/2023/rmrs_2023_kim_m002.pdf

Klopfenstein, N.B.; Kim, M.-S.; Hanna, J.W.; Richardson, B.A.; Lundquist, J.W. 2009. Approaches to predicting potential impacts of climate change on forest disease: An example with Armillaria root disease. Research Paper RMRS-RP-76. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, USA. 10 p.

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.; Rigling, D.; Prospero, S.; Tsykun, T.; Bérubé, J.A.; Stefani, F.O.P.; Jafarpour, S.; Antonín, V.; Tomšovský, M.; McDonald, G.I.; Woodward, S.; 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: 75-91.

Lockman, I.B.; Kearns, H.S.J., eds. 2016. Forest root diseases across the United States. Gen. Tech. Rep. RMRS-GTR-342. U.S. Dept. of Agriculture, Forest Service, RMRS, Ogden, UT, USA. 55 p.

McDonald, G.I. 1999. Preliminary report on the ecology of *Armillaria* in Utah and the Inland West. pp. 85-92 in: Trummer, L., compiler. Proceedings of the 46th Western International Forest Disease Work Conference. 28 September – 2 October 1998, University of Nevada-Reno, Reno, NV, USA.

Phillips, S.J.; Anderson, R.P.; Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecol. Model. 190: 231-259.

Rehfeldt, G.E.; Crookston, N.L.; Warwell, M.V.; Evans, J.S. 2006: Empirical analyses of plant-climate relationships for the western United States. Int. J. Plant Sci. 167: 1123-1150.

Rehfeldt, G.E.; Ferguson, D.E.; Crookston, N.L. 2009. Aspen, climate, and sudden decline in western USA. For. Ecol. and Manage. 258: 2353-2364.

Rosen, D.; Nauels, A.; Tokarska, K.B.; McKenna, C.; Schleussner, C.-F.; Rogelj, J.; Forster, P. 2020. CONSTRAIN (2020) ZERO IN ON: A new generation of climate models, COVID-19 and the Paris Agreement. The CONSTRAIN Project Annual Report 2020, DOI:10.5281/zenodo.4282461

Ross-Davis, A.L.; Hanna, J.W.; Kim, M.-S.; Klopfenstein, N.B. 2012. Advances toward DNA-based identification and phylogeny of North American *Armillaria* species using elongation factor-1 alpha gene. Mycoscience 53: 161-165.

Physiological and transcriptional responses of well-watered and drought-stressed black walnut and *Geosmithia morbida* during infection and colonization

Jorge R. Ibarra Caballero[1]*, J.P. Ata[1,2], R.A. Sitz[3], D. Spitzer[4], T. Ocheltree[4], D. West[5], and J.E. Stewart[1]

The ascomycete *Geosmithia morbida* is vectored by the walnut twig beetle *Pityophthorus juglandis* and their combined action causes the Thousand Cankers disease in walnut species (*Juglans* spp.). This disease can kill trees in 2 to 3 years after initial colonization; among those trees, Black walnut, *Juglans nigra*, is a very susceptible species. The disease has been present for a long time in the western states and more recently in several eastern states; it is less severe in the east, maybe because climate conditions are less dry compared to the western states. There is also some evidence that well-watered trees are less susceptible than drought-stressed trees.

The objectives of this projects are: 1) to analyze at the gene expression level the response of Juglans nigra trees to inoculation with Geosmithia morbida, comparing well-watered and drought-stressed tress; 2) to analyze at the same level how the pathogen interacts with the host, under both water regimes.

The experimental setting consisted of 1.5 years old walnut trees, kept either at 100% or 60% pot capacity. The fungus was grown in broth, to prepare inoculum and as a control. Trees were inoculated and sampled at 12 hours and at 1-, 2-, 4-, 8- and 16-days post inoculation. Mock inoculated trees were included as controls. Leaf water potential, leaf water content, water required to full turgor, photosynthetic rate and stomatal conductance were measured 24 hours before inoculation and right before tissue sampling. Canker size was measured at each time point after inoculation. From the samples, mycelium and tissue from fungus-inoculated and mock-inoculated trees, RNA was extracted and sequencing using the 3'TagSeq technique. Obtained reads were mapped to a walnut transcriptome and to a *G. morbida* transcriptome to get counts per transcript; then differential expression was analyzed using the R package DESeq2.

Differences in the average canker size between drought-stressed and well-watered conditions started to increase on 4dpi but significant difference was only observed on 16dpi (p-value < 0.01). Prior to inoculation, water required to full turgor was not significantly different comparing water conditions, but leaf water potential, photosynthetic rate and stomatal conductance were significantly higher in well-watered sapling (p-values: 0.05, 0.03 and 0.03 respectively). After inoculation, the interaction between water condition and inoculation treatment had no significant effect on leaf water potential nor amount of water required to full turgor. *Juglans* showed increase at 2dpi of transcripts with significantly higher counts comparing well-watered-inoculated to well-watered-mock-inoculated and drought-inoculated to drought-mock- inoculated and a large increase in drought-inoculated at 16dpi. There were also increase at 2dpi of transcripts with significantly higher counts in *Geosmithia* inoculated in walnut compared to mycelium in broth both in well-watered and drought conditions. At day 2pi, for each water treatment *Juglans* produced many transcripts that code for defense proteins, more and greater diversity in well-watered condition. *Geosmithia* produced more transcripts that code for pathogenicity related proteins also in the well-watered treatment. At 16 days post inoculation, the very large increase in significantly higher expressed transcripts in *Juglans* under drought stress was not matched by *Geomithia*. However, close examination of the transcripts showed that 71.5% of those pathogenesis-related transcripts coded for proteins involved in secondary metabolite production, ineffective to stop colonization by the pathogen but producing the distinct canker. We think this shows that *Juglans* has a stronger response in well-watered condition compared to in drought, and

---

[1]Colorado State University, Department of Agricultural Biology; Fort Collins CO, USA
[2]University of the Philippines, Department of Forest Biological Sciences; Los Baños, Philippines
[3]Davey Resource Group; Fort Collins, CO, USA
[4]Colorado State University, Department of Forest and Rangeland Stewardship; Fort Collins, CO, USA
[5]Colorado State Forest Service; Fort Collins, CO, USA
*Jorge.Ibarra_Caballero@colostate.edu

Geosmithia responds accordingly but still being able to produce disease faster in the drought-stressed trees. More in depth analyses at every sampling time point are in progress.

A recent finding of Armillaria root disease on black oak (*Quercus velutina*) caused by *Armillaria solidipes* in North Carolina, USA

Duncan R. Kroese[1], Ryan A. Blaedow[2], Kathleen M. McKeever[2], Rabiu O. Olatinwo[3], Ned B. Klopfenstein[4], and Mee-Sook Kim[2]

Introduction

Root disease caused by *Armillaria* spp. is among the leading causes of mortality and lost productivity in forests around the world (Kim et al. 2022). In the northern and western USA, *A. solidipes* (previously known as North American *A. ostoyae*) is considered the most damaging Armillaria root disease pathogen in coniferous forests (Lockman and Kearns 2016). In many regions, climate change is expected to result in an increasing likelihood of damage from Armillaria root disease as trees become more stressed from maladaptation to climate and extreme weather events (Murray and Leslie 2021; Kim et al. 2021). Although *A. solidipes* has been reported in Massachusetts (Brazee and Wick 2009), it had not been previously identified in the southeastern USA until recently (Kim et al. 2023). The objective of this study was to determine distribution of *Armillaria* species in a mixed-hardwood/conifer stand of western North Carolina.

Methods

On a clear and calm day in August 2021, a black oak (*Quercus velutina*), ca. 29 m tall and 64 cm DBH, failed structurally within the Pisgah National Forest near Brevard, North Carolina (Figure 1A). The fallen tree displayed no readily observable, above-ground indications of injury or signs/symptoms of insect- or disease-related damage. Close inspection of the exposed root plate revealed advanced decay inside the roots (Figure 1B) and abundant rhizomorphs attached to the outer root surfaces (Figure 1C). At the point of failure, white mycelial fans were found under the bark of a large primary root (23 cm in diameter) that also showed extensive decay within the root itself (Figure 1D; Kim et al. 2023).

---

[1]USDA Forest Service, Pacific Northwest Research Station; Corvallis, OR, USA
[2]USDA Forest Service, Forest Health Protection; Asheville, NC, USA
[3]USDA Forest Service, Southern Research Station; Pineville, LA, USA
[4]USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA
*Duncan.Kroese@usda.gov

Figure 1: (A) Failed black oak (*Quercus velutina*) tree, (B) with exposed root plate, (C) covered in abundant black rhizomorphs, and (D) exposed decay column with white mycelial fan.

Rhizomorph samples were collected from the fallen tree and established in culture. Two *Armillaria* isolates were identified (PNF#001R-1 and PNF#001R-2), but somatic pairing tests revealed that these isolates belonged to the same genet (vegetative clone). DNA extracted from fungal mycelia was subjected to PCR and DNA sequencing of the translation elongation factor 1α (*tef1*) gene. Somatic pairing tests were conducted as a second method of species identification. Nine, replicated pairings were conducted using the *Armillaria* isolate (PNF#001R-1) paired with three standard isolates of five other *Armillaria* spp. that occur in North America [*A. solidipes, A. mellea, A. gallica, A. mexicana,* and *Desarmillaria caespitosa* (= *A. tabescens*)] (Kim et al. 2023).

Subsequent surveys were conducted through September 2022 to collect additional samples of *Armillaria* fruiting bodies (basidiomata), rhizomorphs, and mycelial fans from the adjacent mixed-hardwood/conifer forest in the Pisgah National Forest (Figure 2). Samples were collected from diverse tree and shrub species that were symptomatic and asymptomatic for Armillaria root disease, and isolates were established in culture. . *Armillaria* species identification was confirmed via DNA sequencing of *tef1* gene.

Figure 2: (A) Surveys of the area were conducted to collect (B) fruiting body, (C) rhizomorph, and (D) mycelial fan samples of *Armillaria* spp.

Results

Based on *tef1* sequences, both isolates (PNF#001R-1 and PNF#001R-2) were identified as *A. solidipes* (GenBank accession no. OP823701), showing 98% similarity with *A. solidipes tef1* sequences (e.g., MH879015) in GenBank. Somatic pairing tests with *Armillaria* isolate (PNF#001R-1) showed 67% compatibility with *A. solidipes*, but only 0-22% compatibility with the other *Armillaria* species. On the basis of *tef1* and somatic pairing tests, the original *Armillaria* isolate (PNF#001R-1) was identified as *A. solidipes* (Kim et al. 2023).

From a total of 35 additional sample locations (e.g., PNF#002–PNF#036) in the area adjacent to the original *Armillaria* collection (PNF#001), 56 suspected *Armillaria* samples were collected. A majority of sample isolates were established in culture, and potential *Armillaria* isolates were identified based on *tef1* sequences. In total, 45

Armillaria spp. isolates were identified, with 24 identified as *A. mellea*, 16 identified as *A. gallica*, and 5 identified as *A. solidipes* (PNF#003, PNF#033–PNF#36). Somatic pairing tests of all *A. solidipes* isolates, including the original isolate (genet, PNF#001R-1) associated with first detection, showed that these isolates of *A. solidipes* belong to four distinct genets (PNF#001, PNF#003, PNF#033=PNF#034=PNF#035, and PNF#036) (Table 1; Figure 3).

Table 1: Sample isolates identified as *Armillaria solidipes* based on translation elongation factor 1α sequences, and their assignment to genets based on somatic pairing tests.

Armillaria Isolate ID	Sample Date	Sample Type	Host	Genet
PNF#001	8/14/2021	Rhizomorph	*Quercus velutina* (Black Oak)	1
PNF#003	9/7/2021	Rhizomorph	*Fagus grandifolia* (American Beech)	2
PNF#033	9/21/2022	Mycelial Fan	*Kalmia latifolia* (Mountain Laurel)	3
PNF#034	9/22/2022	Rhizomorph	*Quercus montana* (Chestnut Oak)	3
PNF#035	9/23/2022	Rhizomorph	*Oxydendrum arboretum* (Sourwood)	3
PNF#036	9/24/2022	Rhizomorph	*Quercus rubra* (Northern Red Oak)	4

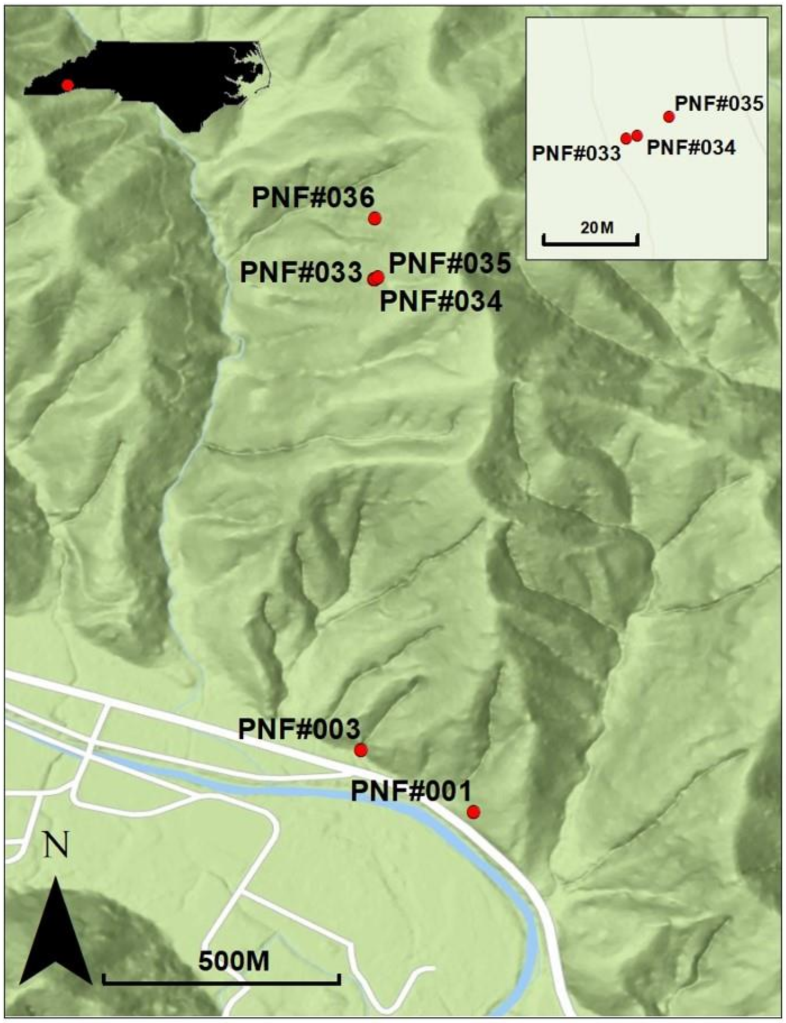


Figure 3: Map showing the location of *Armillaria solidipes* samples collected from Pisgah National Forest in North Carolina, USA.

Conclusions

Based on available knowledge, the original report (Kim et al. 2023) is the first known, confirmed report of *A. solidipes* in North Carolina, which is also the most southerly confirmed presence of *A. solidipes* in eastern North America. Furthermore, our preliminary results indicate that *A. gallica, A. mellea*, and *A. solidipes* can co-occur within a mixed hardwood/conifer stand in the southeastern USA. In western North America, the distribution of *Armillaria* spp. and their ecological behaviors are likely to shift as the climate continues to change (Kim et al. 2021). While it is undetermined if this occurrence of *A. solidipes* is related to a changing climate, continued surveys/studies will help to better understand the range, ecological behaviors, and impact of this Armillaria root disease pathogen in mixed forests across the southeastern USA and beyond.

Acknowledgments

This work was partially funded by USDA Forest Service (FS), State, Private and Tribal Forestry, Forest Health Protection Region 8, USDA FS R&D Pacific Northwest Research Station, and Rocky Mountain Research Station. 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.

Literature Cited

Brazee, N. J., Wick, R. L. (2009). *Armillaria* species distribution on symptomatic hosts in northern hardwood and mixed oak forests in western Massachusetts. *Forest Ecology and Management 258*(7), *1605-1612. https://doi.org/10.1016/j.foreco.2009.07.016*

Elías-Román, R. D., Medel-Ortiz, R., Alvarado-Rosales, D., Hanna, J. W., Ross-Davis, A. L., Kim, M.-S., Klopfenstein, N. B. (2018). *Armillaria mexicana*, a newly described species from Mexico. *Mycologia 110*(2), *347-360. https://doi.org/10.1080/00275514.2017.1419031*

Lockman, I. B., Kearns, H. S. J., eds. (2016). Forest root diseases across the United States. Gen. Tech. Rep. RMRS-GTR-342. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 55 p.

Kim, M.-S., Hanna, J. W., Stewart, J. E., Warwell, M. V., McDonald, G. I., Klopfenstein, N. B. (2021). Predicting present and future suitable climate spaces (potential distributions) for an Armillaria root disease pathogen (*Armillaria solidipes*) and its host, Douglas-fir (*Pseudotsuga menziesii*), under changing climates. *Frontiers in Forests and Global Change 4: 740994. https://doi.org/10.3389/ffgc.2021.740994*

Kim, M.-S., Heinzelmann, R., Labbé, F., Ota, Y., Elías-Román, R. D., Pildain, M. B., Stewart, J.E., Woodward, S., Klopfenstein, N. B. (2022). Armillaria root diseases of diverse trees in wide-spread global regions. In *Forest Microbiology* (pp. 361-378). Academic Press. *https://doi.org/10.1016/B978-0-323-85042-1.00004-5*

Kim, M.-S., Blaedow, R. A., McKeever, K., Olatinwo, R. O., Klopfenstein, N. B. (2023). First report of the Armillaria root disease pathogen, *Armillaria solidipes*, on black oak (*Quercus velutina*) in North Carolina, USA. *Plant Disease 107 (7), 2261. https://doi.org/10.1094/PDIS-11-22-2689-PDN*

Murray, M. P., Leslie, A. (2021). Climate, radial growth, and mortality associated with conifer regeneration infected by root disease (*Armillaria ostoyae*). The Forestry Chronicle 97(1), 43-51. https://doi.org/10.5558/tfc2021-006

Dynamics of the phyllosphere fungal microbiome in Douglas-fir needles associated with *Nothophaeocryptopus gaeumannii* in coastal Oregon, USA

Yung-Hsiang Lan[1]* and Jared M. LeBoldus[1,2]

Foliar fungal community is important for host resistance to diseases, it also affects plant physiological and responses to abiotic stress. As the cause of Swiss needle cast (SNC), *Nothophaeocryptopus gaeumannii* is the most abundant fungal endophyte of Douglas-fir needles. The disease occurs when pseudothecia emerges in the spring blocking the stomata, affecting gas exchange and reducing tree growth. In this study, we are going to (1) characterize the foliar microbiome community of old-growth Douglas-fir across the Elliott State Forest in Oregon, USA; (2) evaluate the incidence and severity of SNC; and (3) correlate the foliar microbiome community with SNC incidence and fog.

Four trees in foggy area and five trees in non-foggy area were selected and pre-measured before sampling. Each tree canopy was tagged at five heights and four directions (20 sampling locations per tree). 2.5-year-old needles in Nov 2022, and 3-year-old needles in June 2023 were collected for microbiome analysis. 3-year-old needles collected in June 2023 were also used to evaluate *N. gaeumannii* infections. The preliminary analysis showed that (1) the fungal endophyte communities were significantly at different foggy and non-foggy plots (p=0.0001), and among the different sampling heights (p=0.02) (Figure 1). However, the communities did not differ among sampling direction (p=0.17). (2) *N. gaeumannii* was abundant in most samples (Figure 2); (3) other needle pathogens, such as *Zasmidium pseudotsugae* (syn.= *Rasutoria pseudotsugae*) and *Rhabdocline* spp., and some lichen associated species, like *Cliostomum griffithi* and *Scoliciosporum umbrinum,* were also detected in the phyllosphere (Figure 2).

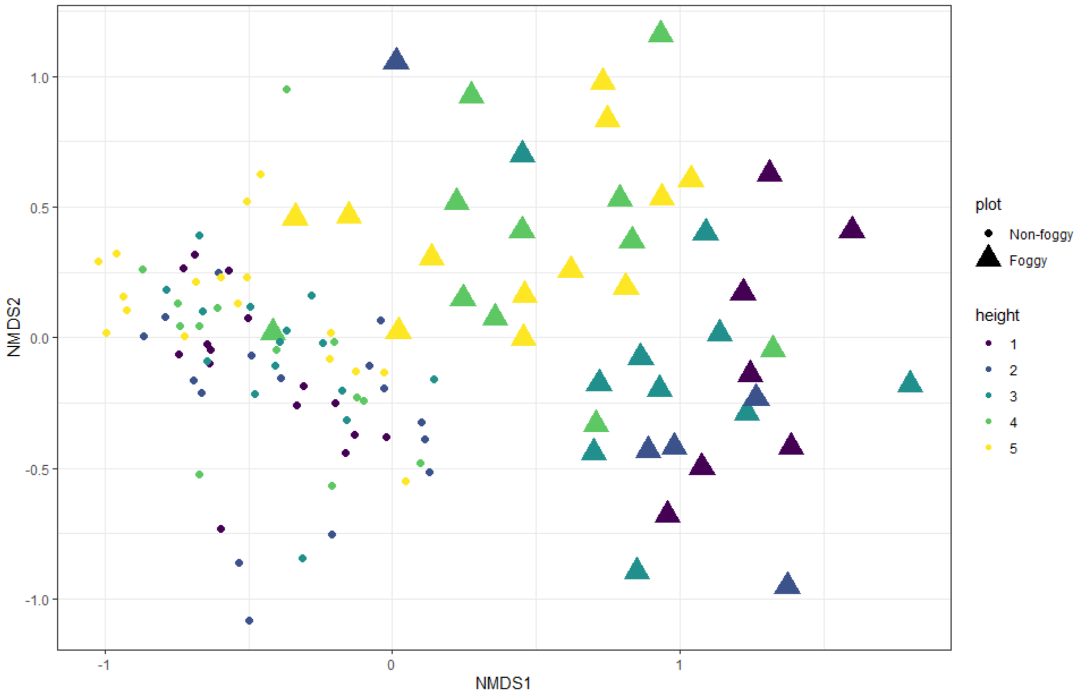


Figure 1: Non-metric multidimensional scaling (NMDS) results of all ASVs. Height 1 to 5 represent the canopy height beginning at the bottom of the tree.

---

[1] Oregon State University, Department of Botany and Plant Pathology; Corvallis, OR, USA

[2] Oregon State University, Department of Forest, Engineering Resources and Management; Corvallis, OR, USA

*Yung-Hsiang.Lan@oregonstate.edu

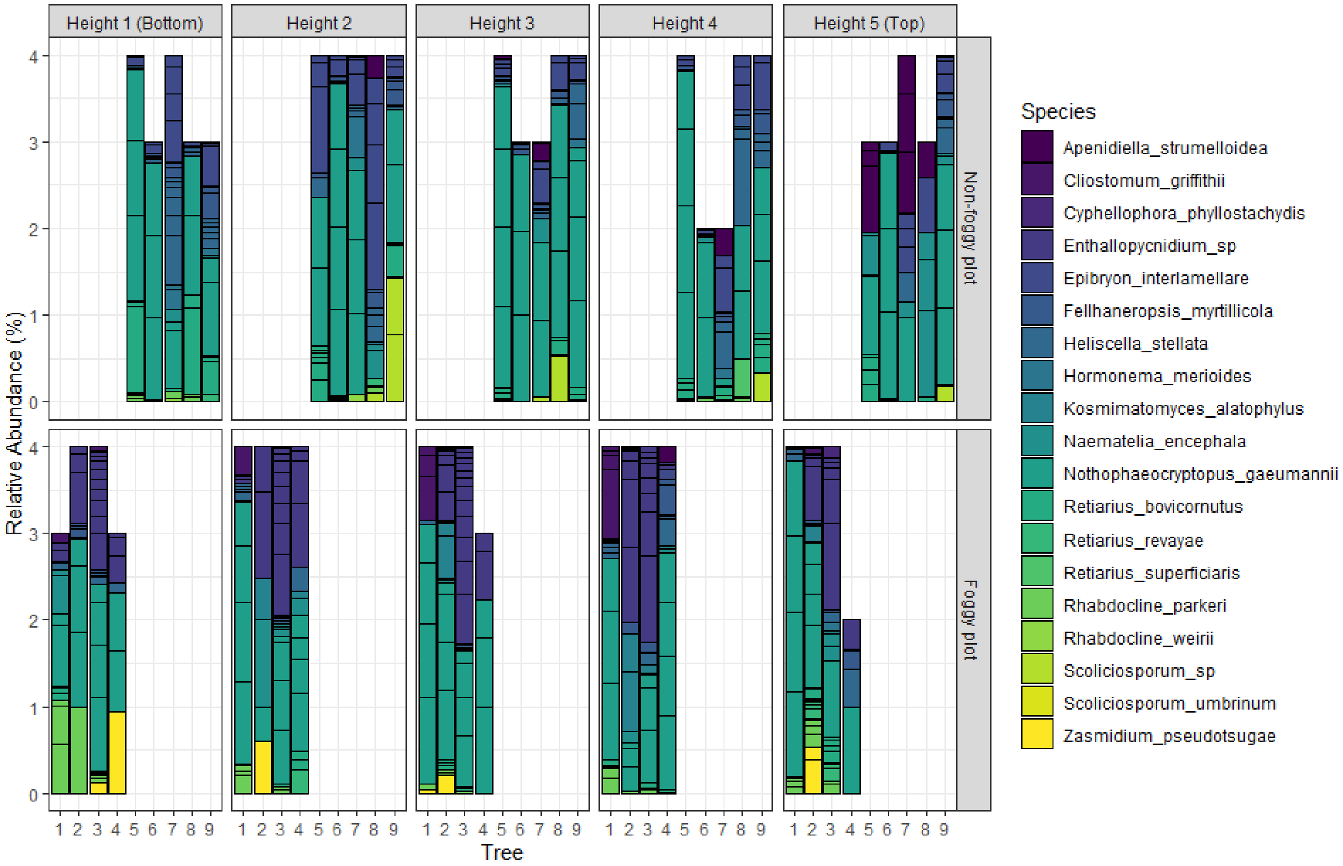


Figure 2: The relative abundance of the known species of the 100 most abundant ASVs.

The effects of sudden oak death and wildfire on the overstory composition of a mixed evergreen forest

Alex Martin[1]*, Nathan Rank[1], Lisa Bentley[1], Ross Meentemeyer[2], and Wahlen Dillon[3]

Introduction

Sudden Oak Death (SOD), caused by the pathogen *Phytophthora ramorum* (*P. ramorum*), has killed millions of trees in northern California and southern Oregon. While SOD can infect many different species, only a few species are relevant to the epidemic: non-lethal leaf infections on California bay laurel leaves drive reproductive spread. Non-reproductive trunk infections on several true oak species, including the iconic coast live and California black oaks, and tanoaks are often lethal. These asymmetrical effects on hosts may result in a positive feedback loop of steadily increased densities of bay laurels, decreases in susceptible oaks and tanoaks and increased pathogen levels (Davidson et 2005).

This would likely result in observable changes to tree succession, with increasing densities of non-lethal host and non-host species along with a decline in susceptible oak species. However, while SOD has been shown to increase mortality of canker host species in mixed evergreen forests (McPherson 2010), a substantial effect on the species composition of infected stands has yet to be demonstrated. Differences in stand characteristics like community type and density may play a role in determining the degree to which SOD can alter forest composition.

Additionally, both wildfire and SOD are important disturbance agents which regularly co-occur, the effects of their interaction on forest community change are of interest (Cobb 2022). SOD-susceptible oaks are typically more resistant to fire than many species that may replace them, which may result in wildfire acting as a stabilizing disturbance in SOD-affected forests.

Questions

How have patterns of overstory species compositional change differed in relation to *P. ramorum* symptom level, tree density, and forest type category?

Does the interaction between wildfire and SOD result in different directional patterns of compositional change than SOD on its own?

Field Methods

This project uses data from a network of 198 mixed evergreen forest study plots in Sonoma County, CA (fig. 1). Plots were established in 2003-04 and measured until 2016. *P. ramorum* was present in the majority of plots by the time of establishment.

Diameters for all overstory trees within each plot were collected at plot establishment and in 2016. Understory transects collected population data about tree seedlings and saplings at plot establishment and 2011. P. ramorum foliar symptoms were measured using timed counts of infected leaves on all bay laurel and tanoaks.

Approximately half of the plots in the network burned in 2017 and 2020 wildfires. In the summer of 2022, we re-measured overstory tree diameters and *P. ramorum* foliar and stem surveys on a subset of 19 plots (nine burned, 10 unburned).

---

[1]Sonoma State University, Department of Biology; Rohnert Park, CA, USA
[2]North Carolina State University, Center for Geospatial Analytics; Raleigh, NC, USA
[3]USDA APHIS; Raleigh, NC, USA
*martinale@sonoma.edu

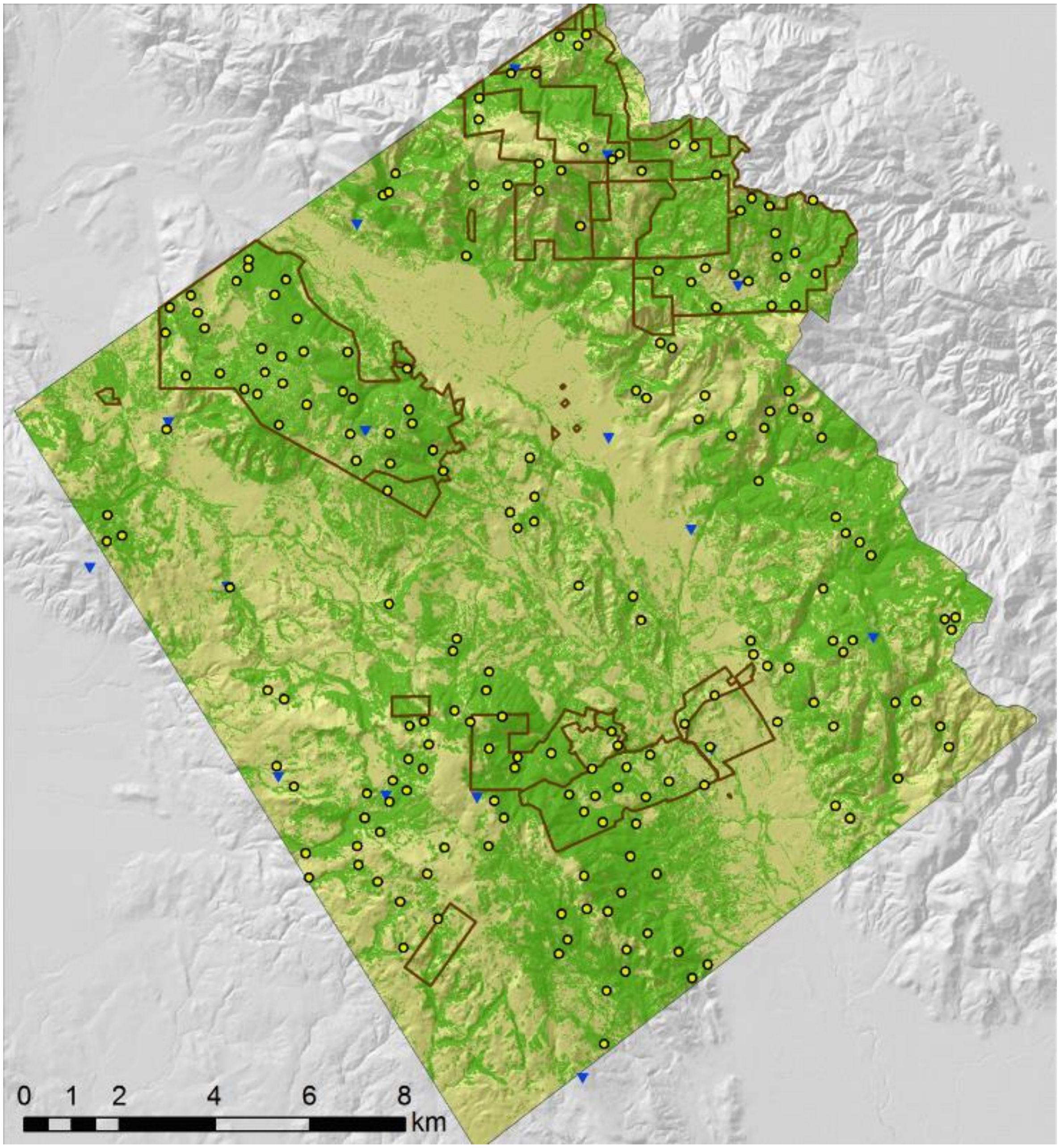


Figure 1. A map of the Sonoma County Sudden Oak Death plot network

Planned Analysis

We intend to use ordination techniques to identify and visualize the most important predictor variables of disease-driven compositional change (fig. 2). We plan to use distance-based multivariate techniques, such as permutational analysis of variance (PERMANOVA) and PERMDISP, to statistically test for changes in composition over time (Anderson et al 2008, Buckley et al 2021). We also intend to investigate the relationship between a variety of environmental and forest structure related variables and changes in abundance of the most epidemiologically relevant trees using path analysis modeling (Grace and Pugesek 1998).

We plan to use this general flow of analysis for the three sets of data: 1: Overstory composition data between 2003-04 and 2016 (Question 1). 2: Recruitment data between 2003-04 and 2011 (Question 1) . 3: Overstory composition data from the 19 plot subset of burned and unburned plots (Question 2).

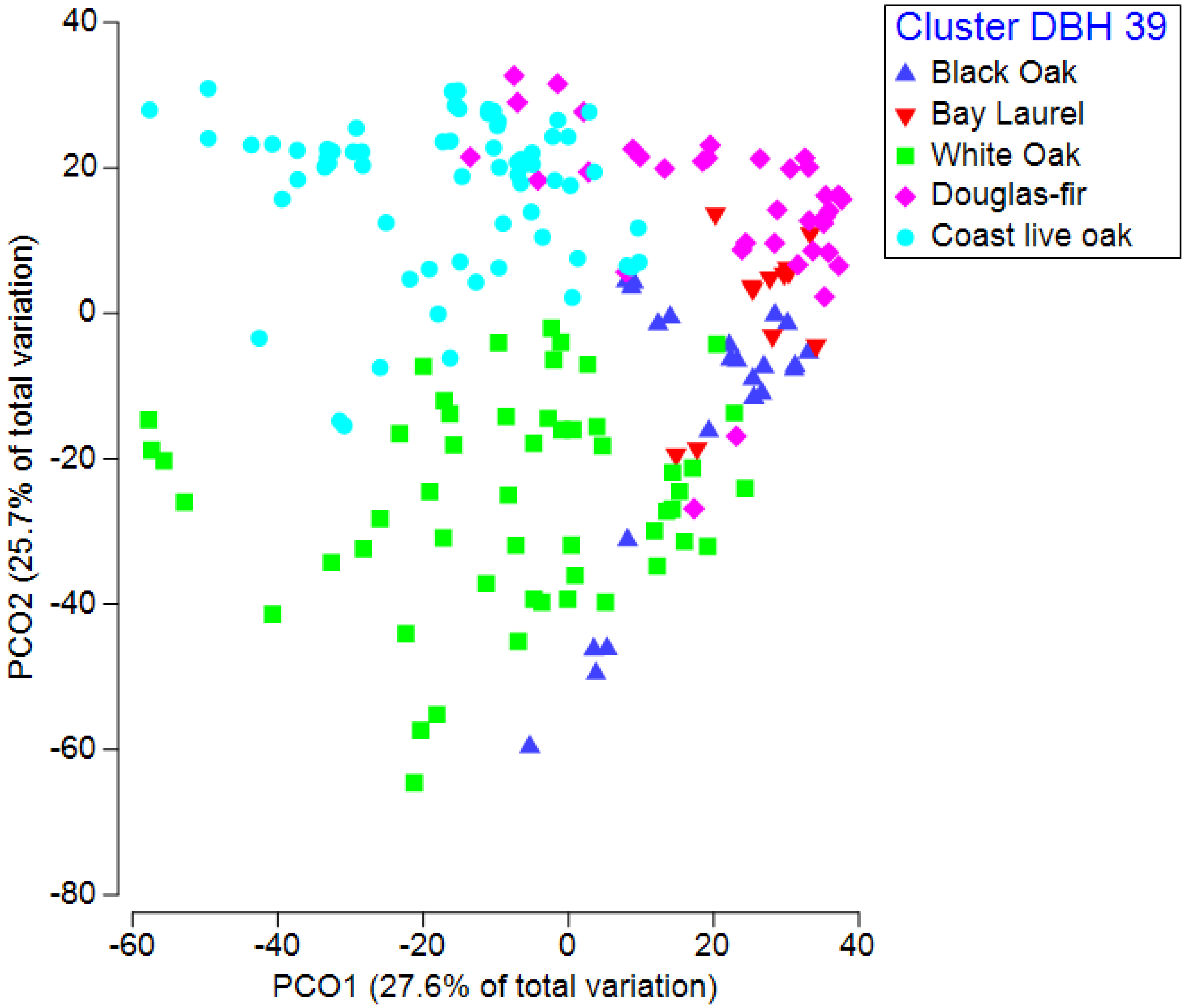


Figure 2. Principle Coordinates Analysis (PCO) ordination plot of the Sonoma County sudden oak death plot network overstory community composition at each plot's first year of measurement. Colors indicate each plots stand composition type, determined using a hierarchical cluster analysis, cut into five cluster types at 39% of the information left and named after the species that prominent tree species. Ordination performed using Primer v6 with the PERMANOVA+ add-on.

Literature Cites

Anderson M.J., Gorley R.N. & Clarke K.R. 2008. PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods. PRIMER-E: Plymouth, UK.

Buckley, H. L., Day, N. J., Case, B. S., & Lear, G. (2021). Measuring change in biological communities: Multivariate analysis approaches for temporal datasets with low sample size. PeerJ, 9, e11096. https://doi.org/10.7717/peerj.11096

Cobb, R. C. (2022). The Intertwined Problems of Wildfire, Forest Disease, and Climate Change Interactions. *Current Forestry Reports*, *8*(2), 214–228. https://doi.org/10.1007/s40725-022-00161-2

Davidson, J. M., Wickland, A. C., Patterson, H. A., Falk, K. R., & Rizzo, D. M. (2005). Transmission of *Phytophthora ramorum* in Mixed-Evergreen Forest in California. Phytopathology®, 95(5), 587–596. https://doi.org/10.1094/PHYTO-95-0587

Grace, J. B., & Pugesek, B. H. (1998). On the use of path analysis and related procedures for the investigation of ecological problems. American Naturalist, 152(1), 151. https://doi.org/10.1086/286156

McPherson, B. A., Mori, S. R., Wood, D. L., Kelly, M., Storer, A. J., Svihra, P., & Standiford, R. B. (2010). Responses of oaks and tanoaks to the sudden oak death pathogen after 8 y of monitoring in two coastal California forests. Forest Ecol. Manage 259(12): 2248-2255, 259(12), 2248–2255. https://doi.org/10.1016/j.foreco.2010.02.020

Monitoring disease and saving trees: Capturing aerial spores to detect the spread of white pine blister rust

Ashley E. Miller[1]*, Kelly S. Burns[2], Anna W. Schoettle[3], and Jane E. Stewart[1]

Five-needle white pine trees exhibit great ecological importance as foundation and keystone species, particularly in mountainous, high-elevation regions. White pine blister rust, a disease on five-needle white pines caused by the invasive fungal pathogen *Cronartium ribicola*, has caused widespread tree decline and mortality of five-needle white pines since its introduction in 1910, most notably in whitebark pine (*Pinus albicaulis*) and limber pine (*P. flexilis*). *C. ribicola* relies on aerial transmission and can travel viably for hundreds of miles. As the latent period of *C. ribicola* can span years, it is crucial to monitor the presence of aerial inoculum to predict disease establishment in naïve, at-risk forests. The monitoring method used in the present study involved collecting aerial *C. ribicola* inoculum via spore traps and use of real-time PCR to quantify *C. ribicola* DNA. Traps were deployed from June to October 2022 at six sites in the Rocky Mountain region of Colorado and Wyoming. *Cronartium ribicola* was identified in 6% of the total air samples collected, with positives occurring between July and September across all six sites. Approximately 39% of collected *C. ribicola* DNA was captured in August, followed by 32% in September, and 29% in July. Results of a mixed-effects ANOVA provide evidence of a significant linear relationship between quantity of aerial *C. ribicola* DNA and relative humidity ($F = 3.90$, $p < .05$). Continuation of this work is ongoing with additional sites in Colorado, Utah, New Mexico, Arizona, and Wyoming, and include forest surveys to assess differences in localized sources of spore inoculum between sites.

Figure 1: Motorized spore trap used to capture aerial inoculum of *Cronartium ribicola*, the causal agent of white pine blister rust disease on five-needle white pine trees.

---

[1] Colorado State University, Department of Agricultural Biology; Ft. Collins, CO, USA
[2] USDA Forest Service, Region 2, Forest Health Protection; Lakewood, CO, USA
[3] USDA Forest Service, Rocky Mountain Research Station; Fort Collins, CO, USA
*Ashley.E.Miller@colostate.edu

Evaluating heights to white pine blister rust cankers on young western white pine in central Oregon with implications for pruning

Brent W. Oblinger[1] and Cameron M. Stauder[1]

Lower branch pruning is a management strategy to mitigate adverse effects of *Cronartium ribicola* on young western white pine (*Pinus monticola*; WWP) in portions of the Interior Northwest, USA (INW). In addition to developing resistant WWP populations (King et al., 2010; Sniezko and Liu, 2022), sanitation and preventative pruning practices are used to enhance survival of young WWP (Zeglen et al., 2010). Sanitation pruning involves the removal of infected branches before *C. ribicola* reaches the bole and becomes lethal while preventative pruning removes susceptible branches and reduces the likelihood of potentially lethal, future infections (Zeglen et al., 2010). Guidelines by Schnepf & Schwandt (2006) are often considered in the INW when planning white pine blister (WPBR) rust pruning efforts. However, only data on heights to WPBR cankers and post-treatment effects from outside the Oregon East Cascades (OEC) have previously informed pruning guidelines. To evaluate the appropriateness of these guidelines for WWP in the OEC, heights to cankers on young WWP were measured in 120 plots within 12 stands throughout the OEC. Canker heights were analyzed for live WWP ≥2.54 cm in diameter at 1.37 m (dbh). Selected stands included those with planted or naturally regenerated WWP and nearly all WWP were < 30 years old at the time of measurement between 2015 and 2021. Genetic resistance to WPBR of both planted stock and naturally regenerated WWP populations was unknown. Mean diameter at dbh and height of WWP in stands ranged 7.9-13.6 cm and 5.1-10.1 m, respectively. Incidence and severity of WPBR on live WWP, in addition to heights to cankers, varied among stands. Increased severity of WPBR (number of cankers on live-infected trees and percent mortality by WPBR) was observed in stands with the alternate host Ribes more frequently occurring in plots. Of all cankers, approximately 97% were found in the lower half of total tree height and only 10% of cankers on young WWP were found above the first third of total tree height. When evaluating canker heights in stands, mean heights to branch and bole cankers were <2.2 m. Bole cankers were lower than branch cankers ($p = 0.01$). In every stand >79% of all cankers were below 2.45 m. Within stands, the number of plots with Ribes present was positively correlated with the number of cankers on live-infected WWP and percent mortality of WWP due to WPBR ($p < 0.04$). As incidence of WPBR on live WWP increased in stands, heights to the highest cankers also increased ($p = 0.002$). The number of cankers on live-infected trees was positively correlated with the mean and highest heights to cankers ($p < 0.002$). In addition to this assessment, long-term monitoring of treatment effects is underway in the OEC. Given that the vast majority of cankers were prunable and occurred in the lower crown of young WWP, pruning lower branches to increase survival of WWP is a management option in the OEC, and prioritization of stands for treatment is recommended. For more details of this study, see the publication by Oblinger and Stauder (2023).

Literature Cited

King, J. N., David, A., Noshad, D., & Smith, J. (2010). A review of genetic approaches to the management of blister rust in white pines. Forest Pathology, 40, 292-313.

Oblinger, B.W. & Stauder, C.M. (2023). Heights to white pine blister rust cankers caused by *Cronartium ribicola* on young *Pinus monticola* in the Oregon East Cascades. Forest Pathology, p.e12832. https://doi.org/10.1111/efp.12832

Schnepf, C. & Schwandt, J. W. (2006). Pruning western white pine: a vital tool for species restoration. University of Idaho Cooperative Extension System. 62 p.

---

[1] USDA Forest Service, Pacific Northwest Region, Forest Health Protection; Bend, OR, USA

Sniezko, R.A. & Liu, J.J. (2022). Genetic resistance to white pine blister rust, restoration options, and potential use of biotechnology. Forest Ecology and Management, 520, p.120168. https://doi.org/10.1016/j.foreco.2022.120168

Zeglen, S., Pronos, J., & Merler, H. (2010). Silvicultural management of white pines in western North America. Forest Pathology, 40, 347-368.

Correlating health and performance phenotypes of *Arbutus menziesii* with provenance

Priya Puri[1]* and Richard Hamelin[1]

Introduction

Arbutus menziesii (arbutus, Pacific madrone) is an iconic tree species characteristic of the Pacific Northwest (McDonald & Tappeiner 1990). Arbutus is an ecologically important native tree for pollinators, wildlife, and soils, and it holds significant cultural value for Indigenous nations and local communities (Adams & Hamilton 1999; McDonald & Tappeiner 1990). Since the early 1970s, arbutus has been in decline throughout its range due to biotic and abiotic factors (Adams & Hamilton 1999). Multiple pathogens, often exacerbated by climate change and urban encroachment, have been found to cause foliar blights, cankers, dieback and root diseases (Adams & Hamilton 1999; Elliott et al. 2014; McGregor 2016).

While diseases are a prominent driver of the decline, the influence of seed source on arbutus health and performance is unknown (Kamakura et al 2021). In this research, we assess the health and performance phenotypes collected for 2280 arbutus between two provenance trial sites in British Columbia (BC), Canada. The objective of this research is to determine the provenances associated with decreased or increased health and performance phenotypes of arbutus. The results of this research have the potential to inform the conservation and management of this iconic tree species by finding locally adapted, high-performing and healthy seed sources able to resist disease.

Methods

Seed sources were collected within the natural range of arbutus between 2006-2010 during the fruiting season. The seed source collection is comprised of 105 open-pollinated half-sibling families from 44 provenances. Seeds were stored and sown at the WSU Puyallup research facility and transplanted in the provenance trial sites after growing in the nursery for 1 year. Both provenance trial sites in BC (Figure 1) are located in clear cuts near active forest service roads. The Texada Island site is flat, fenced, and has a row of border trees on all four sides. Conversely, the Holt Creek site is sloped with varying topography, unfenced and without border trees. Additionally, the Holt Creek site was planted in 2016 to replace the original planting site established in 2012 which was abandoned due to high mortality. Both sites were planted with 2x2 m spacing using a randomized complete block design and the Holt Creek site also includes a demonstration area with three replicates of the same family planted consecutively. The Texada Island planting is larger with 1733 trees originally planted, while the Holt Creek site was planted with 1340 trees, and both sites are comprised of the same seed sources (Table 1).

---

[1] University of British Columbia, Forestry Department of Forest and Conservation Sciences; BC, Canada
*ppuri@mail.ubc.ca

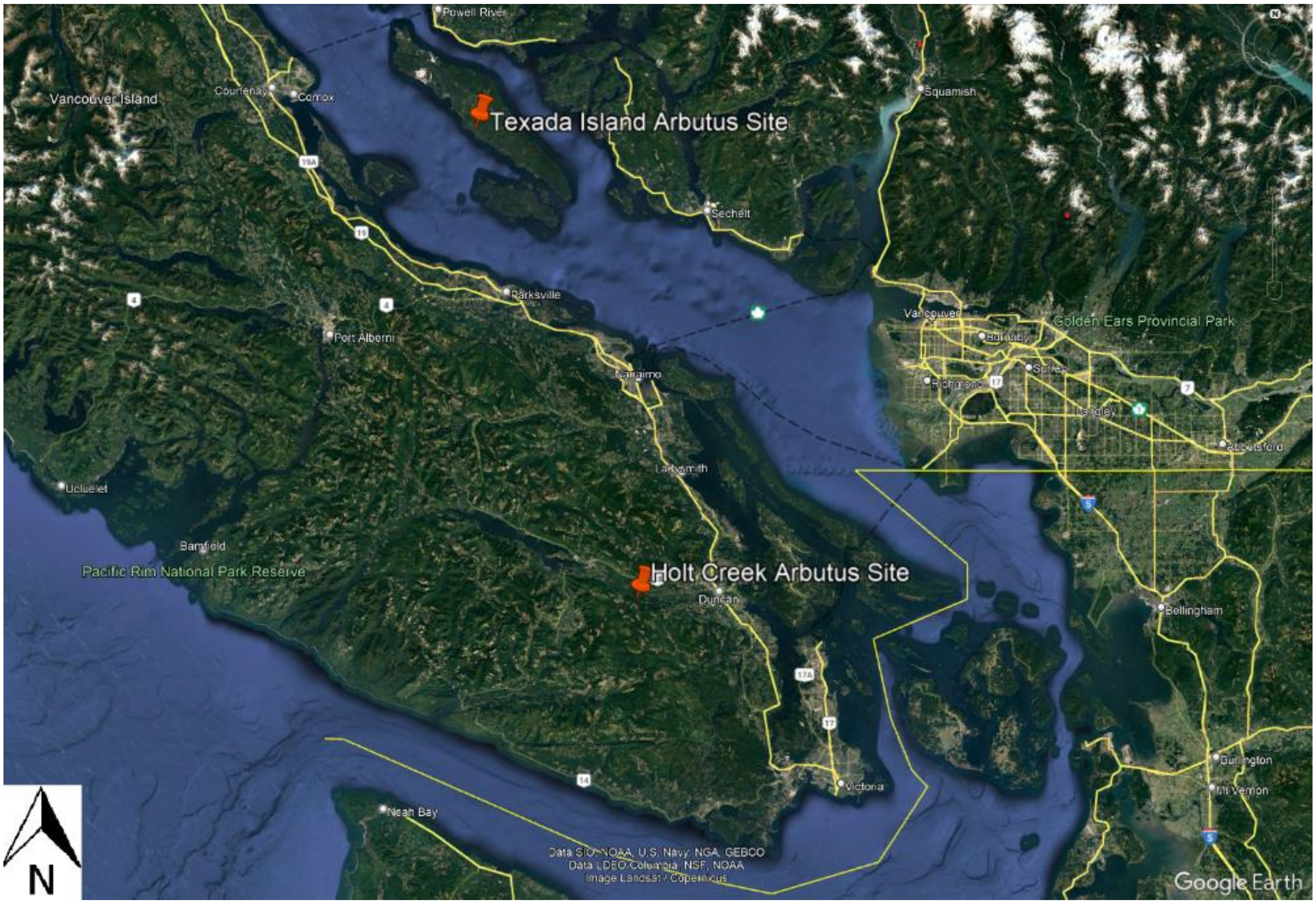


Figure 1: Geographic locations of Holt Creek and Texada Island provenance trial sites in British Columbia, Canada.

Table 1: Texada Island and Holt Creek provenance trial site age, size, biogeoclimatic zone and seed source composition information.

Site	Year planted	Size	BEC zone	No. of families	No. of provenances
Texada Island	2012	1.0 ha	CDF	92	39
Holt Creek	2016	1.0 ha	CWH	81	38

All surviving trees at both sites were measured during the 2022 field season (Holt Creek done in late-May/early-June and Texada Island done in mid-July). Trees at both sites are tagged to identify their row and column location and their family ID. Trees excluded from measurements included border trees and trees that were untagged/unable to identify the family. All measurements listed in Table 2 were collected for each tree. Row, column, and family ID for tags found in planting locations with no tree were recorded as ‘na’ for all Table 2 measurements. Additional variables added in for each measured tree *post hoc* include survival, seed source latitude, longitude, and elevation, and provenance and state associated with each family (e.g., if the family is MB1 or MB4, provenance is Maple Bay and state is BC for both MB1 and MB4). Survival since the initial planting year was determined by cross-checking the row, column, and family ID for trees measured in 2022 with the site maps for trees planted in 2012 (Texada Island) or 2016 (Holt Creek).

Table 2: All phenotypes measured in the field to assess *A. menziesii* health and performance. Health phenotypes consist of disease symptoms and biotic disturbances, while performance phenotypes consist of growth and reproductive characteristics. Height and crown spread were measured using telescoping measuring poles and basal stem width was measured using a calliper. All remaining measurements were collected via visual observation with the assistance of comprehensive guides including written and photo descriptions.

Health	Performance
Condition (1-4)	Height (m)
Dieback (%)	Number of stems
Foliar symptoms (y or n categories)	Basal stem width (mm)
Foliar symptoms severity (binned categories)	Crown spread (m)
Stem symptoms (y or n categories)	Flush (y or n)
Stem symptoms severity (binned categories)	Bud swell (y or n)
Insect damage (y or n categories)	Number of flushes and buds
Wildlife damage (y or n categories)	Flowering (y or n)
Healthy or Unhealthy	

Figure 2: Selected examples of health and performance phenotypes observed at both provenance trial sites. Top row pictures were taken at the Texada Island site and bottom row pictures were taken at the Holt Creek site.

Results

Observationally, arbutus planted on Texada Island have better health and performance than those planted at Holt Creek. 11-year survival at Texada Island was 84% while 7-year survival at Holt Creek was 61%. Texada Island trees tended to be taller with less dieback while Holt Creek trees tended to be shorter with more dieback (Figure 3). Between both sites, trees from California seed sources tended to have the most dieback and be the shortest, while trees from Oregon, Washington, British Columbia seed sources tended to show more similar height and dieback patterns (Figure 3).

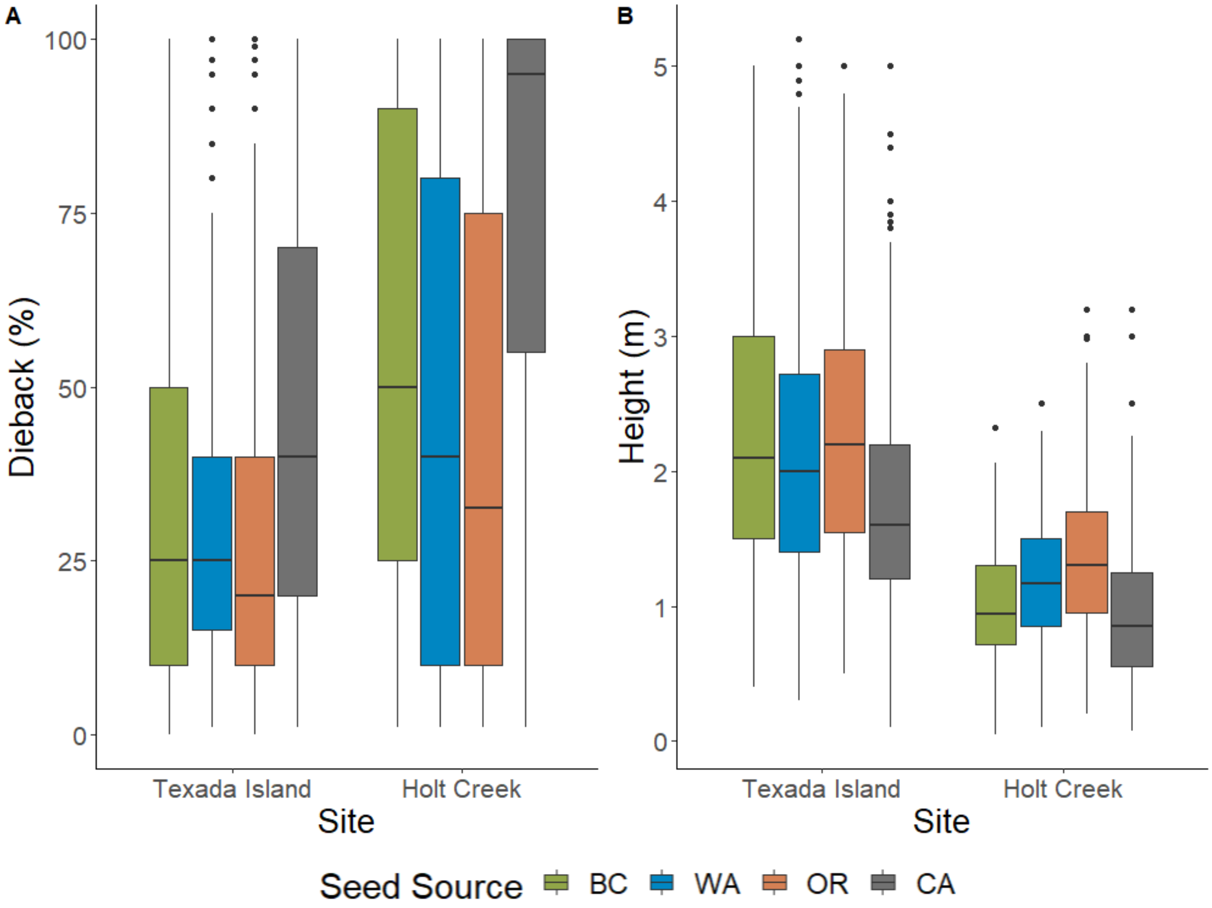


Figure 3: a) Boxplots showing mean and interquartile ranges for the proportion of dieback on *A. menziesii* grouped by broad seed origin (British Columbia, Washington, Oregon, California) between two provenance trial sites in British Columbia. b) Boxplots showing mean and interquartile ranges for *A. menziesii* height (m) grouped by broad seed origin (British Columbia, Washington, Oregon, California) between two provenance trial sites in British Columbia.

Between both sites, over half of the trees measured were categorized as condition 1 or 2 indicating less than 50% dieback and overall excellent to good health and performance by appearance (Figure 4). Most of the trees classified in condition 1 and 2 were from Oregon, Washington and British Columbia seed sources, while California seed sources proportionally were more represented in conditions 3 and 4 (Figure 4). There were fewer families from California planted at each site; however, of those families planted, most showed notably poor health and performance and many had been overcome by necrosis.

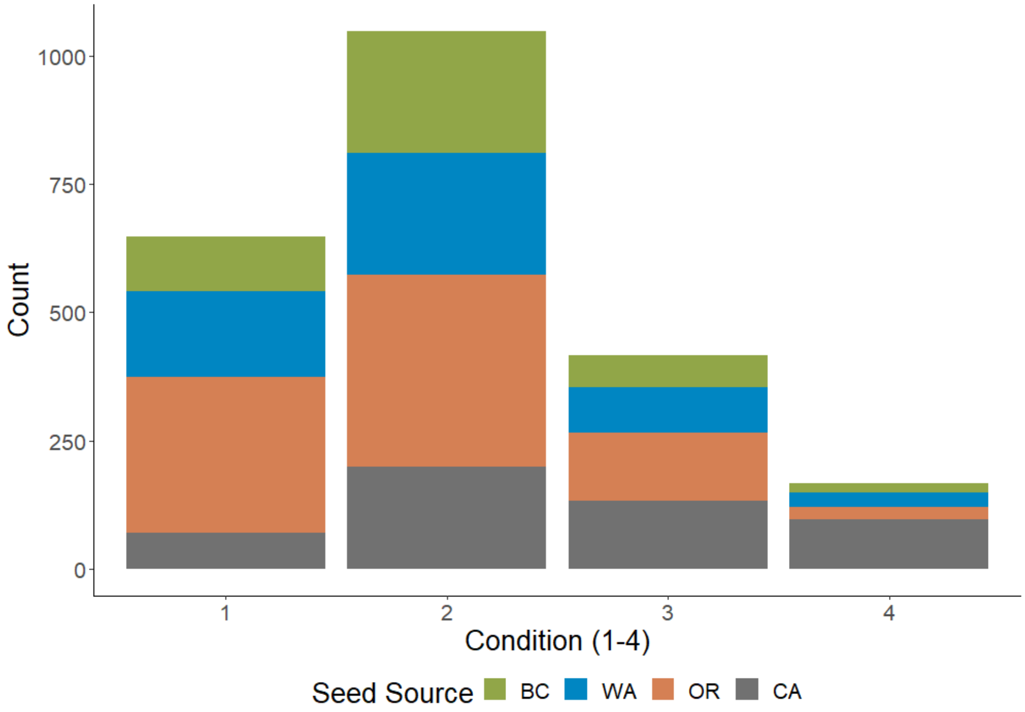


Figure 4: Mosaic barplot showing the distribution of 2280 *A. menziesii* across four health condition classifications. Colours represent broad seed origin (British Columbia, Washington, Oregon, California) and show the relative number of trees from each location measured in each condition category.

Survival of just BC seed sources was 80% with 426 trees surviving out of 534 originally planted between both provenance trial sites (Figure 5a). Similar to the condition results for both sites shown in Figure 4, most BC trees measured between both sites were categorized as condition 1 or 2 and fewer as condition 3 or 4 (Figure 5b). BC trees planted on Texada Island tended to be taller with less dieback than BC trees planted at Holt Creek which tended to be notably shorter with much more variation in dieback (Figure 5c & 5d). BC trees planted on Texada Island did not show much variation in dieback and height between provenance (Figure 5c & 5d). Conversely, BC trees planted at Holt Creek showed a wide range of dieback with Maple Bay trees showing particularly high dieback at Holt Creek while also being quite short (Figure 5c & 5d). BC trees at Holt Creek were notably shorter, due in part to being four years younger than Texada Island trees, with most trees averaging 1.0-1.5 m tall (Figure 5d).

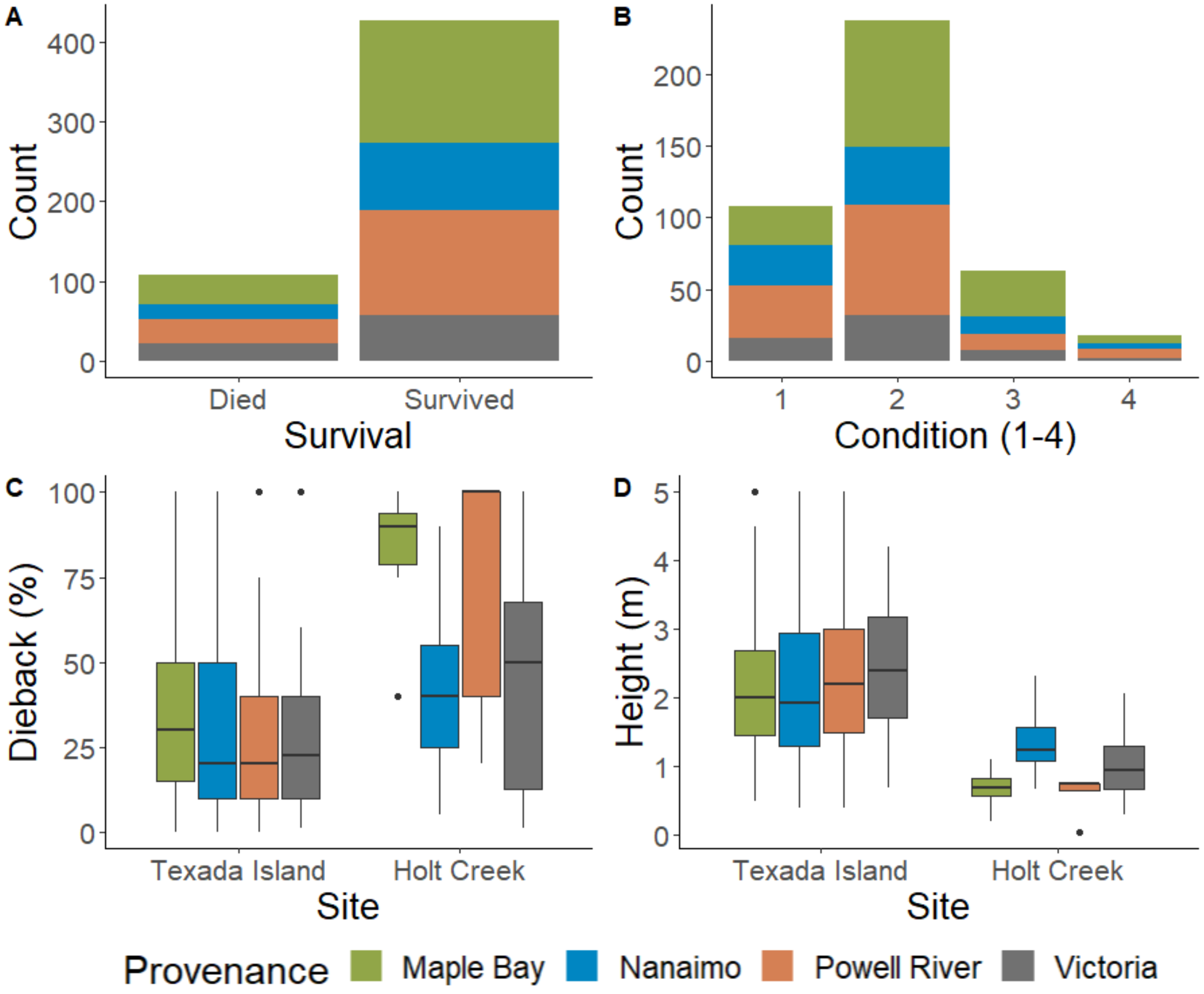


Figure 5: Data subset of *A. menziesii* from only British Columbia seed sources grouped by four local BC provenances (Maple Bay, Nanaimo, Powell River, Victoria) planted in the Texada Island and Holt Creek trial sites. a) Mosaic barplot showing the survival of 534 *A. menziesii* BC seed sources with colours representing local provenances. b) Mosaic barplot showing the distribution of 426 *A. menziesii* across four health condition classifications. Colours represent local BC provenances and show the relative number of trees from each location measured in each condition category. c) Boxplots showing mean and interquartile ranges for the proportion of dieback on *A. menziesii* grouped by local BC provenances between two provenance trial sites in British Columbia. d) Boxplots showing mean and interquartile ranges for *A. menziesii* height (m) grouped by local BC provenances between two provenance trial sites in British Columbia.

Previous research in the Washington and Oregon provenance trials has identified two families as being blight-resistant, OR1, and blight-susceptible, HC2, (personal communications with Marianne Elliott). OR1 showed 100% survival at both sites in BC while HC2 showed 40% (Figure 6).

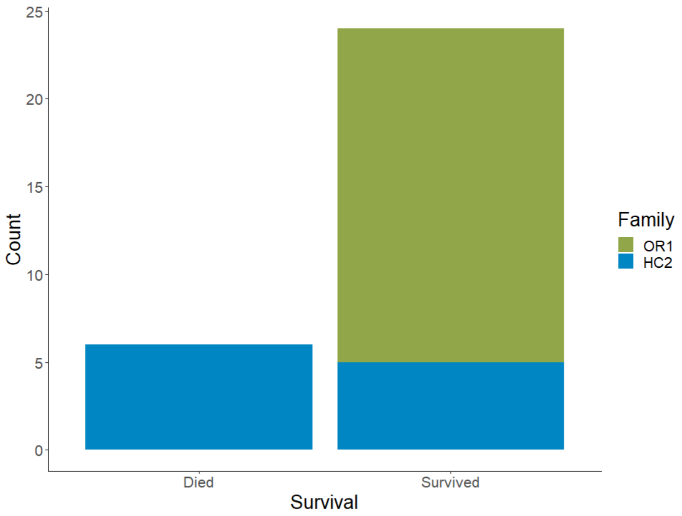


Figure 6. Data subset of 30 *A. menziesii* from two families identified as being blight-resistant (OR1, Cornelius, Oregon) and blight-susceptible (HC2, Humboldt County, California). Mosaic barplot shows the survival OR1 and HC2 seed sources with colours representing each family.

Next Steps & Implications

Further analysis will use statistical models to identify healthy, high-performing provenances and unhealthy, low-performing provenances. Additional sampling of leaves, stems, roots and soil will be used to identify microbes associated with the range of health and performance phenotypes measured. The results of this research can be used to characterize local adaptation and maladaptation of arbutus in British Columbia. Additionally, model results paired with microbiome results may identify key interacting biotic and abiotic factors contributing to the range-wide decline of arbutus. Future iterations of this research should look to select and breed healthy, high-performing arbutus seed sources for natural resistance to disease and resilience. The overarching goal of this research is to inform management decisions regarding the conservation of arbutus and associated endangered ecosystems.

Acknowledgements

Thank you to my supervisory committee (R. Hamelin, P. Arcese & N. Feau) for their support and guidance. This project has been made possible due to a generous donation from a private foundation. This project is part of a collaborative effort to conserve this iconic tree species—thank you to our collaborators from the BC Ministry of Forests, USFS, WSU, and Arbutus ARME for your partnerships and ongoing teamwork. Thank you to my field assistants for your hard work to help with data collection.

Literature Cited

Adams, A.B. & Hamilton, C.W. (1999). The Decline of Pacific Madrone (*Arbutus menziesii* Pursh): Current Theory and Research Directions.

Elliott, M. et al. (2014). First Report of a New Leaf Blight Caused by *Phacidiopycnis washingtonensis* on Pacific Madrone in Western Washington and Oregon. APS.

Kamakura, R.P. et al. (2021). Using differences in abiotic factors between seed origin and common garden sites to predict performance of Pacific madrone (*Arbutus menziesii* Pursh). FEM.

McDonald, P.M. & Tappeiner, J.C. (1990). *Arbutus menziesii* Pursh Pacific madrone.

McGregor, R.R. et al. (2016). *Neofusicoccum arbuti*: a hidden threat to *Arbutus menziesii* characterized by widespread latent infections and a broad host range. CJPP.

Balsam woolly adelgid infestations and grand fir decline on the North Coast of California

Michael Jones[1], Chris Lee[2], Yana Valachovic[1], Wallis Robinson[1]*, and Ryan Maberry[1]

Abstract

We investigated balsam woolly adelgid infestations on grand fir (*Abies grandis*) in its southern range along the North Coast of California. Although declining grand firs in the study area exhibited symptoms of balsam woolly adelgid infestation, many also were affected by other pathogens and other stressors. Root disease caused by *Heterobasidion occidentale* and *Armillaria* species was present at most of our plots. Invasive understory plants and windthrow from recent storms also affected some of our sites. We conclude that a combination of multiple stressors is likely responsible for grand fir decline on the North Coast.

Introduction

Balsam woolly adelgid (*Adelges piceae*, BWA) is a non-native sap-sucking insect that parasitizes firs. According to Spiegel et al. (2013) BWA likely caused the elimination of most if not all large-diameter, low-elevation grand fir in Oregon during the twentieth century. Since BWA was first detected on the California coast in 2011, grand fir decline has visibly increased, with dead trees and contorted fir crowns visible in many locations. In some places, grand fir mortality is occurring in the same places as bishop pine decline and sudden oak death, raising the question of whether these forests are experiencing a transition from forest to shrubland or coastal prairie. More information on this phenomenon is needed to inform management efforts on these landscapes. This project examines the extent of BWA infestations on coastal grand fir within the context of various other biotic and abiotic stressors. To this end, we asked the following three questions: 1) To what degree are coastal grand fir declining on the North Coast?, 2) How widespread and severe are BWA infestations on grand fir on the North Coast?, and 3) What other factors contribute to grand fir decline on the North Coast?

Figure 1: Healthy and declining grand firs at Lake Earl site. Photo credit: Chris Lee

---

[1] University of California Cooperative Extension; CA, USA
[2] California Department of Forestry and Fire Protection; Fortuna, CA, USA
*wlrobinson@ucanr.edu

Methods

We established five 0.1 ha plots at each study site along the range of grand fir on the California coast (Del Norte, Humboldt, Mendocino, and Sonoma Co.). In each plot, we collected data on tree species, diameter, status, and for living grand fir, height, and presence of other pests/disease. For living fir trees, bole infestations were assessed using methods developed by Spiegel et al. (2013). Crown dieback, gouting, and deformities were assessed using methods developed by Hrinkevich et al. (2016). Environmental variables, including elevation, slope position, aspect, and distance from ocean were recorded for each plot.

We also investigated the occurrence of *H. occidentale* intensively because it is known to reside endophytically in white fir (*Abies concolor;* M. Garbelotto, pers. comm.) and we reasoned the same could be true in grand fir. We removed four short increment cores from five grand firs in each plot—two from the root crown area and two from roots—and incubated them in a moist bag for 7-10 days, checking them every other day for the appearance of the characteristic conidiophores of the fungus.

Results

Grand fir mortality

97% of the trees in our Humboldt and Del Norte study plots were still alive at the time of our second survey. The Lake Earl site experienced no mortality during the study period, while the Trinidad and Fortuna sites experienced 4% and 6% mortality rates, respectively. The highest mortality rate was at a Fortuna plot, where 19% (5) of the study trees died during the year between surveys. Mortality occurred at all but the greatest size and height classes, of which there were very few individuals to begin with.

Grand fir decline (Canopy cover and crown decline)

The average canopy cover for our Humboldt and Del Norte sites (excluding LE5 and SWD3) was 92% during the initial survey, while the average canopy cover a year or two later during the second survey was 87%, for an average reduction of 5% canopy cover between the two survey periods.

Grand fir of all heights and sizes experienced decline between the two survey periods. Although the trees at the Fortuna site had the greatest average canopy decline during both survey periods, the trees Seawood Cape Preserve experienced the greatest change in canopy decline between survey periods (Table 1). This is probably due to the site’s proximity to the ocean and the extreme wind events during the winter preceding resurvey.

Table 1: Site averages for crown decline, bole infestation and gouting during the first and second survey periods (S1 and S2 respectively).

Site	Crown Decline		Bole Infestation		Gouting	
	S1	S2	S1	S2	S1	S2
FNA	2.89	3.09	0.82	0.69	1.86	1.97
LE	2.34	2.47	0.40	0.40	1.08	1.30
SWD	0.44	2.63	0.29	0.20	0.00	1.32

BWA presence and severity

We found evidence of BWA infestation (bole and/or gouting) during at least one survey period on 94% of our study trees in our Humboldt and Del Norte sites. We found the lowest infestation rate at Seawood Cape Preserve, where 91% of study trees exhibited signs or symptoms of BWA. Our highest infestation rate occurred at our Fortuna site, with 99% of trees showed evidence of BWA infestations.

Gouting ranged from absent to moderately severe gouting during the first survey period and from mild to moderately severe gouting during the second survey period (Table 1). The average level of bole infestation at each site stayed between zero and less than 1 adelgid per square foot during both survey periods, with infestation levels either staying similar or dropping during the second survey period (Table 1). Trees at the Fortuna site experienced the most severe signs and symptoms of BWA infestation, while trees at the Seawood Cape Preserve experienced the least severe signs and symptoms.

Bigger, taller grand firs experienced less gouting during the first survey period, but all grand firs experienced similar and increased gouting during the second survey period. Bole infestation was negatively correlated with size during both survey periods. Bole infestation was also positively correlated with gouting for both survey periods.

Other diseases

We observed a variety of other pathogens and insect pests infesting grand firs in our study sites. Occurrence of these agents varied seasonally and from site to site. They included the root pathogens *Heterobasidion occidentale, Armillaria mellea, Armillaria gallica,* and potentially other unidentified *Armillaria* spp.; a bark beetle, the fir engraver (*Scolytus ventralis*); the twig beetle *Cryphalus pubescens;* the butt and stem decay fungi *Ganoderma brownii*, *Ganoderma oregonense,* and *Porodaedalia cancriformans;* and a variety of invasive plants, particularly at the Fortuna site (e.g., *Hedera helix, Cotoneaster* sp*., Rubus discolor, Cytisus scoparius*). Observed incidence of *H. occidentale* at our site in Humboldt and Del Norte Counties was 19% at Lake Earl, 32% at Seawood Cape Preserve, and 75% at Fortuna, suggesting that the fungus may indeed maintain a relatively constant endophytic presence in coastal grand firs and/or may develop increased pathogenic aggressiveness on these trees in the presence of other stress agents.

Discussion

BWA and grand fir decline

Unlike its effect on subalpine fir (*Abies lasiocarpa*), BWA does not seem to be the sole cause of death for coastal grand firs. While infestations cause notable canopy damage that likely contributes to decline, many trees were also contending with other biotic and abiotic stressors (e.g., root disease, beetles, windthrow). Of our three northernmost sites, the Fortuna site had the most obviously stressful conditions, with a high incidence of invasive plants and root disease, as well as the most severe BWA infestations. This site also consistently had the highest levels of crown decline and mortality. Although not conclusive, our findings suggest that decline occurs to a greater extent in stands that are facing multiple stressors at a time.

BWA extent on the North Coast

During travel between sites, we detected BWA infestations at several other sites along California's north coast that were not known to be infested prior to this project. These areas include Salt Point State Park and Gualala in southern Mendocino County, the Mattole River corridor in southern Humboldt County, Sequoia Park in Eureka, and Azalea State Preserve in northern Humboldt County. BWA is clearly well-established and has probably been so for several decades in coastal grand fir.

Conclusions

Coastal grand firs are declining across stands in a variety of conditions. Decline appears to be extensive throughout the North Coast.

Balsam woolly adelgid infestations are widespread throughout the southern range of coastal grand fir but are more severe in areas with additional stressors.

The decline in coastal grand fir in northern California is not attributable to any one pest or pathogen and is instead the result of the accumulation of multiple biotic and abiotic factors.

Acknowledgements

This project was funded by the United States Forest Service through Evaluation Monitoring Program Grant 19-DG-213. We thank California State Parks, the Wildland Conservancy, and private landowners for allowing us to do this work on their property.

Literature Cited

Spiegel, L.H., Chadwick, K., Mehmel, C. 2013. Assessment of balsam woolly adelgid damage to eastern Washington and Oregon subalpine fir. in Potter, K.M., Conkling, B.L., eds. Forest Health Monitoring: National Status, Trends, and Analysis 2010. Gen. Tech. Rep. SRS-GTR-176. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 129-134.

Hrinkevich K.H., Progar R.A., Shaw D.C. 2016. Climate risk modelling of balsam woolly adelgid damage severity in subalpine fir stands of western North America. PLoS ONE 11(10): e0165094. https://doi.org/10.1371/journal.pone.0165094

Assessing historical and contemporary rates of white pine blister rust incidence in naturally regenerated stands of western white pine for the prioritization of restoration sites under changing climate

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

Introduction

Western white pine (WWP; *Pinus monticola*) is a keystone species in moist forests of western North America that displays adaptation to ranging climates and resilience to native root diseases. Since *Cronartium ribicola*, the cause of white pine blister rust (WPBR), was introduced to North America in the early 1900s, WBPR has caused dramatic reductions in WWP across its native range. Although WPBR is well established throughout WWP's range, observations have suggested some recent, naturally regenerated WWP stands in northern Idaho, USA display lower rates of WPBR incidence than was recorded historically in WWP stands that were established at similar sites. Analyses of recent WPBR incidence rates in regenerated WWP at these sites may be useful to determine if favoring natural WWP regeneration can aid restoration of WWP stands with reduced WPBR in some areas. Areas with reduced WPBR rates can be prioritized by forest managers for encouraging WWP regeneration and fostering 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. However, inclusion of WWP in future forests might offer some resilience to climate change, provided that WPBR rates allow for WWP survival to maturity.

Objectives

The objectives of this project are to 1) assess WPBR incidence over time in naturally regenerated WWP at diverse sites in northern Idaho; 2) compare recent WPBR incidence rates with that recorded in WWP that existed at the same locations ca. 80 years ago; and 3) identify areas where naturally regenerated stands of WWP are experiencing rates of WPBR that allow persistence of WWP as fully functioning component of the forest ecosystem. The long-term goal of this project is to characterize areas where WWP regeneration should be encouraged to increase forest resilience to climate change, root diseases, and other disturbances.

Materials and Methods

Surveys determined contemporary incidence of WPBR over time by determining approximate ages of all WPBR cankers based on their position in the branch whorls of each tree (representing the previous 15-year period) for ca. 30 naturally regenerated WWP within each stand at 26 sites [with the exceptions at two sites including the HM site (15 WWP trees) and CT site (16 WWP trees)] (Figure 1). Preliminary, historical WPBR progress curves were determined for nine these sites based on 1967 data in which WPBR canker numbers and ages were determined from felled WWP trees that had been growing since ca. 1940. The 15-year WPBR increase rates (1940-1954) from the historical records were used for comparison with contemporary 15-year (2006-2020) WPBR increase rates. Assigning years / ages for each the WPBR canker assumed that all *C. ribicola* infections had occurred in the first-year needles. The following current information was collected from each tree for all sites:

---

[1] Colorado State University, Department of Agricultural Biology; Fort Collins, CO, USA
[2] USDA Forest Service, Pacific Northwest Research Station; Corvallis, OR, USA
[3] USDA Forest Service, NFS, Southern Region; Atlanta, GA, USA
[4] USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA
[5] USDA Forest Service, FHP-Region 1; Coeur d'Alene, ID, USA
*jane.stewart@colostate.edu

- Age (yr), DBH (cm), height (m) of regenerated trees
- Counts of WPBR cankers, WPBR canker age, and *Ribes* spp. (alternate host) (Figure 2)

Preliminary Results

- From contemporary and historical WPBR incidence rates, WPBR rates have decreased at most sites (Figs. 3 and 4).
- WPBR incidence rate appears to vary among sites (Figs. 3 and 4)
- At most sites, WPBR rates appear to be low enough to allow sustainable growth of regenerated WWP. In these areas, WWP regeneration should be encouraged, provided that management to enhance regeneration does not adversely affect subsequent rates of WPBR incidence.

On-going Analyses

Areas where WWP has natural recovery that is exhibiting low WPBR incidence will be identified along with geographic areas where WWP is predicted to remain climatically adapted. The potential influence of climate on WPBR rates will also be examined, if significant differences in WPBR rates are found in a sufficient number of sites.

Management Implication

It is unknown if apparently lower WPBR incidence rates 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), changes in general environmental conditions (e.g., climate or weather), or other unknown factors. However, it appears that rates of WPBR are low enough (less than 30%) in most sites that WWP regeneration should be encouraged, especially if the future climate is predicted to be 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.

Acknowledgements

This project is supported by USDA-Forest Service (FS), State, Private, and Tribal Forestry, Forest Health Protection - Special Technology Development Program (STDP-R1-2020-01), USDA FS Rocky Mountain Research Station, USDA FS Pacific Northwest Research Station, and Colorado State University. 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.

The soil microbiome associated with brown root rot pathogen (*Phellinus noxius*) in the Pacific Islands – Implications for disease management

Olga Kozhar[1], Mee-Sook Kim[2], Phil G. Cannon[3], Jane E. Stewart[1]*, and Ned B. Klopfenstein[4]

Introduction

Phellinus noxius, is a destructive, fast-growing pathogen that causes brown root rot disease of a very wide range of woody hosts (Cannon et al. 2022). Its devastating effects on fruit trees, cacao, ornamentals, coffee, and rubber have been documented across diverse global regions, such as Taiwan, Japan, Hong Kong, Southeast Asia, Australia, and various Pacific Islands (e.g., Guam, Saipan, Kosrae, Pohnpei, Palau, American Samoa, etc.) (Stewart et al. 2020; Cannon et al. 2022). To date, this pathogen has not been reported in some Pacific Islands and other U.S. states/territories (e.g., Hawaii, Florida, Puerto Rico), but it represents a major invasive threat based on our bioclimatic models (Stewart et al. 2020). Current concerns are that future human activities will exacerbate this disease or even potentially introduce it to other locations, where it has not been reported (e.g., Kozhar et al. 2022; Stewart et al. 2020).

With a broad host range of over 200 host species (e.g., Ann et al. 2002; Brooks 2002; Cannon et al. 2022), *P. noxius* can cause extensive damage to sub- and tropical forest ecosystems when present on a site. Further, as a root pathogen that can exist as a saprophyte for long periods (e.g., Chang 1996), *P. noxius* can be extremely difficult to eradicate from a site. In attempting to reduce inoculum density of *P. noxius*, some soil amendments (e.g., urea) were added and showed promising results (Chang and Chang 1999; Cannon et al. 2022). To assess the efficacy of treatments to reduce *P. noxius*, it is essential to monitor and determine changes of *P. noxius* inoculum density as influenced by different soil amendments over time. Monitoring inoculum density through traditional techniques (e.g., cultured-based) can be challenging, time consuming, and lack sensitivity. A molecular approach with microbiome sequencing and species-specific markers will enable monitoring of the management treatment effects over time more quickly and efficiently. The goal of this study was to characterize microbial communities associated with soils of trees infected with *P. noxius* on Guam and Pohnpei.

Methods

Sampling: Rhizosphere soils collected from healthy and *P. noxius*-infected trees including 3 healthy and 3 diseased *Meiogyne cylindrocarpa* (an evergreen rainforest plant also known as fingersop) trees in Guam, and 2 healthy and 2 diseased *Artocarpus altilis* (breadfruit) trees in Pohnpei, FSM.

Procedure: For each brown root rot diseased (*P. noxius*-infected/symptomatic) tree, soil samples were collected on the sides of infected lateral roots with symptoms/signs (encrusted fungal mat and/or soft-rot). Similar rhizosphere samples were collected from asymptomatic (healthy) trees that were at least 15 m (50 ft) away from any tree with brown root rot disease symptoms.

Soil collection, extraction, sequencing and analyses: To collect soil samples from the rhizosphere of healthy and diseased trees, the organic debris was first removed from the soil surface, and then ca. 50 g (3 tablespoons) of soil was collected at a depth of 7.5 cm (3 inches) and placed in LifeGuard Soil Preservation solution to protect the DNA. Additional soil associated with each sample was collected in bags and placed in a freezer for subsequent analyses of soil pH and % soil moisture. Total soil DNA was extracted using the Qiagen PowerSoil Kit. Libraries

---

[1] Colorado State University, Department of Agricultural Biology; CO, USA
[2] USDA Forest Service, Pacific Northwest Research Station; Corvallis, OR, USA
[3] USDA Forest Service, State, Private, and Tribal Forestry, Pacific Southwest Region, Forest Health Protection; Vallejo, CA, USA
[4] USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA
*jane.stewart@colostate.edu

were generated for each sample at the ITS for fungal communities and 16s for bacterial communities, and Illuminia sequenced on a MiSeq. For investigating soil microbes associated with *P. noxius* inoculum density, reads from the pooled dataset were separated for each sample. Software mothur (Schloss et al. 2009) was used for reads identification and package vegan v.2.6-4 (implemented in R) (Oksanen et al. 2020) for overall fungal and bacterial diversity estimates and ordination plots for estimating changes occurring over time and with different treatments.

Preliminary Results

- Principal coordinates analyses showed that microbial communities (both fungi and bacteria) differ by geographic location, but not by rhizosphere samples from *P. noxius*-infected (symptomatic) and healthy (asymptomatic) trees (Figure 1).
- In Guam, fungal diversity decreases and bacterial diversity increases within the rhizosphere of symptomatic trees, but this trend was not apparent in rhizosphere samples from Pohnpei (Figure 2).
- Comparisons between the rhizospheres of symptomatic and asymptomatic trees from Guam revealed a greater shift in the fungal communities compared to the bacterial communities (Figure 3).
- Significantly higher abundances of Sympoventuriaceae and *Trechispora* were found in rhizospheres of symptomatic trees, whereas significantly higher abundances of *Leohumicola*, *Plenodomus*, and Didymosphaeriaceae were found in rhizospheres of healthy trees (Figure 4).

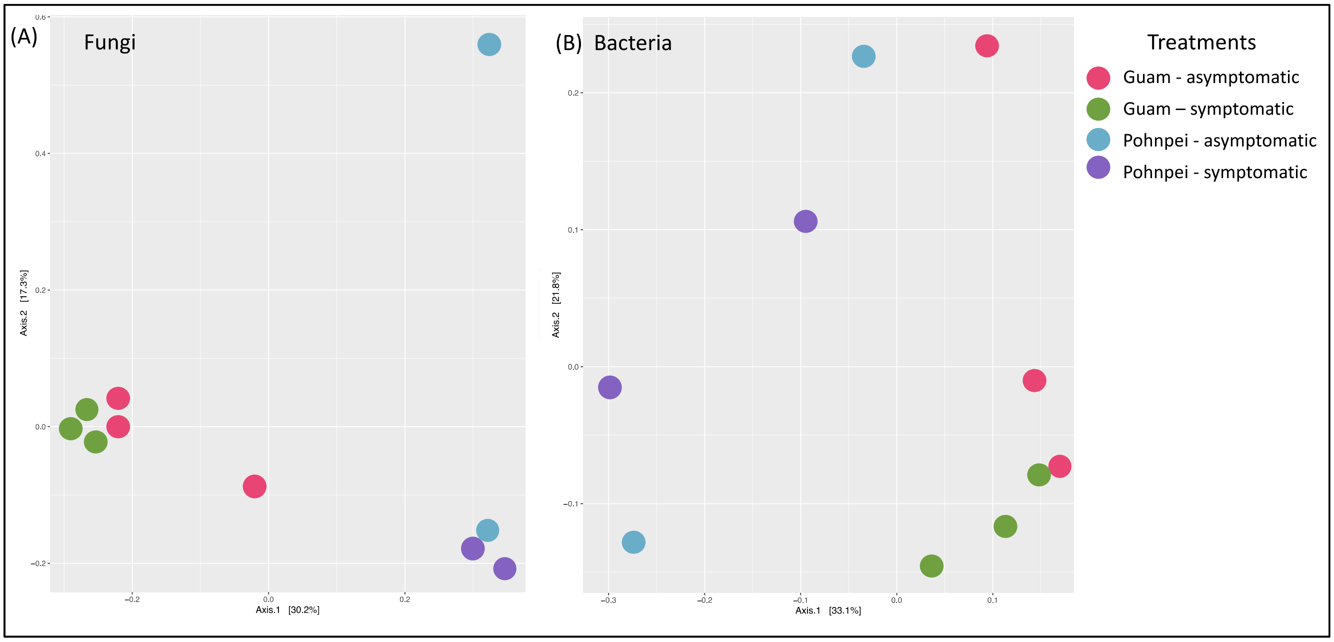


Figure 1: **Principal Coordinates Analyses** of microbial communities (A: Fungi and B: bacteria) from Guam and Pohnpei (FSM) associated with the rhizospheres of *Phellinus noxius*-infected (symptomatic) and healthy (asymptomatic) trees.

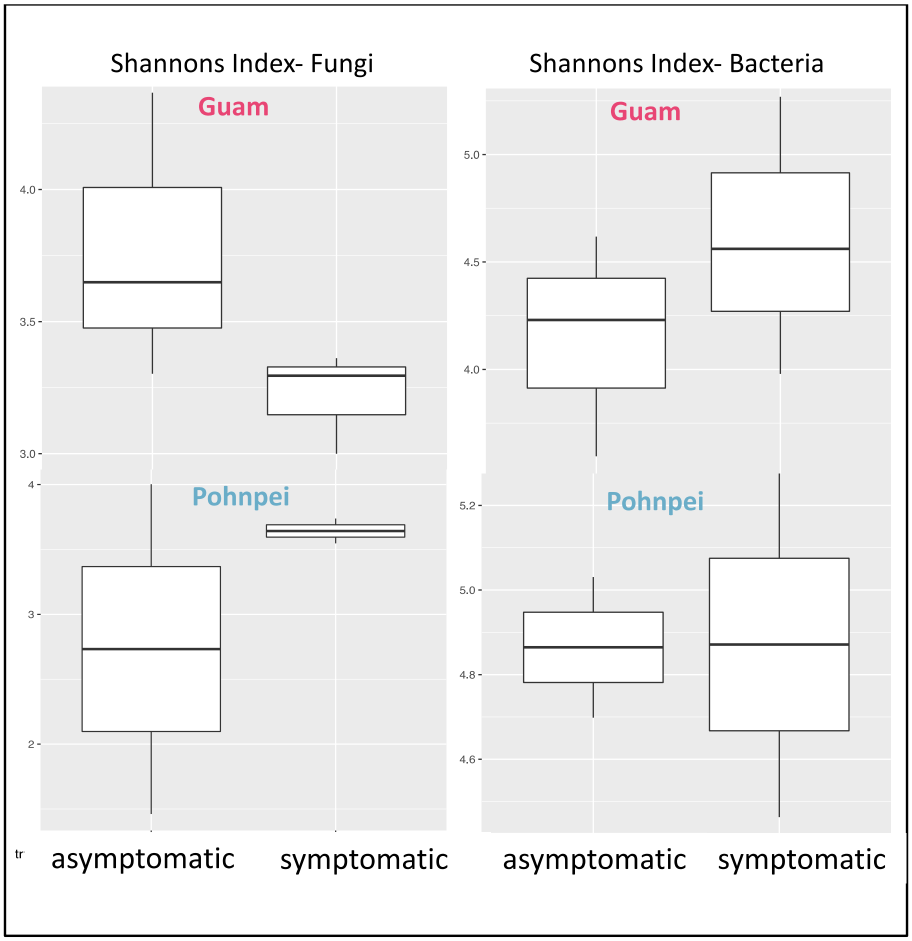


Figure 2: Shannon diversity index of microbial communities from Guam and Pohnpei associated with the rhizospheres of *Phellinus noxius*-infected (symptomatic) and healthy (asymptomatic) trees.

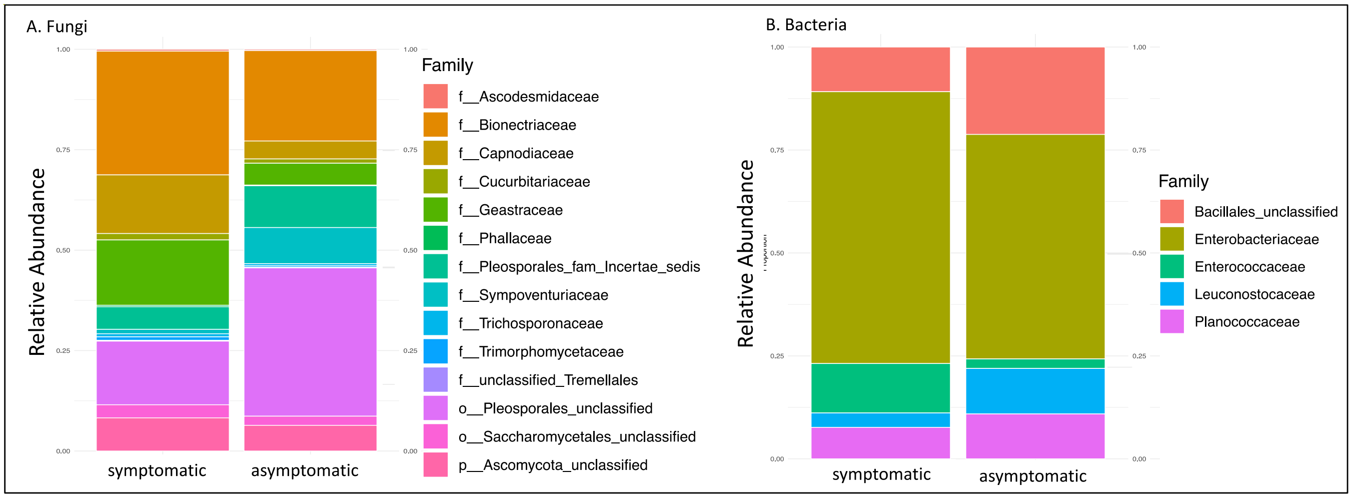


Figure 3: Top 1% of the relative abundance of fungal (A) and bacterial (B) taxa from the rhizospheres of *Phellinus noxius*-infected (symptomatic) and healthy (asymptomatic) trees from Guam.

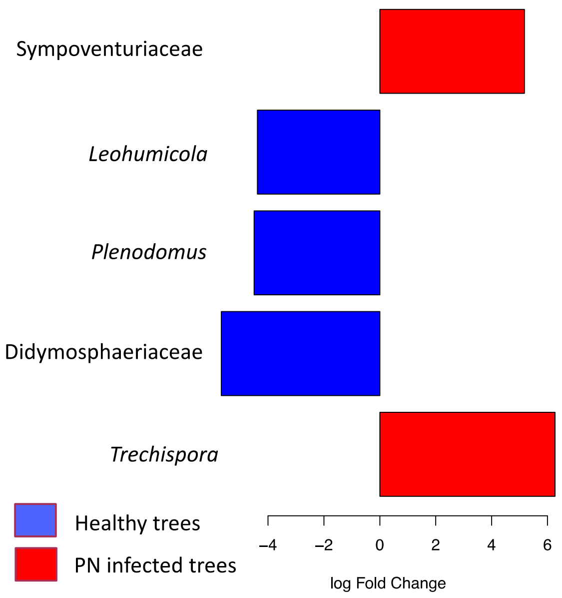


Figure 4: Significant log fold change of fungal communities from Guam. Red bars indicate taxa with significant higher abundance in rhizosphere samples from *Phellinus noxius*-infected (symptomatic) trees and blue bars indicate rhizosphere samples from healthy (asymptomatic) trees.

Discussion and Conclusions

This preliminary study obtained baseline data on the microbial communities associated with the rhizospheres of *P. noxius*-infected (symptomatic) and healthy (asymptomatic) trees in Guam and Pohnpei (FSM). In Guam, more change in the fungal community were observed in association with the rhizosphere of *P. noxius*-infected trees. This concurs with a recent study that showed one fungal taxa (*Cosmospora*) was associated with *P. noxius* infection (Liu et al. 2022). Dysbiosis is perhaps occurring in the rhizospheres of *P. noxius*-diseased (symptomatic) trees, whereby changes in the fungal communities are driven by pathogen pressure. Interestingly, little change was observed in the bacterial community of rhizospheres in response to *P. noxius* infection, both in Guam and Pohnpei. This work is the first step for developing novel approaches to reduce inoculum of *P. noxius* on the Pacific Island sites. Planned future studies include assessing *P. noxius* inoculum levels in the tree rhizosphere via quantitative PCR and analyzing microbial communities within the tree rhizosphere in association with different urea and lime soil treatments (e.g., urea, lime, urea + lime, and control). These planned studies will help determine effects of soil amendments on *P. noxius* abundance and microbiome composition in tree rhizospheres on sites prone to brown root rot disease.

Acknowledgments

We thank Robert L. Schlub, Julia Hudson, Michael Jordan, Roger Brown (deceased), and other field and laboratory personnel, who helped collect the soil samples in Guam, and Rodasio Samuel, Konrad Englberger, David Komorowski, and others who helped collect soil samples in Pohnpei, FSM. Funding sources include the USDA Forest Service (FS), State, Private and Tribal Forestry, Forest Health Protection, Special Technology Development Program (STDP R5-2019-02), USDA FS R&D Bipartisan Infrastructure Law (BIL) Ecosystem Restoration Research (ERR09), and USDA FS R&D, Rocky Mountain Research Station and Pacific Northwest Research Station. Any 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.

Literature Cited

Ann, P.-J.; Chang, T.-T.; Ko, W.-H. 2002. *Phellinus noxius* brown root rot of fruit and ornamental trees in Taiwan. Plant Disease. 86: 820–826.

Brooks, F.E. 2002. Brown root rot disease in American Samoa's tropical rain forests. Pacific Science *56*: 377–387.

Cannon, P.G.; Klopfenstein, N.B.; Kim, M.-S.; Stewart, J.E.; Chung, C.-L. 2022. Brown root rot disease caused by *Phellinus noxius* in U.S.-Affiliated Pacific Islands. Gen. Tech. Rep. PNW-GTR-1006. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR, USA. 99 p.

Chang, T.-T. 1996. Survival of *Phellinus noxius* in soil and in the roots of dead host plants. Phytopathology. 86: 272–276.

Chang, T.-T.; Chang, R.J. 1999. Generation of volatile ammonia from urea fungicidal to *Phellinus noxius* in infested wood in soil under controlled conditions. Plant Pathology. 48: 337–344.

Kozhar, O.; Kim, M.-S.; Ibarra Caballero, J.; Klopfenstein, N.B.; Cannon, P.G.; Stewart, J.E. 2022. Long evolutionary history of an emerging fungal pathogen of diverse tree species in eastern Asia, Australia, and the Pacific Islands. Molecular Ecology 31: 2013–2031.

Liu, T.Y.; Chen, C.H.; Yang, Y.L.; Tsai, I.J.; Ho, Y.N.; Chung, C.L. 2022. The brown root rot fungus *Phellinus noxius* affects microbial communities in different root-associated niches of Ficus trees. Environmental Microbiology 24: 276–297.

Oksanen, J.; Simpson, G.L.; Guillaume Blanchet, F.; Kindt, R.; Legendre, P.; Minchin, P.R.; et al. 2020. Package ‘vegan’: Community Ecology Package.

Schloss, P.D.; Westcott, S.L.; Ryabin, T.; Hall, J.R.; Hartmann, M.; Hollister, E.B.; Lesniewski, R.A.; Oakley, B.B.; Parks, D.H.; Robinson, C.J.; Sahl, J.W.; Stres, B.; Thallinger, G.G.; Van Horn, D.J.; Weber, C.F. 2009. Introducing mothur: Open-source, platform-independent, community-supported software for describing and comparing microbial communities. Applied and Environmental Microbiology 75: 7537–7541.

Stewart, J.E.; Kim, M.-S.; Ota, Y.; Sahashi, N.; Hanna, J.W.; Akiba, M.; Ata, J.P.; Atibalentja, N.; Brooks F.; Chung, C.-L.; Dann, E.K.; Farid, A.M.; Hattori, T.; Lee, S.S.; Otto, K.; Pegg, G.S.; Schlub, R.L.; Shuey, L.S.; Tang, A.M.C.; Tsai, J.-N.; Cannon, P.G.; Klopfenstein, N.B. 2020. Phylogenetic and population genetic analyses reveal three distinct lineages of the invasive brown root-rot pathogen, *Phellinus noxius*, and bioclimatic modeling predicts differences in associated climate niches. European Journal of Plant Pathology 156: 751–766.

Outstanding Achievement Awards

Presented to:

Greg Filip (2019)

Ned Klopfenstein (2020)

Phil Cannon (2020)

Outstanding Achievement Awardees: Ned Klopfenstein, Greg Philip, and Phil Cannon. (photo: Rachel Brooks)

Temporal and spatial meanderings in forest pathology, and fun along the way

Ned B. Klopfenstein[1]* and many others

First of all, I am both very grateful and extremely humbled to receive the WIFDWC Outstanding Achievement Award, and, of course, I can easily recognize so many other candidates who are more deserving. However, I am extremely happy that Phil Cannon is a co-recipient of this award, because Phil and I have collaborated on diverse projects for about 25 years, and Phil is an exemplary recipient for this award. Unfortunately, I have little idea about what sort of topics I should address here, so I decided to include a bit on various topics.

In past WIFDWCs and other meetings, I think it was Ellen Goheen, Kim Corella, and others who continued a project to track our academic lineages or our forest pathology family tree. Like many other WIFDWC attendees, I come from the Hartig – Meinecke – Boyce academic lineage. I received my Ph.D. in Plant Pathology at Iowa State University, with Harold S. "Sande" McNabb, Jr. as my Major Professor. Sande was known for his work on Dutch elm disease, poplar diseases, teaching forest pathology, and his relentless advocacy for students of diverse backgrounds.

My earliest forest pathology- and mycology-related memories are of Dutch elm disease that began to dramatically change the landscape and aesthetics of cities, small towns, and countrysides across the midwestern USA in the 1950s and 1960s. Subsequently, I also became drawn into the springtime hunts for morel mushrooms that were associated with the dying elm trees in the Iowa forests. These events planted an inspiration for my studies in forest pathology, although I followed a somewhat circuitous route along the way.

Although I wasn't quite born when Franklin, Watson, and Crick contributed to our understanding of the DNA double helix, many other subsequent landmarks in DNA technology occurred when I was a young, impressionable undergraduate student in biology. In fact, I still remember my inspiration when I first learned about recombinant DNA in a second-year biology class. As a side note, this same biology class in 1973 also had a section devoted to inevitable climate change from burning fossil fuels, which was over 50 years ago. Along the way, I became interested in tissue culture of woody plants, and I became a graduate student in Plant Pathology. As a part of my graduate studies, I took the first university class in genetic engineering, which I found highly interesting. A continuation of my work with tissue culture and genetic engineering led to the genetic engineering of *Populus* hybrids with genes to study pest resistance (Klopfenstein et al. 1991, 1997). In 1989, the first field test of genetically engineered trees was established (Figure 1).

---

[1] USDA Forest Service, Rocky Mountain Research Station; Moscow, ID, USA
*ned.klopfenstein@usda.gov

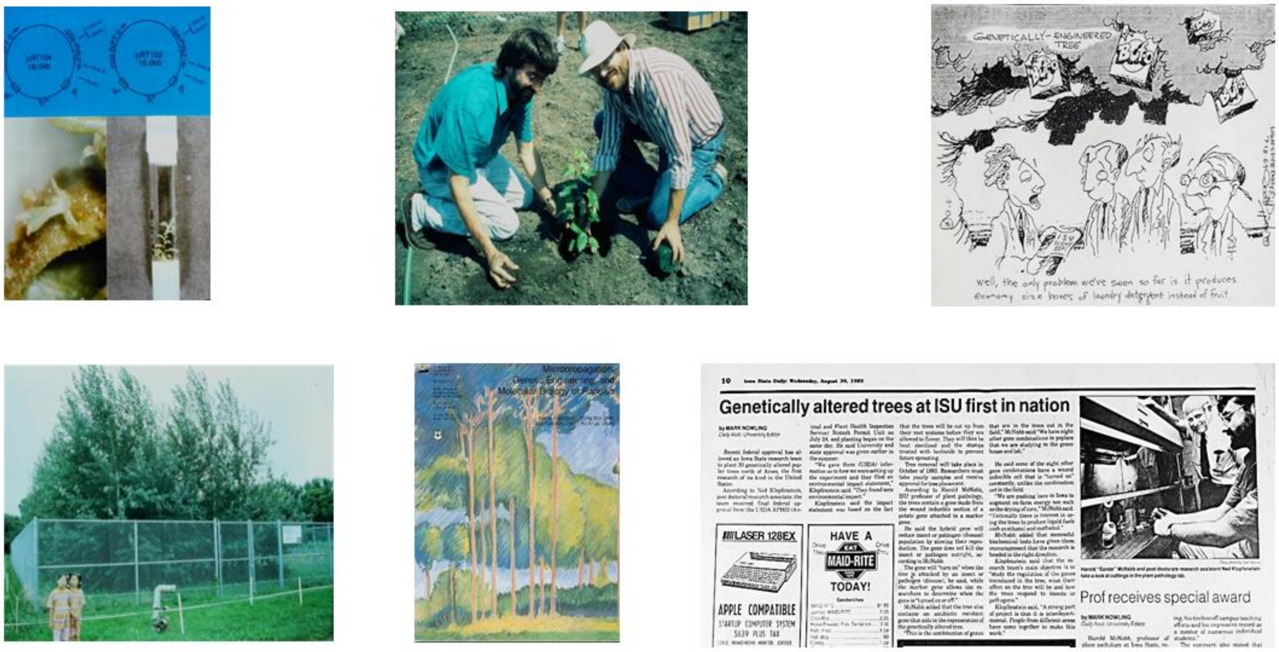


Figure 1: First field test of genetically engineered trees in 1989 (Klopfenstein et al. 1991, 1997).

Subsequently, a large part of my research in forest pathology has focused on diverse aspects of molecular genetics. My collaborative studies in forest pathology have covered diverse topics, such as DNA-based diagnostics of forest pathogens, phylogenetic studies to examine evolutionary relationships among forest pathogens, population genetics of forest pathogens and hosts, genomic and transcriptomic sequencing of forest pathogens to determine genes contributing to pathogenicity, and metagenomics or metabarcoding to examine the roles of associated microbes in forest health. Indeed, I feel quite fortunate to have participated in so many interesting research projects, of which I will briefly mention only a few.

Out of many collection trips, one especially memorable travel was to protected areas at high elevations in Japan to collect white pine blister rust samples. Based on this phylogenetics study, we concluded that the *Cronartium ribicola* that was introduced to North America did not originate from the high-elevation *Pinus pumila* in Japan. Another highlight was when our group traveled with Phil Cannon on a trip to Mexico, where we met Professor Dionicio Alvarado Rosales and conducted surveys for *Armillaria*. This collaboration produced several interesting results, including describing a new species, *Armillaria mexicana*, which appears to be an evolutionary ancestor to all other *Armillaria* species in the Northern Hemisphere (Elías-Román et al. 2018: Figure 2).

Figure 2: *Armillaria* surveys in Mexico (Elías-Román et al. 2018; Kim et al. 2022).

Our collaborative studies on myrtle rust have been both interesting and fun. These studies showed that myrtle rust on eucalypts in Brazil did not emerge via a host jump of the myrtle rust pathogen from guava (Graça et al. 2013). Subsequently, Jane Stewart et al. (2018) determined that the myrtle rust pathogen comprises multiple biotypes that have distinct host associations and different climatic requirements or invasive threats (Figure 3). We also collaborated with Phil Cannon, Colorado State University, and several other international forest health professionals to examine *Phellinus noxius*, the cause of the destructive brown root rot disease on diverse woody hosts in eastern Asia, Australia, and the Pacific Islands. These studies showed that *P. noxius* comprises multiple genetic groups – each with distinct invasive threats (Stewart et al. 2020; Cannon et al. 2022). Subsequent analyses by Olga Kozhar et al. (2022) determined that most recent emergences of brown root rot disease in the Pacific Islands are not the result of a recent invasion by *P. noxius* (Figure 4).

Figure 3: Myrtle rust (caused by *Austropuccinia psidii*) in Brazil and other global regions. Myrtle rust on eucalypts in Brazil did not emerge via a host jump of *A. psidii* from guava (Graça et al. 2013). The myrtle rust pathogen comprises multiple biotypes that have distinct host associations and different climatic requirements or invasive threats (Stewart et al. 2018).

Figure 4: Brown root rot disease (caused by *Phellinus noxius*) surveys in the Pacific Islands. *Phellinus noxius* comprises multiple genetic groups – each with distinct invasive threats (Stewart et al. 2020; Cannon et al. 2022). Most recent emergences of brown root rot disease in the Pacific Islands likely did not result from a recent introduction of *P. noxius* (Kozhar et al. 2022).

Over the years, I have had the pleasure of working with nearly 400 co-authors from the USA and international institutions from 32 countries. These diverse collaborations are an especially rewarding part of my work. My collaborations with Jane Stewart, Mee-Sook Kim, Geral McDonald, John Hanna, Phil Cannon, Marcus Warwell, Bryce Richardson, Margaret Mmbaga, Girma Tabor, Young Woo Chun, and many others have been a cornerstone for much of my collaborative work, and I feel especially indebted to these folks! As forest pathologists, we all have the pleasure of working in some incredible places in the USA, which is a highlight of our work. In addition, I have also had the pleasure of conducting work internationally, which I also greatly enjoy. My work in forest pathology has included travel to fascinating destinations, such as Puerto Rico, Guam, Northern Mariana Islands, Federated States of Micronesia, Canada, Mexico, Colombia, Brazil, Poland, Turkey, Philippines, Australia, New Zealand, India, Thailand, Hong Kong, Taiwan, Japan, and South Korea. Although I thoroughly enjoy international travel, I am quick to remind younger forest pathologists that international work is essential to remain current in nearly all aspects of forest pathology.

Of course, the colleagues and friends that we meet over the course of our careers are what makes our work and life especially meaningful. Friends and colleagues who have contributed to the quality of various stages of my life and career are too many to mention here, but I trust that they know I am thankful for spending time with them along the way (Figure 5). As I was preparing for this presentation, I again realize how quickly time passes, but of course, we can all find time for fun along the way (Figure 6).

Figure 5: Friends and colleagues.

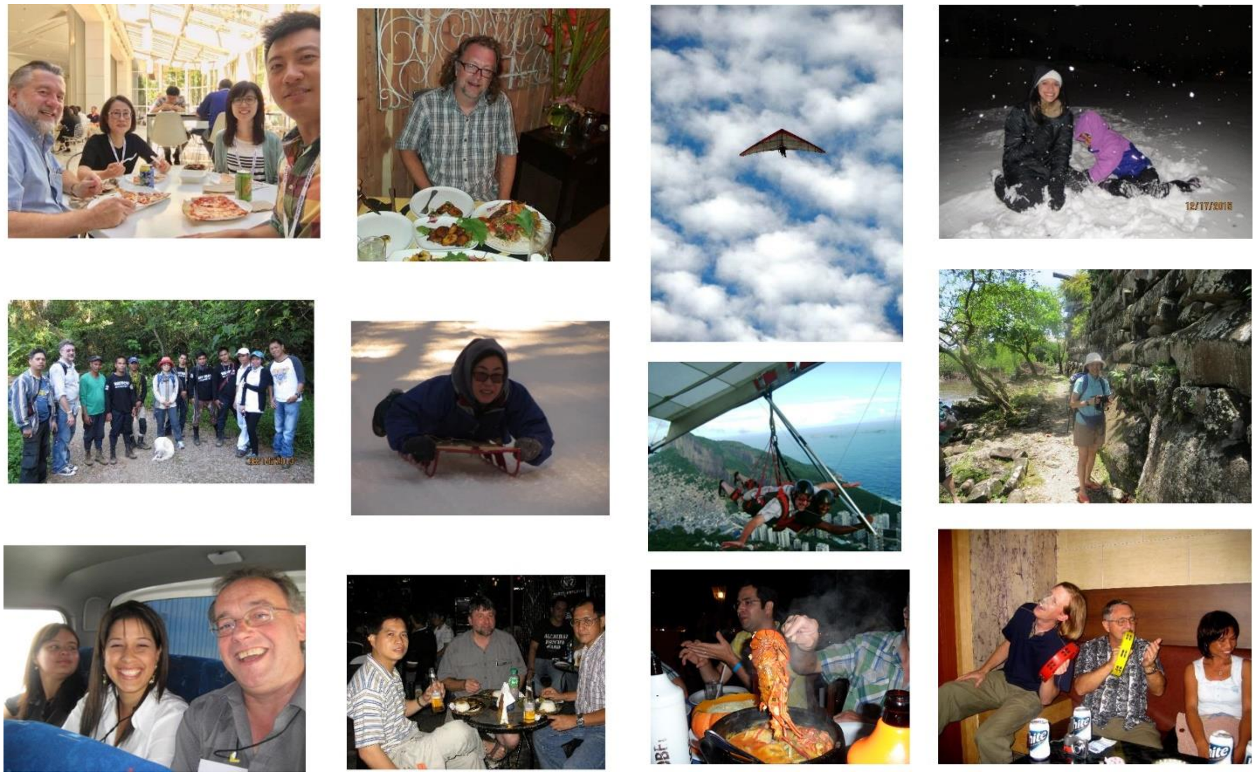


Figure 6: Fun along the way …

As I mentioned, Phil Cannon and I have collaborated for 25 years, both domestically and internationally (Figure 7). In short, I simply cannot overstate Phil's enormous and diverse contributions to forest pathology. Phil has a tremendous depth of experience in the USA and abroad, and he is extremely knowledgeable about almost any subject in forest pathology. I look forward to continued collaborations with Phil and others.

Figure 7: Phil Cannon in various times and places.

I was advised to provide any perspectives that I learned over the years, but I doubt that I can provide many insights that most of you don't already know. It goes without saying that we need to increase diversity, capacity, inclusion, and collaboration in forest pathology, mycology, and associated disciplines if we want to successfully address future issues in forest pathology. DNA-/RNA-based technologies, environmental metadata, and remote sensing will likely continue to play ever-increasing roles in forest pathology. It also seems likely that paradigms in forest pathology will change as we better understand pathogen variation at the sub-species level and the phytobiome or microbial communities associated with plant disease. And, as everyone already knows, climate change and invasive pathogens will continue to have ever-increasing impacts in forest pathology.

Lastly, I want to reiterate my tremendous appreciation to WIFDWC. I always especially enjoy attending WIFDWC meetings – thank you, everyone!

Acknowledgments

I thank the many collaborators on diverse research efforts over the years. Funding sources include the USDA Forest Service (FS), State, Private and Tribal Forestry, Forest Health Protection, Special Technology Development Program, and USDA FS R&D, Rocky Mountain Research Station and Pacific Northwest Research Station. Any 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.

Literature Cited

Cannon, P.G.; Klopfenstein, N.B.; Kim, M.-S.; Stewart, J.E.; Chung, C.-L. 2022. Brown root rot disease caused by *Phellinus noxius* in U.S.-Affiliated Pacific Islands. Gen. Tech. Rep. PNW-GTR-1006. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR, USA. 99 p. https://www.fs.usda.gov/pnw/pubs/pnw_gtr1006.pdf

Elías-Román, R.D.; Medel-Ortiz, R.; Alvarado-Rosales, D.; Hanna, J.W.; Ross-Davis, A.L.; Kim, M.-S.; Klopfenstein, N.B. 2018. *Armillaria mexicana*, a newly described species from Mexico. Mycologia 110: 347–360. https://www.fs.usda.gov/rm/pubs_journals/2018/rmrs_2018_elias_roman_r001.pdf

Graça, R.N.; Ross-Davis, A.L.; Klopfenstein, N.B.; Kim, M.-S.; Peever, T.L.; Cannon, P.G.; Aun, C.P.; Mizubuti, E. S.G.; Alfenas, A.C. 2013. Rust disease of eucalypts, caused by *Puccinia psidii*, did not originate via host jump from guava in Brazil. Molecular Ecology 22: 6033–6047. https://www.fs.usda.gov/rm/pubs_other/rmrs_2013_graca_r001.pdf

Kim, M.-S.; Heinzelmann, R.; Labbé, F.; Ota, Y.; Elías-Román, R.D.; Pildain, M.B.; Stewart, J.E.; Woodward, S.; Klopfenstein, N.B. 2022. Armillaria root diseases of diverse trees in wide-spread global regions. pp. 361-378 in: Asiegbu, F.O.; Kovalchuk, A. eds., *Forest Microbiology Forest Tree Health*, Volume 2, Academic Press (Elsevier), London, chapter 20. https://www.fs.usda.gov/rm/pubs_journals/2022/rmrs_2022_kim_m002.pdf

Klopfenstein, N.B.; Chun, Y.W.; Kim, M.-S.; Ahuja, M.R., eds. 1997. Micropropagation, Genetic Engineering, and Molecular Biology of *Populus*. General Technical Report, RM-GTR-297. Ft. Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 326 p. (34 chapters contributed by 85 international authors) https://www.fs.usda.gov/rm/pubs_rm/rm_gtr297.pdf

Klopfenstein, N.B.; Shi, N.-Q.; Kernan, A.; McNabb, H.S., Jr.; Hall, R.B.; Hart, E.R.; Thornburg, R.W. 1991. A transgenic *Populus* hybrid expresses a wound-inducible potato *Proteinase Inhibitor II-CAT* gene fusion. Canadian Journal of Forest Research 21: 1321–1328. http://www.nrcresearchpress.com/doi/pdf/10.1139/x91-186

Kozhar, O.; Kim, M.-S.; Ibarra Caballero, J.; Klopfenstein, N.B.; Cannon, P.G.; Stewart, J.E. 2022. Long evolutionary history of an emerging fungal pathogen of diverse tree species in eastern Asia, Australia, and the Pacific Islands. Molecular Ecology 31: 2013–2031. https://www.fs.usda.gov/rm/pubs_journals/2022/rmrs_2022_kozhar_o001.pdf

Stewart, J.E.; Kim, M.-S.; Ota, Y.; Sahashi, N.; Hanna, J.W.; Akiba, M.; Ata, J.P.; Atibalentja, N.; Brooks F.; Chung, C.-L.; Dann, E.K.; Farid, A.M.; Hattori, T.; Lee, S.S.; Otto, K.; Pegg, G.S.; Schlub, R.L.; Shuey, L.S.; Tang, A.M.C.; Tsai, J.-N.; Cannon, P.G.; Klopfenstein, N.B. 2020. Phylogenetic and population genetic analyses reveal three distinct lineages of the invasive brown root-rot pathogen, *Phellinus noxius*, and bioclimatic modeling predicts differences in associated climate niches. European Journal of Plant Pathology 156: 751–766. https://www.fs.usda.gov/rm/pubs_journals/2020/rmrs_2020_stewart_j001.pdf

Stewart, J.E.; Ross-Davis, A.L.; Graça, R.N.; Alfenas, A.C.; Peever, T.L.; Hanna, J.W.; Uchida, J.Y.; Hauff, R.D.; Kadooka, C.Y.; Kim, M.-S.; Cannon, P.G.; Namba, S.; Simeto, S.; Pérez, C.A.; Rayamajhi, M.B.; Lodge, D.J.; Arguedas, M.; Medel-Ortiz, R.; López-Ramirez, M.A.; Tennant, P.; Glen, M.; Machado, P.; McTaggart, A.R.; Carnegie, A.J.; Klopfenstein, N.B. 2018. Genetic diversity of the myrtle rust pathogen (*Austropuccinia psidii*) in the Americas and Hawaii: Global implications for invasive threat assessments. Forest Pathology 48: e12378. https://www.fs.usda.gov/nrs/pubs/jrnl/2017/nrs_2017_stewart-j_001.pdf

2019 outstanding achievement award recipient

Gregory Filip[1]*

I want to thank the members of WIFDWC for this prestigious “Outstanding Achievement Award” (OAA). It means a lot to me because it was given to me by you, my peers. Thank you!

In 2005, my good friend and colleague, Walt Thies, a fine pathologist who worked at the PNW Research Station in Corvallis, OR, received the OAA. In the 2006 WIFDWC proceedings, Walt recommended five ways to improve your career: 1) Marry well, 2) Have a clear image of who you are working for, 3) Support WIFDWC and its members, 4) Keep a perspective of your own importance in the workplace, and 5) Last and most important, marry well.

Not to be outdone, another good friend and colleague of mine, Don Goheen, also a fine pathologist and entomologist at the FHP Service Center in Central Point, OR, received the OAA in 2013, and recommended 14 ways for a better career that were published in the 2014 proceedings for the meeting in Cedar City, UT. I won’t list all 14 ways, but in item 13, Don recommended to “*Cherish your mentors and be a mentor yourself*”. For the rest of my presentation, I would like to dwell on Don’s very important advice.

My most important mentor was my father, Stanley Filip. He was a USFS research forester at the former Northeastern Research Station in Laconia and Durham, NH from 1949 to 1978. We overlapped in employment about two years when I joined the USFS in 1976. Most of my father’s research involved the silviculture of the northern hardwoods: beech, birch, and maple. Dad taught me the love of forestry, silviculture, and forest science. My father was part of “the greatest generation” having served in WWII in the US Marines.

Another important mentor for me was chief-pathologist Alex Shigo who worked with my father at the NE Research Station from 1958 to 2001. Alex fostered my love of forest pathology when I was 12-years old and visited his lab in 1962. His cutting-edge research included the compartmentalization of decay in living trees. I cherished his Extension-type publications such as “A Tree Hurts Too”, and “Your Tree’s Trouble May be You”.

In 1972, my first mentor in the Pacific Northwest was Lewis Roth, professor of forest pathology from 1940 to 1979 at Oregon State University in Corvallis where I pursued a doctorate in forest pathology. Lew often got mad at me, which was quite often, to make an important point. Lew and his graduate students researched many of the important forest-pathology problems in the PNW: Armillaria root disease, Port-Orford-cedar root disease, western dwarf mistletoe, and Elytroderma needle blight. Lew was the first recipient of the OAA in 2000 with Duncan Morrison. Lewis Roth was part of “the greatest generation” having served in WWII in the US Navy.

As an OSU graduate student in 1973, Terry Shaw took me under his wing and taught me all about ponderosa pine and *Armillaria* which were the subjects of his PhD dissertation. Terry worked as a research forest pathologist from 1974 to 2011 in Rotorua, NZ; Juneau, AK; Ft. Collins, CO; Washington, DC; and Prineville, OR. Terry received the OAA in 2014. In retirement, he and I co-authored a FIDL on Armillaria root disease. Terry helped to shape forest pathology in the Western US.

I first met Jim Hadfield in 1971when I was an undergraduate student at the University of New Hampshire. Jim worked 46 years from 1967 to 2013 as a USFS forest pathologist in Amherst, MA; Portsmouth, NH; Portland, OR; and Wenatchee, WA. In 1976, he was my first boss with FHP in Portland. Jim taught me much about PNW pathology in general and hazard-tree management in particular. He was an excellent mentor.

Paul Aho was a research plant pathologist with the PNW Research Station in Corvallis from 1964 to 1984. Paul taught me plenty about decay in living trees. He worked in New England with two giants in the heartrot field, John

---

[1] USDA Forest Service & Oregon State University (retired), USA
*gregoryfilip44@gmail.com

Boyce and Alex Shigo. Paul and I published several papers on the Indian paint fungus and other decay fungi. He is alive at 85+ years and still lives in Corvallis. Paul was an outstanding mentor that I need to visit again.

Don Goheen and I started our careers together in 1976 working for the USFS in Portland, OR. Don finished his brilliant career in 2013 as an entomologist in Central Point, OR. He and I loved to write and publish reports and manuscripts. We wrote on several subjects including root diseases, hazard trees, and revised a FIDL on the Indian paint fungus. Don and I are aficionados of Italian-Western movies starring our favorite Hollywood actor and director, Clint Eastwood.

Craig Schmitt served with the USFS from 1980 to 2013 starting in Wallace, ID; transferring to Portland, OR; and ending in La Grande, OR. Craig and I worked on many topics together and wrote papers and reports on laminated root rot, Armillaria root disease, Heterobasidion root disease, true fir mistletoe, snag inoculations, and hazard/danger trees. Together we climbed many of the Cascade volcanoes in our younger days. We also worked together for the OPB-TV series on Armillaria, the humongous fungus. I often went pheasant hunting with Craig and his dog on his 18-acre ranch near La Grande. I often email him.

I met Alan Kanaskie as a USFS summer employee in our Portland office in 1980, even though we were born only 50 miles apart in eastern Pennsylvania. Alan started his career as a forest pathologist for the Weyerhaeuser Corporation in 1983 and finished his career in 2016 with the Oregon Department of Forestry. We worked together primarily on Swiss needle cast of Douglas-fir in Oregon. Alan was program chair when I was local arrangements co-chair for the 2011 WIFDWC in Leavenworth, WA. Alan and I climbed a few Cascade peaks together, and in 1984we had to spend an unplanned night in the woods with Susan Frankel while descending Mt. Adams in Washington. Alan received the OAA in 2006 for his undaunted work with sudden oak death.

Jerry Beatty and Bob Mathiasen are two of my former mountain-climbing buddies who also loved to study and write about dwarf mistletoes. Jerry was a forest pathologist from 1977 to 2008 who worked for FHP in Albuquerque, NM; Portland and Sandy, OR; Washington, DC; and Prineville, OR. Bob Mathiasen worked as a pathologist from 1977 to 2019 for the USFS in Ogden, UT; Idaho Dept. of Lands in Coeur d'Alene; and Northern Arizona University in Flagstaff. In 2002, the three of us spent two weeks in Mexico collecting dwarf mistletoes, climbing volcanoes, and consuming outstanding food!

Ellen Michaels Goheen and Susan Frankel were summer temporaries with me in Portland in the early 1980s. They were the "Young Lionesses" who both received the OAA in 2011 for their excellent work with sudden oak death in Oregon and California. Ellen worked at our FHP Service Center in Central Point, OR from 1986 to 2019. Susan worked for FHP in San Francisco before transferring to the PSW Research Station in Albany, CA where she works today. We wrote papers and reports together on Armillaria root disease and hazard trees.

I first met Helen Maffei when she began working as a forest pathologist in 1988 with our FHP Service Center in Bend, OR. Helen worked from 1986 starting with FHP in Albuquerque, NM until she retired in Bend with a grand party in 2017. Our two most prominent projects were studying the effects of silviculture on Armillaria in southern Oregon, and our Douglas-fir dwarf mistletoe-pruning study in central Oregon. "Helen of Bend" is a true gladiatrix and always will be a cherised friend of mine!

Catherine Parks and I started working together on May 13, 1985 with the PNW Research Station in La Grande, OR. Catherine was our biological technician who returned to school at OSU and received her doctorate studying the effects of spruce-budworm defoliation and drought on Armillaria infection of grand fir seedlings. I was on her graduate committee when I began working at OSU in 1991. We wrote several papers together concerning Armillaria root disease, dwarf mistletoe, and live-tree inoculations for wildlife use. Catherine retired in 2015 after serving details in Washington, DC; Rome, Italy; and Afghanistan. I try to visit my good friend when I am in La Grande.

Mi amigo, Angel Saavedra and I loved to work on many projects together including devouring Mexican food! We served together in several hazard and danger-tree workshops and wrote two manuals on the same subject. My most enjoyable time with Angel was when we served as local arrangement co-chairs for the 2011 WIFDWC in Leavenworth, WA. In 2006, Angel started his FHP career as a forest pathologist in Wenatchee, WA, worked with FHP in Boise, ID, and is currently a USFS regional forest pathologist for the northeastern US. We still email each other.

Matteo Garbelotto is a forest pathologist and mycologist at UC Berkeley. Matteo is from the South Tyrolean Alps in northern Italy. In 2018, my wife and I visited this beautiful part of Europe. Matteo's research focused on *Heterobasidion* taxonomy and sudden oak death. My association with Matteo is mainly through the IUFRO Root and Butt Rot Working Group, especially the 2007 meeting in California and Oregon. Matteo and I were local-arrangements co-chairs and hosted a marathon meeting from Berkeley, CA to Medford, OR where we visited three National Parks and nine National Forests in our quest to show off West-Coast forest pathology to our world colleagues!

While serving as an OSU Extension forest-health specialist from 1991 to 2003, I had the great opportunity to mentor several graduate students. From 1991 to 1995, Katy Mallams worked with me on an MS dealing with Douglas-fir dwarf mistletoe, stand conditions, and plant associations in SW Oregon. After graduating, Katy worked until 2012 as a forest pathologist with Don and Ellen Goheen at the FHP Service Center in Central Point, OR. One day in the field, Katy and I had to escape to our car when a black bear and her cubs approached us.

From 1991 to 1996, I mentored Ron Rhatigan on his MS thesis concerning the toxicology of methyl bromide to four species of pathogenic fungi in Siberian larch. This was an important topic when we were considering importing larch logs from Russia to the PNW. After graduating from OSU, Ron worked as a silviculture forester with OSU in Corvallis, the USFS in Gold Beach, OR, and with the BLM in Corvallis. He worked primarily on Swiss needle cast and sudden oak death on the Oregon coast. I always enjoyed his sharp wit!

Kelly Burns was my MS student at OSU from 1993 to 1997. Her thesis involved *Heterobasidion*-caused decay in thinned and wounded noble fir in central Oregon. After graduating, Kelly began her career with FHP in Lakewood and Golden, CO where she still works today. I also served as chairman with Kelly as local arrangements co-chair during the 2009 WIFDWC in Durango, CO. I will never forget when Kelly's tent blew into the Deschutes River and sank!

When we started our program on Swiss needle cast of Douglas-fir at OSU, we were looking for a PhD candidate to work on fungal and host physiology. From 1997 to 2000, Dan Manter worked with me on his doctorate concerning the effects of Swiss needle cast on Douglas-fir physiology. After Dan graduated, he accepted a position with the USDA Agricultural Research Service in Ft. Collins, CO; the PNW rained too much for Dan!

From 2000 to 2003, I had the pleasure of working with Kristen Chadwick on her MS thesis concerning the effects of stand conditions on Armillaria and Heterobasidion root diseases in central Oregon. After graduating, Kristen accepted a position with Helen Maffei at our FHP-Service Center in Bend and then transferred to our Service Center in Sandy, OR where she works today. Over the years, we published numerous reports together concerning Armillaria and Heterobasidion root diseases, live-tree inoculations for wildlife, and hazard and danger trees. Kristen and I spent many days at "Camp Armillaria" surveying our Armillaria-thinning plots in south-central Oregon. Studying, surveying, and teaching with Kristen was one of the many joys of my long career.

Mike Kangas was an MS student with me from 2000 to 2002. Mike's thesis concerned the effects of prescribed fire on bark beetle attack and wildlife use of ponderosa pine in eastern Oregon. We worked with Walt Thies and Jeff Morrell, an OSU forest-products pathologist. After graduating, Mike became a forest-health specialist at North Dakota State University in Fargo where I am sure he continues with his fine impression of comedian Chris Farley!

Diane Hildebrand worked as an FHP pathologist in Lakewood, CO and Portland and Sandy, OR from 1984 to 2014. Our main work together involved hazard-tree workshops in Oregon and Washington. Diane was instrumental in helping to start our R6 tree-inoculation for wildlife program and our danger-tree program for trees along forested roads. We also worked together on surveying for Swiss needle cast in the north-Oregon Cascade foothills. After retiring, Diane returned to school and received a BS in engineering, her dream come true!

Mike McWilliams started working for the PNW Research Station in Corvallis, transferred to the Oregon Department of Forestry in Salem, and returned to the USFS as a forest pathologist at the FHP Service Center in La Grande, OR. Mike helped us write our 2016 danger-tree guidebook. He was also involved in our OPB-TV segment on *Armillaria*, the humongous fungus. He is best known, however, for chanting “Hail Beavers” at most WIFDWC meetings.

Dan Omdal and Amy Ramsey worked as forest pathologists for the Washington Department of Natural Resources in Olympia. I worked with Dan and Amy after they began managing Lew Roth’s Armillaria plots near Glenwood, WA. For the 2011 WIFDWC at Leavenworth, WA, I helped Dan and Amy as local arrangements co-chair to host the best WIFDWC ever! I continue to work with Dan on the Armillaria plots near Glenwood.

Dave Shaw’s career began as the canopy-crane operator for the University of Washington at Wind River, WA. Fearing heights, he left the UW crane, and in 2004 he replaced me as director of the OSU Swiss Needle Cast Cooperative when I transferred to the USFS-FHP in Portland. Together we wrote several publications on Swiss needle cast. Dave served as program chair with me as chair for the 2009 WIFDWC in Durango, CO. We also served together as local-arrangements co-chairs for the 2015 WIFDWC in Newport, OR. Dave was a great person to know and work with!

Will Littke and John Browning worked as forest pathologists for the Weyerhaeuser Corporation in Federal Way and Centralia, WA. Together we surveyed for Swiss needle cast in the north-Oregon Cascade foothills. Will and John experienced migraines trying to count pseudothecia on infected fir needles until they developed a computer program and camera system to do the counting. Will was awarded the OAA in 2011 and retired in 2015.

Brennan Ferguson and Betsy Goodrich are forest pathologists at our FHP Service Center in Wenatchee, WA. I knew Brennan when he previously worked as a private contractor for the States of Idaho and Montana. I helped Brennan and Betsy with our danger-tree workshops and the writing of our 2016 danger-tree guidebook. Brennan was lead author on our 2003, Armillaria humongous-fungus manuscript that, as a perfectionist, he worked on the journal reviews for three years before it was finally published! In retirement I still consult with my friends, Brennan and Betsy.

Near the end of my career, I had the great opportunity to work with Brent Oblinger and Josh Bronson who are forest pathologists in our FHP Service Centers in Bend, OR and Central Point, OR, respectively. Brent and Josh helped to co-author our 2016 danger-tree guidebook. More recently, I have been helping them with various Armillaria thinning projects including the study begun by Helen Maffei and I in south-central Oregon.

Blakey Lockman and Holly Kearns were forest pathologists in Region 1 who saw the light and transferred to Region 6 in Oregon and Washington. I worked with Holly at her FHP Service Center in Sandy, OR on our danger-tree workshops and guidebook. When I retired in 2016, Blakey replaced me as regional forest pathologist in Portland. Together we worked on an Armillaria FIDL and the western-US hardwood-pest guide, both monumental tasks.

In 1989 as research plant pathologist in La Grande, OR, I had the opportunity to work outside of Oregon and Washington and did a project with pathologists John Schwandt and Sue Hagle concerning heartrot of grand fir in northern Idaho. In 2010, I also co-authored with Sue a new FIDL on *Phaeolus schweinitzii*. In 2003, John and I worked with our OSU-graduate student, Amy Eckert on an MS thesis concerning white pine blister rust-canker types in northern Idaho.

Pete Angwin and Borys Tkacz were OSU-graduate students of Everett Hansen who studied laminated root rot. After graduating in 1989, Pete served as an FHP forest pathologist, first in Gunnison, CO and then in Redding, CA where he retired in 2019. Pete was chair and I local-arrangement co-chair for the 2011 WIFDWC in Leavenworth, WA. I first met Borys in 1980 when he was one of our summer employees. Borys began his career in Ogden, UT in 1981 and subsequently held USFS positions in Albuquerque, NM; Washington, DC; and Portland, OR before retiring in 2017 in Bend, OR.

Also near the end of my career, I had the pleasure of working with Robin Mulvey and Gabriela Ritóková primarily on Swiss needle cast in Oregon. Robin subsequently began her career as an FHP forest pathologist in Juneau, AK. Gabriela was assistant director of the OSU Swiss Needle Cast Cooperative working with Dave Shaw in Corvallis, OR. She currently works as the State forest pathologist for the Oregon Department of Forestry in Salem.

I dedicate my presentation and report to my wonderful wife, Patricia, who has been married to me for 47 years in 2023. Only a person of tremendous tolerance and courage could do that! She even attended most WIFDWC meetings with me starting in 1978 in Tucson, AZ and she is with us at our meeting today. As Walt Thies and Don Goheen so wisely recommended, I did marry well! I call her the wife from God.

In closing, I would like to share some important advice. Try to do other than professional work with your WIFDWC colleagues; your work with your colleagues will benefit from your non-professional association with them, and you will become friends for life. *Remember, it is not the places, or the pathogens, or the peaks, but the people that really matter. When it is all over, it is the people that you will remember the most!* The places, peaks, and pathogens will always be there; it is the people who will move away or die! Warriors of WIFDWC, thank you again for this prestigious award.

Committee Reports

Committee meeting attendees. (photo: Rachel Brooks)

Foliar and Twig Committee Meeting Notes

Chairs: Adam Carson[1] and Kelsey Sondreli[2]*

The 2023 WIFDWC Foliar and Twig Committee Meeting followed a roundtable format with informal presentations and discussions on foliage and twig diseases.

There were 42 attendees.

The following is a summary of roundtable items discussed by meeting participants:

Adam Carson: Overview of previous research on Sudden Oak Death during graduate studies. He announced that he is the new assistant director for the Swiss Needle Cast Cooperative.

Kelsey Sondreli: Gave an update on *Sphaerulina musiva* in Oregon research as well as previous Sudden Oak Death research.

Gabi Ritokova: Gave a presentation showing the results from the 2022 Swiss needle cast (SNC) aerial detection surveys in Oregon. Digital maps were presented that showed the geographic areas containing Douglas-fir forests exhibiting symptoms of SNC infection. The 2022 survey results were compared to the results of previous surveys. The results showed increased SNC symptoms in northwest Oregon compared to the southwest. There was a discussion on how the results have changed over time and about the flight paths used to conduct the surveys. Additionally, a question was asked about the presences of Swiss needle cast in southern Oregon and California.

Rachel Brooks: Gave an update on the status of Swiss needle cast in Washington. Ground surveys and aerials surveys were done in 2022. While the aerial survey resulted in the observation of many symptomatic areas, this did not seem to correspond with the pseudothecia counts obtained from the ground survey.

Gabi Ritokova: Oregon doesn’t do ground surveys for Swiss needle cast but the Swiss Needle Cast Cooperative has a coastal research plot network and a monitoring plot network in the cascade foothills. High occlusion and normal needle retention have been observed in the foothills, but on the coast less needle retention is observed when occlusion is high.

David Rusch: Update on Swiss needle cast in Canada. Test flights were conducted in spring.

Nicolas Feau: Question on observed heat dome effects in aerial surveys. Rachel and Gabi – Yes, tracked effects.

David Shaw – Discussed seed source effects of heat dome.

Sky Lan: Discussed tree climbing to look at Swiss Needle Cast.

Alex Woods: Dothistroma update. Overnight minimum temperature increases due to climate change is favorable for Dothistroma. Discussed setting up permanent plots and area transects across zones.

There was discussion on the locations of Dothistroma on Ponderosa Pine, Lodgepole pine, and Shore pine.

Jim Blodgett: South Dakota/Nebraska update on the Diplodia Foresty Health Survey. Aspen Sooty Bark and Cytospora inoculations produced cankers.

Ashley – Ponderosa Pine disease in California looked like red band.

---

[1] Oregon State University, Swiss Needle Cast Cooperative, Corvallis, OR, USA
[2] Oregon State University, Botany and Plant Pathology Department, Corvallis, OR, USA
*kelsey.sondreli@oregonstate.edu

Stephanie Chase: Found it was four different species causing a complex in New York white pine.

Jill Hautaniemi: Discussed Diplodia and gull rust.

Josh Bronson: *Lophergamela morbina* on Ponderosa Pine. Shoot blights in southern Oregon with Gull Rust.

Mike McWilliams: Larch needle cast and blight – didn't find a lot and the disease seems to occur in waves and episodically. Not any long-term effects. Larch locations were discussed.

Trees seen on Wednesday's fieldtrip (Photo: Betsy Goodrich)

Root Disease Committee Meeting Notes

Chair: Blakey Lockman[1]*

After a late start due to the main meeting running over, we jumped into our lunch meeting with two presentations, some discussion, and then minimal time for round robin. In lieu of a round robin, I asked attendees to send me any updates on their root disease work to be included in the meeting notes. The “theme” for this year’s WIFDWC Root Disease Committee meeting was stump treatments for preventing Heterobasidion root disease. There were approximately 65 in attendance.

Presentations

1. Heterobasidion spore trapping project- Dr. Patrick Bennett- USDA RMRS, Moscow, ID (15 min)

Patrick is leading a project to develop protocols for monitoring *Heterobasidion irregulare* spore density and deposition rates in ponderosa pine stands. Additionally, he is applying existing molecular tools for detecting *H. irregulare* in stumps and standing trees. Patrick gave a powerpoint presentation- the bulk of this presentation can be found as an extended abstract for his poster also presented at this meeting: “Developing protocols for detecting and monitoring Heterobasidion irregulare in ponderosa pine stands”.

A big push for getting this work done was driven by the need to refine stump treatment recommendations. Although treating stumps isn’t overly costly, it does add cost and extra complications to harvesting ponderosa pine. The ability to easily sample the spore load in an area to assist with the decision of whether to treat stumps or not will be extremely helpful for managing ponderosa pine stands in the West.

2. Heterobasidion biocontrol project- Dr. Matteo Garbelotto- UC Berkeley (15 min)

Matteo gave us an update on a multi-year STDP project on *Phlebiopsis gigantea.* In his earlier works, on this project, he demonstrated the genetic differences between *P. gigantea* from the eastern US and from the western US are enough to discourage using eastern isolates for biocontrol of *Heterobasidion* spp. in the West. Once this earlier work was completed, he moved forward with determining the effectiveness of western isolates of *P. gigantea* in preventing *H. irregulare* stump infections.

In 2020 and the first part of 2021, several in vitro studies were conducted to compare the growth rate at various temperatures of isolates of the biocontrol *Phlebiopsis gigantea* (Pg) and the sporulation potential at room temperatures (70 F). Isolates were previously collected in California, and, to our knowledge, they represent the only viable collection of California isolates. The purpose of these trials is to identify isolates that a) perform reasonably well at all temperatures in terms of growth rates, to ensure they are fit in forests that may experience significant thermal excursions, and b) sporulate well at room temperature; this is important because the biocontrol is applied as a spore (conidia) suspension, more easily prepared at room temperature. Growth tests and sporulation studies were performed in Petri dishes filled with agar amended with sawdust as described in Giordano, L., Sillo, F., Garbelotto, M. and Gonthier, P., 2018. Mitonuclear interactions may contribute to fitness of fungal hybrids. *Scientific Reports*, *8*(1), pp.1-7. Ten replicates per isolate at each temperature. Sporulation studies had five replicates per Pg isolate.

Growth Rates Studies:

---

[1]USDA Forest Service, Pacific Northwest Region, State and Private Forestry, Portland, OR, USA
*irene.lockman@usda.gov

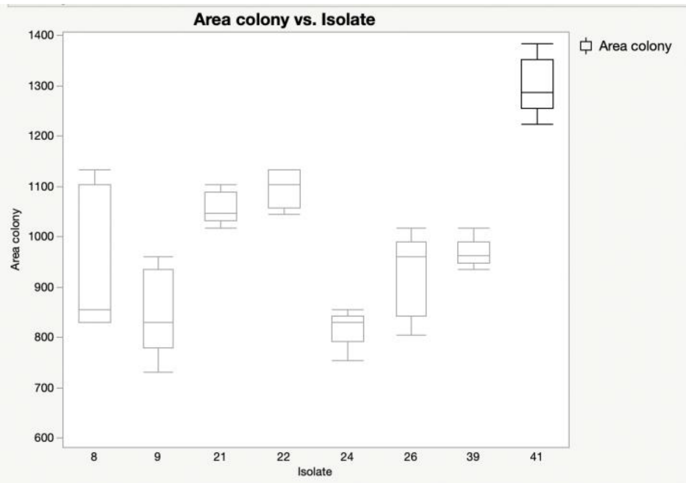


Figure 1: Results of comparative growth tests at 15 C after 6 days.

At the cool temperature of 15C, the top performer is isolate 41 (Sierra Nevada). Isolates 20, 21 from the Coast Range ranked second and third, respectively, while isolate 39 from the Sierra Nevada ranked fourth.

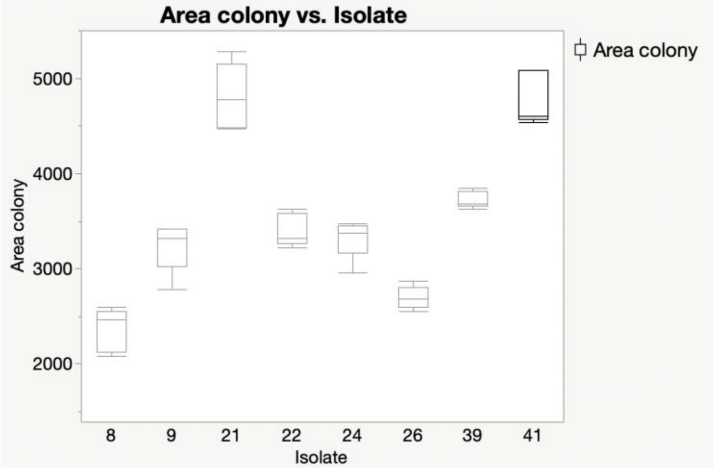


Figure 2: Results of comparative growth tests at 20 C after 6 days.

At 20 C, isolates 41 and 21 outperform all others, with 39 ranking third and 22 ranking fourth.

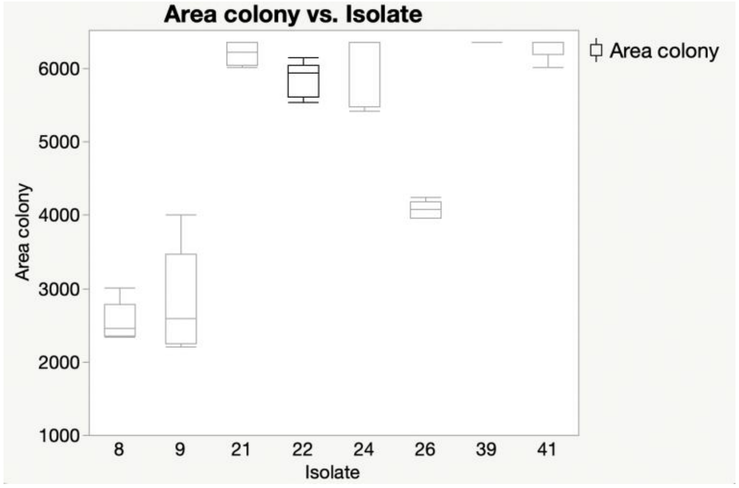


Figure 3: Results of comparative growth tests at 25 C after 6 days.

At 25 C, three isolates were performing equally well as top performers: 21, 39 and 41. Isolates 22 and 24 were also performing well but had more variability within replicates.

Conclusions: only one isolate was a top performer at all three temperatures: isolate Pg41 from the Sierra Nevada. Isolate Pg21 from the Coast Range was the second-best isolate, but it was significantly slower to grow at 15 C than Pg41.

Sporulation studies

Petri dishes were inoculated and kept at 20 C. Ten days after inoculation they were flooded with 5 ml of sterile water. Water was collected in a falcon tube, and conidia were counted through microscopic examination using a hemocytometer. Results are shown in Figure 4.

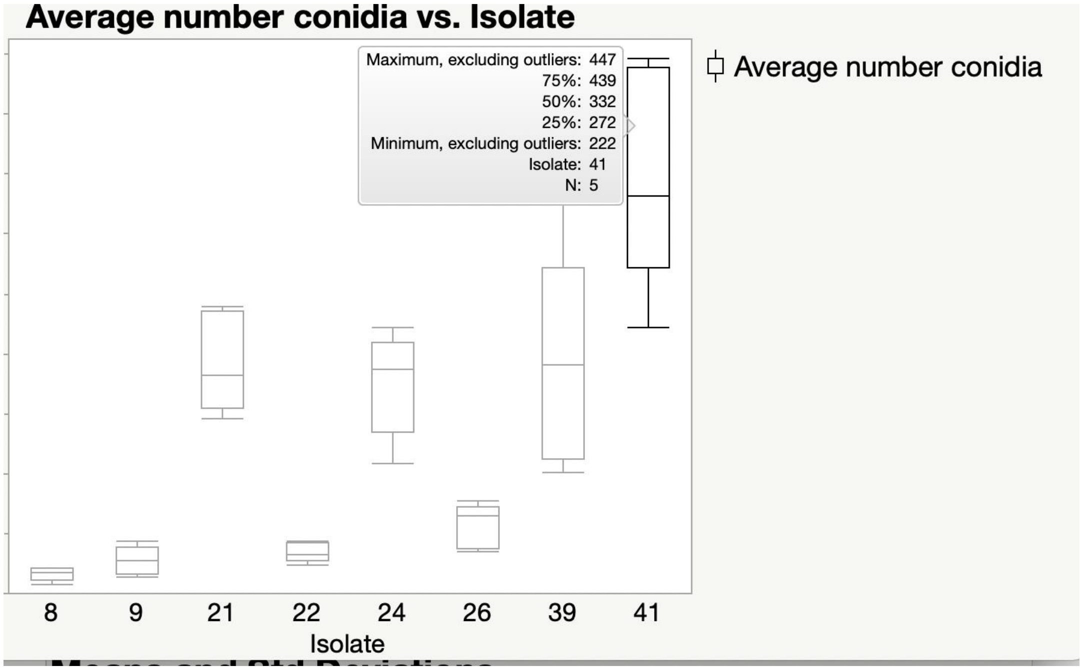


Figure 4: Boxplot showing number of conidia produced by each Pg isolate.

Isolate Pg41 is the top producer of conidia, followed by Pg 21, 24 and 39.

Conclusions: we have identified four isolates that are prolific sporulators, however Pg41 is once again the best performer.

Overall conclusions: Pg41 is the top performer in terms of growth rates at all temperatures and in terms of sporulation. A valid second is isolate Pg21. A possible third is Pg39. Pg 24 is a good sporulator but does not grow well at all temperatures.

Wood disk assay to test the efficacy of Pg isolates as potential biocontrols

We used freshly cut pine wood disks to study the efficacy of the various *P. gigantea* isolate in preventing colonization by *H. irregulare*. Briefly, 2 cm thick sections of pine stems were cut and surface sterilized using Ethanol 70% before being placed on top of a wet filter paper placed inside a deep Petri dish. Each wood disk was subjected to one of three treatments (water, borate according to label, P. gigantea isolates at 10^3 conidia per mL). A day later, a suspension of 10^3 conidia of *Heterobasidion irregulare* was sprayed on each disk and then Petri dishes were kept sealed and in the dark at 20 C. Ten days post the spraying of the pathogen, the area of the disk with *Heterobasidion* colonies was counted. Results are shown in Figure 5.

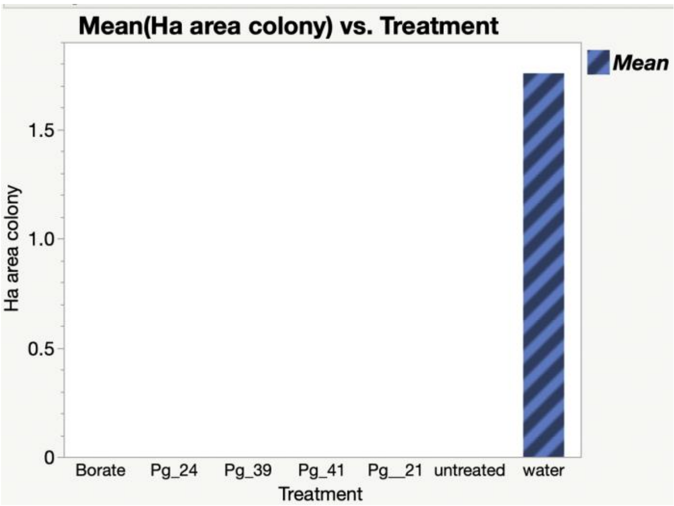


Figure 5: Wood disk area colonized by Heterobasidion irregulare, after disks were treated with Borate, the four most promising Pg isolates, water or were untreated, i.e. were not inoculated with conidia at all

Borates and all Pg isolates were 100% effective in preventing colonization by *Heterobasidion irregulare.*

Field trials

In October 2021, UC Berkeley researchers and USFS pathologist William Woodruff set up a replicated experiment in two sites in the Modoc National Forest. In each of the two sites, three trees were felled and within 48 hours their trunks were sectioned in 60 cm logs. Immediately after sectioning, the bottom side of the log was sealed with a sprayable polymer, the logs were placed upright with the sealed face downwards and the upper side was treated with water, Cellutreat borate, or with a suspension of conidia of a California strain of the biocontrol fungus *Phlebiopsis gigantea* isolate 41 (Victor41). Twenty-four hours later, each stump was treated with a suspension of conidia of a local strain of the pathogen *Heterobasidion irregulare*. Each of the three treatments included 20 logs per site, for a total of 120 logs.

In May 2022 the experiment was ended. First 4 monitoring logs were sent to Berkeley to determine the best portion of the log to be. sampled. Then that portion, i.e. a 5 cm thick cross section of the log, was cut from each log. Bark was shaved off, logs were sprayed with ethanol 70%, the section was cut, bagged and delivered to the UC Berkeley laboratory. At 10, 15 and 20 days all sections were examined to determine the percentage of the cross section that was colonized by *H. irregulare.* Attempts of isolations were made from each disk of both the pathogen and the biocontrol. Cultures are stored at UCB.

Results were promising and in line with what reported in our previous study on fir stumps. Figure 1 shows the preliminary results. This experiment allows to analyze the effect of tree genotype as well. These additional results will be presented in the next report.

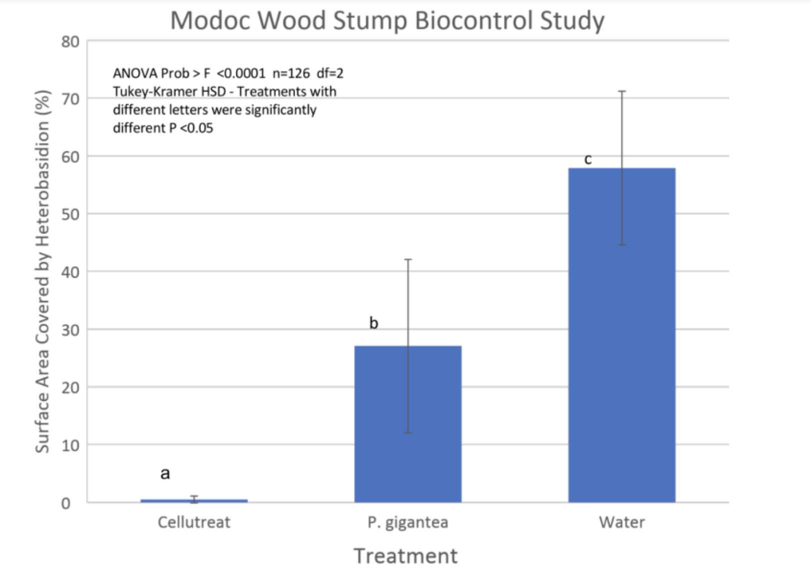


Figure 6: Percentage of cross sections of trunks of Ponderosa pine colonized by the pathogen *Heterobasidion irregulare*. The top surface of each log was treated with water, Cellutreat or the biocontrol *Phlebiopsis gigantea*, 24 hours before being inoculated with a conidial suspension of the pathogen.

Conclusion

The experimental set up is strongly biased in favor of the pathogen, due to the incredibly high numbers of conidia used. Hence, the statistically significant reduction in wood colonization by *H. irregulare* as a result of log treatment with Pg41 aka PgVictor41, although not as completely effective as that obtained when using Cellutreat, is what we expected and a very promising result. These results are comparable to those presented in: Poloni, A., Garbelotto, M, Lee, C., Cobb, R. 2021. Efficacy of Chemical and Biological Stump Treatments for the Control of *Heterobasidion occidentale* Infection of California *Abies concolor*. Pathogens 10, 1390. https://doi.org/10.3390/pathogens10111390, a study also funded by this grant.

Discussion:

Following these two presentations, we had a focused discussion about industry pushback on treating stumps.

Update and discussion around industry pushback on treating stumps (California, Montana, Others?) (15 min)

R5 Perspective- Ashley Hawkins and Martin MacKenzie

R5 has had conversations with industry, which resulted in Bill Woodruff refining stump treatment recommendations.

R1 Perspective- Jill Hautaniemi and Katie Minnix

Jill organized and led a pine HRD meeting with a couple timber companies and western Montana forests. It’s become clear R1 needs updated guidelines for HRD treatments. We are getting pushback from industry in part because of the lack of data about the cost of not treating in our area. This kind of data is really difficult to get because to get a true view of the impacts we would have to wait probably a decade and we would be missing out on the opportunity to be pre-emptively treating stumps in the meantime. We have plans to do some spore trapping with Patrick in the Bitterroot Valley and to establish a study design for a future project comparing areas where stumps were and were not treated.

Highlights/Round Robin

of root disease work from others- this includes what was presented during the committee meeting as well as what was submitted after.

1. Phil Cannon- USFS-Pacific Southwest Region, Vallejo, CA

Phil has been collaborating on a Phellinus noxious project, which has resulted in a beautiful new publication. Phil brought a box of the printed pub and handed them out until he ran out!

Cannon, PG; Klopfenstein, NB; Kim, MS; Stewart, JE; Chung, CL. 2022. Brown Root Rot Disease Caused by *Phellinus noxius* on U.S.- Affiliated Pacific Islands. Gen. Tech. Rep. PNW-GTR-1006. Portland, OR. USDA Forest Service, Pacific Northwest Research Station, 99 p.

2. Nicolas Feau- Natural Resources Canada, Canadian Forest Service; Pacific Forestry Centre, Victoria, B.C.

First documented finding of *P. cinnamomi* on Vancouver Island- infecting western white pine. We ran out of time, so I encouraged Nicolas to also present his findings at the Nursery Committee Meeting to be held Thur lunch.

3. Brennan Ferguson and Betsy Goodrich- USFS-Pacific Northwest Region, Wenatchee, WA

Brennan Ferguson, Blakey Lockman, and Betsy Goodrich sampled root and/or basal decay from 12 western redcedar in an approximately 0.5-acre pocket of Coniferiporia weirii at the Mount Rainier National Park Nisqually (West) entrance to test hypotheses on population structure of the pathogen. Exterior, basal fruiting bodies were also sampled. We were accompanied by Beth Fallon, Park Ecologist. We sent all samples to Patrick Bennett (USFS Research Pathologist, RMRS, Moscow, ID), who will carry out isolations and plate pairings to see if there are one, two, or possibly more genets represented in what appears to be a contiguous infection center. The original diagnosis and assessment of the extent of occurrence of fruiting bodies on live western redcedar was made by Traci Degerman, then the hazard-tree coordinator for the park, after a failure of a western redcedar occurred next to valuable infrastructure. Decay in most trees bearing fruiting bodies has been monitored by Park staff using a Resistograph since 2017.

We would like to sample from several more sites, if possible, to provide enough data to Patrick for a possible journal manuscript. Kristen Chadwick knows of a likely site on the Gifford Pinchot National Forest, while Brennan has previously identified a small center on the Colville National Forest. Previously-identified centers in R1 (northern Idaho or western Montana) might be utilized, as well as sites from British Columbia, if there is interest from Canadian pathologists.

4. Greg Reynolds- USFS- Southwestern Region, Albuquerque, NM

Widespread infection by Onnia tomentosa was observed at Hopewell Lake Campground on the Carson National Forest in northern New Mexico during a late 2022 ground survey for various root diseases. The forest had been cutting standing dead trees, mortality which they initially thought was due only to spruce beetle. Numerous green trees had recently blown over, though, and these all had honeycomb-like decay in the roots that is indicative of Tomentosus root rot. Fruiting bodies of O. tomentosa were also found throughout the area. Per FHP recommendations, all Engelmann spruce with high value targets and showing signs or symptoms of Tomentosus root rot or those adjacent to an infected stump have been cut. Signage explaining the treatment was also developed by FHP and posted in the campground. Additional surveys of other high elevation campgrounds on the Carson NF are ongoing.

5. Jane Stewart- Colorado State University, Fort Collins, CO

Brad Lalande- USFS Rocky Mountain Region, Gunnison, CO

Leading a project funded through STDP to establish an Armillaria LAMP assay. The project will provide fast/accurate, field-based diagnostic tools for forest managers/health professionals to identify Armillaria species from environmental DNA (eDNA) collected from diverse samples (infected host tissue, rhizomorphs, mycelial fans, basidiocarps), and determine if silvicultural treatments are needed to address Armillaria root disease.

6. Rachel Brooks- Washington Dept. Natural Resources, Olympia, WA

Washington State Dept of Natural Resources: We are revisiting Lewis Roth's Potato Patch (Armillaria root rot vs root removal treatment) site near Glenwood, WA for the ~50th year check Fall 2023. Also in winter 2020-2021, in coordination with USFS Dorena crew, we planted a western white pine resistance trial on a laminated root rot disease pocket near Shelton, WA.

7. Ned Klopfenstein, USFS-Rocky Mountain Research Station, Moscow, ID

USDA Forest Service, Pacific Northwest Research Station (PNW) and Rocky Mountain Research Station (RMRS) have continued collaborative studies on Armillaria root disease, with a recently published book chapter (Kim et al. 2022). Other collaborative studies include predictions of contemporary and future climate influences on the potential distribution of *Armillaria solidipes* and one of its hosts, Douglas-fir (Kim et al. 2021). In addition, a review of the potential biological control agent, *A. altimontana*, was published (Kim et al. 2023) and work with Colorado State University (CSU) examined the genomes of *A. solidipes* and *A. altimontana* and the soil microbial communities associated with each of these *Armillaria* species (Ibarra Caballero et al. 2023). An ongoing collaborative study with USDA Forest Service, Region 5 - Forest Health Protection (R5 - FHP) is documenting the occurrence of different *Armillaria* species in California. The North American vicariant of *A. tabescens* was redescribed as *Desarmillaria caespitosa*, because of phylogenetic and morphological differences (Antonin et al. 2021). Scientists from Mexico collaborated with PNW and RMRS to determine new hosts for *D. caespitosa* and *A. mexicana* in Veracruz and Michoacan, Mexico (Alvarado-Rosales et al. 2023).

Collaborative studies with USDA Forest Service, R5-FHP, CSU, PNW, and RMRS have continued to investigate brown root rot disease (caused by *Phellinus noxius*) in the U.S.-affiliated Pacific Islands, eastern Asia, and Australia. A recent study demonstrated that most emergences of brown root rot disease could not be attributed to a recent introduction of *P. noxius*, but were likely the result of disturbances, such as land-use changes or climate change (Kozhar et al. 2022). A synthesis of known information on brown root rot disease and its management was recently published (Cannon et al. 2022).

In collaborative studies with Oregon State University, Iowa State University, PNW, RMRS, and CSU, phylogenetic analyses allowed species-level recognition of the three *Leptographium wageneri* varieties that cause black stain root disease of conifers in western North America (Choi et al. 2023)

Alvarado-Rosales, D.; Elías-Román, R.D.; Saavedra-Romero, L. de L.; Michua-Cedillo, J.; Ochoa-Ascencio, S.; Hanna, J.W.; Klopfenstein, N.B.; Kim, M.-S.; Rivas-Valencia, P.; Rojas-Rojas, R. 2023. New hosts for *Desarmillaria caespitosa* and *Armillaria mexicana* in Veracruz and Michoacan, Mexico (Nuevos hospederos para *Desarmillaria caespitosa* y *Armillaria mexicana* en Veracruz y Michoacán, México). Revista Chapingo Serie Ciencias Forestales y del Ambiente 29: 51-59.

Antonín, V.; Stewart, J.E.; Medel Ortiz, R.; Kim, M.-S.; Bonello, P.; Tomšovský, M.; Klopfenstein, N.B. 2021. *Desarmillaria caespitosa*, a North American vicariant of *D. tabescens*. Mycologia 113: 776-790. https://www.fs.usda.gov/rm/pubs_journals/2021/rmrs_2021_antonin_v001.pdf

Cannon, P.G.; Klopfenstein, N.B.; Kim, M.-S.; Stewart, J.E.; Chung, C.-L. 2022. Brown root rot disease caused by *Phellinus noxius* in U.S.-Affiliated Pacific Islands. Gen. Tech. Rep. PNW-GTR-1006. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR, USA. 99 p. https://www.fs.usda.gov/pnw/pubs/pnw_gtr1006.pdf

Choi, D.; Harrington, T.C.; Shaw, D.C.; Stewart, J.E.; Kroese, D.R.; 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 .

Ibarra Caballero, J.; Lalande, B.M.; Hanna, J.W.; Klopfenstein, N.B.; Kim, M.S.; Stewart, J.E. 2022 (2023). Genomic comparisons of two *Armillaria* species with different ecological behaviors and their associated soil microbial communities. Microbial Ecology 85: 708–729. https://www.fs.usda.gov/rm/pubs_journals/2022/rmrs_2022_caballero_j001.pdf

Kim, M.-S.; Hanna, J.W.; McDonald, G.I.; Klopfenstein, N.B. 2023. *Armillaria altimontana* in North America: Biology and ecology. Journal of Fungi 9: 904. https://www.fs.usda.gov/rm/pubs_journals/2023/rmrs_2023_kim_m002.pdf

Kim, M.-S.; Hanna, J.W.; Stewart, J.E.; Warwell, M.V.; McDonald, G.I.; Klopfenstein, N.B. 2021. Predicting present and future suitable climate spaces (potential distributions) of and Armillaria root disease pathogen (*Armillaria solidipes*) and its host, Douglas-fir (*Pseudotsuga menziesii*), under changing climates. Frontiers in Forests and Global Change 4: 740994. 11 p. https://www.fs.usda.gov/rm/pubs_journals/2021/rmrs_2021_kim_m001.pdf

Kim, M.-S.; Heinzelmann, R.; Labbé, F.; Ota, Y.; Elías-Román, R.D.; Pildain, M.B.; Stewart, J.E.; Woodward, S.; Klopfenstein, N.B. 2022. Armillaria root diseases of diverse trees in wide-spread global regions. pp. 361-378 in: Asiegbu, F.O.; Kovalchuk, A. eds., Forest Microbiology Forest Tree Health, Volume 2, Academic Press (Elsevier), London, chapter 20. https://www.fs.usda.gov/rm/pubs_journals/2022/rmrs_2022_kim_m002.pdf

Kozhar, O.; Kim, M.-S.; Ibarra Caballero, J.; Klopfenstein, N.B.; Cannon, P.G.; Stewart, J.E. 2022. Long evolutionary history of an emerging fungal pathogen of diverse tree species in eastern Asia, Australia, and the Pacific Islands. Molecular Ecology 31: 2013–2031. https://www.fs.usda.gov/rm/pubs_journals/2022/rmrs_2022_kozhar_o001.pdf

2024 Root Disease Committee Chair: Dr. Patrick Bennett

It has been a pleasure and honor to Chair the WIFDWC Root Disease Committee for the last eleven years. I will be retiring in 2024, and I asked Patrick if he would be willing to take over as Chair- I am grateful he accepted with enthusiasm!

Thank you to everyone for your participation and for continuing your very important root disease work!

Notes transcribed and respectfully submitted by Blakey Lockman with additional editing from meeting participants.

Hazard Tree Committee Meeting Notes

Chair: Kristen Chadwick[1]*

The hazard tree committee meeting started with an overview of the up-and-coming Western Hazard Tree Workshop which will be held in Wenatchee, Washington the week of October 16th, 2023. This workshop is long overdue and will hosted at the Hilton Garden Inn in Wenatchee. The meeting will follow the previous meetings format with a day and a half of indoor presentations and panels and a day and a half of field trips. Additionally, there will be a ½ day on Friday for Forest Service attendees to have time to discuss the changes from the WO regarding hazard tree management, specifically with concessionaires. The program will focus on the following four main themes: 1) risk, legal issues, and attorney perspectives, 2) technical issues and case studies, 3) historical perspectives and lessons learned, and 4) Post fire assessments and planning. The field trips are planned to complement the indoor sessions and add to the discussions around hazard tree management post fire and demonstrations of tools available for assessing strength loss of trees. The planning committee has put special emphasis on creating an agenda geared towards learning from those pathologists and arborists with decades of experience and allowing for ample time for discussions and questions. The planning committee for the workshop is Kristen Chadwick (chair), James Jacobs (program chair), Betsy Goodrich and Brennan Ferguson (local arrangements), Holly Kearns (treasurer), Scott Baker (Arborist), Christy Cleaver, and Kelly Burns.

The remaining portion of the meeting was a continuation of Bruce Moltzen's talk on Thursday afternoon titled "Hazard-rating activities" focusing on the changes to the Forest Service's Washington Office policies with time for questions and discussions about the trajectory, limitations, and concerns of the new policies. Since some of these policies are not yet published, the time was used to exchange ideas and experiences of how changes are occurring.

The meeting adjourned after a very brief round robin.

---

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

Climate Change Committee Meeting Notes

Chairs: Susan Frankel[1]*, Alex Woods[2], and Charles "Terry" Shaw[3]

Notes by Alex Woods, BC Ministry of Forests and Betsy A. Goodrich, US Forest Service, Forest Health protection and Susan J. Frankel, US Forest Service, Pacific Southwest Research Station

The Western International Forest Disease Work Conference (WIFDWC) Climate Change Committee meeting was held at the end of jam-packed day, and ran from 7:00 pm to just after 9:00 pm. Approximately 50 people attended. Co-chairperson, Alex Woods led the meeting.

The meeting featured two interactive exercises as listed below.

Keeping up with the science

WIFDWCers were asked to select and pitch a favorite climate change forest disease paper. The following papers were volunteered.

Hepting, G.H. 1963. Climate and forest diseases. Annual Review of Phytopathology. 1(1): 31-50.

Michael McWilliams, US Forest Service, Forest Health Protection, La Grande, Oregon (and A. Woods) made their case that Hepting's paper is a must-read and that the arguments Hepting made over 60 years ago have held up very well. Hepting pointed out that weather extremes and not the averages or trends will be critical. Numerous direct quotes from the paper were read aloud.

Hennon, P.E.; Frankel, S.J.; Woods, A.J.; Worrall, J.J.; Norlander, D.; Zambino, P.J.; Warwell, M.V. & Shaw III, C.G. 2020. A framework to evaluate climate effects on forest tree diseases. Forest Pathology. 50(6): e12649.

Chrissy McTavish, US Forest Service, Forest Health Protection, Boise, ID, suggested that the Hennon et al. paper was one of the better climate change papers she had read due to the clarity of the argument and the structured approach that helped her better understand the role of climate in forest disease behaviour.

Bell, D.M.; Pabst, R.J. & Shaw, D.C. 2020. Tree growth declines and mortality were associated with a parasitic plant during warm and dry climatic conditions in a temperate coniferous forest ecosystem. Global Change Biology. 26(3): 1714-1724.

David Shaw, Oregon State University, recommended the Bell et al. paper as it showed a clear mechanistic relationship between increased drought and increased mortality in trees with Dwarf Mistletoe Ratings (DMR) ratings 5-6 with growth reductions in DMRs 2-3. The publication provides excellent evidence of physiological effects of recent hot droughts on trees with moderate to severe dwarf mistletoe. Initial analyses in 1990s only showed mortality associated with severely infested, or DMR $\geq$5, trees.

Intergovernmental Panel on Climate Change (IPPC) Reports.

Paul Hennon, USFS PNW Research/Forest Health Protection, retired. In absentia, recommended looking through the IPCC reports, including the Summary for Policy Makers.

---

[1] USDA Forest Service, Pacific Southwest Research Station, Albany, CA, USA
[2] British Columbia Public Service, Smithers, BC, USA
[3] USDA Forest Service, Pacific Northwest Research Station, Prineville, OR, USA
*susan.frankel@usda.gov

Gullino, M.L.; Pugliese, M.; Gilardi, G., and Garibaldi, A. 2018. Effect of increased CO_2 and temperature on plant diseases: A critical appraisal of results obtained in studies carried out under controlled environment facilities. Journal of Plant Pathology. 100: 371-389.

Terry (C.G.) Shaw, FS Research. Retired. Bend, OR via email suggested this paper to call attention to the complexities of forecasting the impacts of multiple climate factors on trees and pathogens.

Still, C.J.; Sibley, A.; DePinte, D.; Busby, P.E.; Harrington, C.A.; Schulze, M. and others. 2023. Causes of widespread foliar damage from the June 2021 Pacific Northwest Heat Dome: more heat than drought. Tree Physiology. 43(2): 203-209.

Susan Frankel, USFS, PSW Research, Albany suggested this paper and the group discussed more aspects of the 2021 heat dome and what it signaled for the future and the challenges forests will face. Some discussion items included: damages associated with trees in Pacific Northwest forests on the coast vs. interior forests; monitoring options following the heat dome - there haven't been any set up to our knowledge, although Mike Cruikshank has plots across multiple forest types and noted no mortality associated with heat dome; whether a network of monitoring plots would show future tree mortality - most people agreed trees were damaged but not killed; and a discussion on how the omega blocking patterns associated with the heat dome are not well accounted for in climate/weather modeling efforts. It was suggested some trees in urban areas may possibly succumb to the damage. Alex Woods mentioned that tip/branch damage of spruce, presumably due to the heat dome, didn't present until winter.

Agne, M.C.; Beedlow, P.A.; Shaw, D.C., Woodruff, D.R., Lee, E.H., Cline, S.P. and Comeleo, R.L. 2018. Interactions of predominant insects and diseases with climate change in Douglas-fir forests of western Oregon and Washington, U.S.A. Forest Ecology and Management. 409: 317–332.

Patrick Bennett, USFS Rocky Mountain Research Station, Moscow, ID suggested this paper and mentioned the relationship between black stain root disease and drought as a very important accelerator of tree dieback in recent years. The publication also discusses interactions of biotic damages in Douglas-fir forests due to Swiss needle cast, laminated root rot and Douglas-fir beetle.

United Nations Environment Programme (UNEP). 2022. Emissions Gap Report. Closing the Window. Climate Crisis Calls for Rapid Transformation of Societies. 13th edition. October 2022.

Hanno Southam, University of British Columbia, recommended attendees read the 2022 Emissions Gap report that highlights the differences between what countries have pledged to do to reduce greenhouse gas emissions and what they are currently producing. Important emissions gap information and other IPPC figures were discussed. The emissions gap is defined as the difference between the estimated total global greenhouse gas (GHG) emissions resulting from the full implementation of the nationally determined contributions (NDCs), and the total global GHG emissions from least-cost pathways consistent with the Paris Agreement long-term goal of limiting global average temperature increase to well below 2°C, and pursuing efforts to limit it to 1.5°C relative to pre-industrial levels.

Ogris N, Brglez A, Piškur B. 2021. Drought stress can induce the pathogenicity of Cryptostroma corticale, the causal agent of sooty bark disease of sycamore maple. Forests. 12(3): 377.

Rachel Brooks, Washington Department of Natural Resources, brought the group's attention to this paper linking drought stress to sooty bark disease. The work includes pathogenicity tests using temperature and drought treatments.

Blodgett, J.T.; Smith, D.R. and Stanosz, G.R. 2021. First report of Diplodia shoot blight and canker disease caused by Diplodia sapinea on ponderosa pine in Wyoming, U.S.A. Plant Dis. 105: 3289.

(Provided by James Blodgett, USFS Forest Health Protection, Rapid City, SD).

Hamann, A. and Wang, T. 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology. 87(11): 2773-2786.

(Submitted by Paul Hennon, USFS PNW Research/Forest Health Protection, retired. In absentia)

Kannenberg, S.A.; Driscoll, A.W.; Malesky, D. and Anderegg, W.R. 2021. Rapid and surprising dieback of Utah juniper in the southwestern USA due to acute drought stress. Forest Ecology and Management. 480: 118639.

(Submitted by Gregory Reynolds, USFS FHP, Albuquerque, NM.)

General Discussion

Alex Flores, Sonoma State University suggested the use of archived TV footage to look at differences in forest and tree health and changes in the timing of growth and phenology. Robin Mulvey, USFS FHP Alaska suggested we invite more plant physiologists to WIFDWC to gain a better understanding of the physical limits trees are facing under rapid climate change. Robin also discussed the change in winter precipitation type from snow to rain in southeast Alaska and the impact that will have on both hosts and pathogens. Ned Klopfenstein said we need to move forward with plans for climate change adaptation without having 50 years of data as we simply don't have time. Mike Cruikshank reported on networks of plots across biogeographic zones, and using host data to predict what different species will be exposed to in future climate scenarios.

Root Disease and Climate Change Debate

Michael Murray, BC Ministry of Lands and Natural Resource Operations, and David Shaw, Oregon State University, engaged in a rigorous debate arguing whether root diseases would be more severe under a rapidly changing climate. Michael was assigned the view that root diseases will become more damaging given climate change and Dave argued for reduced damage in the future given climate change. Murray used Shaw's own published statements to challenge his debate position that root disease would decline. Some of Michael's arguments, in support of a forecast of expanding root disease given climate change included: 1. Drought predisposes trees to Armilliaria root disease as shown in several historical publications and anecdotes; 2. Juvenile mortality and Armilliaria root disease are increasing with potential evapotranspiration (PET, recent Murray publication); 3. Mortality associated with Armilliaria root disease increases immediately following drought years (Morrison and Murray publications); and 4. climatic maladaptation of host trees will increase Armilliaria root disease. The arguments put forth by Shaw for root disease to diminish due to climate change include: 1. A decrease in tree density leading to less root contacts; 2. Longer hotter drier summers will create conditions too hot for fungal spore production; and 3. Conifer forests will be reduced overall due to combined stresses which will lead to fewer root contacts.

Discussion topics from the group following the arguments included: 1) The ability for pathogens to create their own cool, moist habitats (e.g., in stumps) so they will be buffered from climate changes; 2) Some root pathogens are not dependent on stressed trees; 3) Discussion on root pathogen presence and movement and how quickly they can move to keep up with maladapted hosts; 4) Endophytic fungi may become more pathogenic with variability in weather and a changing climate (i.e., Matteo's recent work on cankers in *Acacia* in the Bay Area).

Dwarf Mistletoe Committee Meeting Notes

Chair: David Shaw[1]*

Dwarf Mistletoe Committee meeting was held, Tuesday June 6. 7 AM – 830 AM

Bob Mathiasen' s new Book: Mathiasen, R.L., 2021. Mistletoes of Continental United States and Canada. Brit Press, Ft. Worth, Texas. https://shopbritpress.org/products/mistletoes (Figure 1).

This book is a fantastic new volume that includes both the Dwarf Mistletoes (*Arceuthobium* species) and the Leafy Mistletoes (*Phoradendron* species) in one classic field guide for the first time. It is fully illustrated with good photos and distribution maps for all the species. It makes the mistletoes of North America north of Mexico accessible to everyone!

There was a meeting of the IUFRO Division 7 (Forest Health) in Lisbon, Portugal September 6 – 9, 2022. The Working Group; 7.02.11, Parasitic Flowering Plants in Forests, sponsored a technical session, which is currently working on a special issue of the journal Botany. Luiza Teixeira-Costa (Brazil/Belgium) is the new Chair.

While in Portugal, D. Shaw visit the Azores Islands and found the endemic, *Arceuthobium azoricum* on *Juniperus brevicomis* (Figure 1: A, B)

Figure 1: *Arceuthobium azoricum* from Terceira Island, Portugal. A. The large basal segments are a distinct feature. B. Aerial shoots emerging from *Juniperus brevicomis*.

Gabi Ritokova, Oregon Dept. of Forestry reported on dwarf mistletoes of the Gilchrist State Forest, Oregon.

Hanno Southham, MS Student at UBC, reported on this project evaluating western hemlock dwarf mistletoe invasion into plantations from adjacent, uncut stands in SW British Columbia.

---

[1] Oregon State University, Department of Forest Engineering, Resources, and Management, Corvallis, OR, USA
*dave.shaw@oregonstate.edu

Announcing the new chair of the WIFDWC Dwarf Mistletoe Committee: Brent Oblinger, Forest Health Protection, USFS, Bend, Oregon

The European Mistletoe, *Viscum album*, in Sonoma, County, California. The famous horticulturist, Luther Burbank, introduced *V. album* to his Gold Ridge Farm in Sebastopol, California around 1900, and the mistletoe has become well established. Hawksworth and Scharpf documented and monitored the mistletoe, and most recently (2019) Dave Shaw and Chris Lee remeasured the distribution and published a map; Figure 2. Shaw, D.C., and C.A. Lee. 2020. Expansion of the invasive European mistletoe in California, USA. Botany 98: 517-524. dx.doi.org/10.1139/cjb-2019-0215

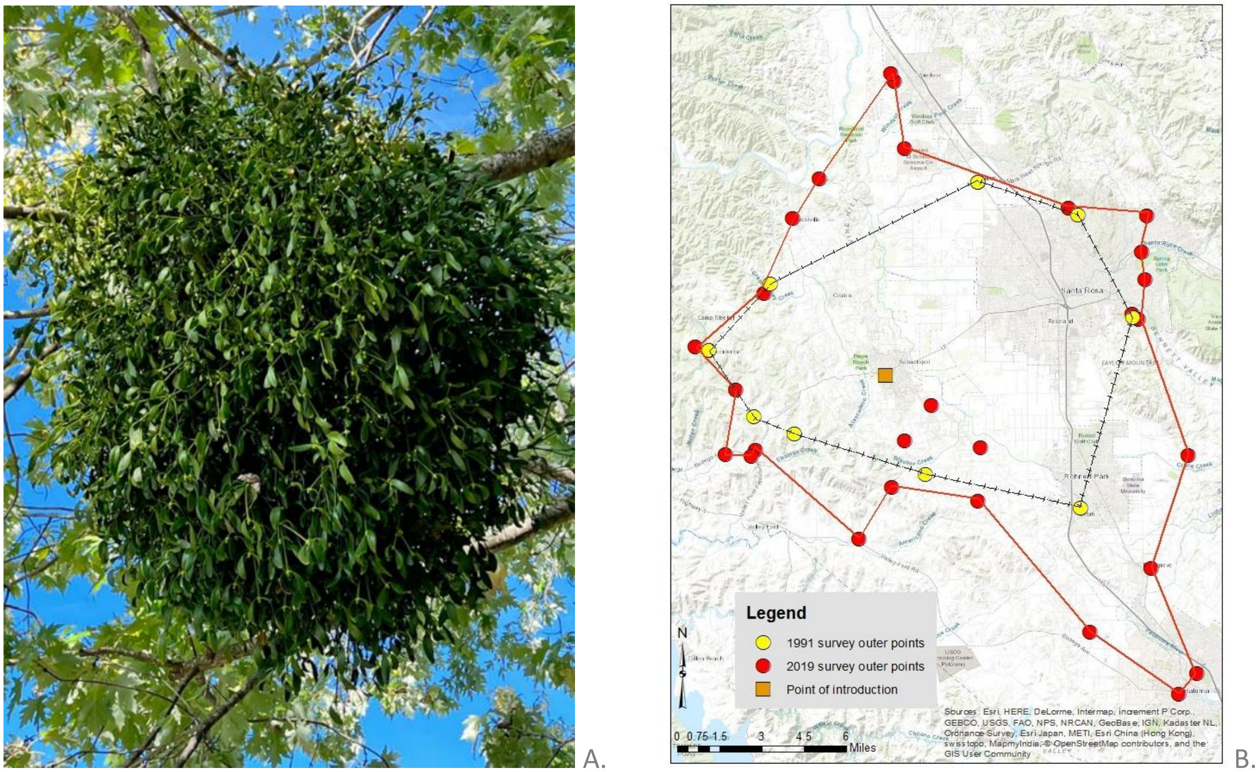


Figure 2: Viscum album in Sonoma County. A. Plant on Acer. B. Map of distribution in 2019, from Shaw and Lee, 2020. Botany.

Nursery Committee Meeting Notes

Chair: Anna Leon[1]*

The 2023 Nursery Committee meeting included a short presentation and a lively round robin discussion of the current state of western nurseries, the current state of phytosanitary nursery regulations, and pathology needs within the nursery system.

Nicolas Feau shared his research on mortality in western white pine seed orchards in British Columbia. A survey was conducted in 2017 and 2018 in which multiple species of *Pythium* and *Phytophthora* were found in dying western white pine. Of particular concern, *Phytophthora cinnamomi* was found at one of the seed orchards on Vancouver Island. This is the first time the disease has been found on western white pine and appears to be contained to one orchard at present. Koch's postulates were conducted, and 50% mortality was found after 45 days. After 56 days at 25°C, 100% mortality was found.

Round Robin

Nursery resources and a lack of trained personnel have been a top concern for this committee for many years. The tide appears to be turning, as millions of dollars have recently become available from the Disaster Recovery Act, resulting in nursery expansion and a nationwide hiring push in 2023. With the rapid expansion of federal nurseries, the group participated in a lively discussion about our current opportunities and challenges. The consensus still remains that nurseries are currently experiencing a people bottleneck where trained nursery professionals are lacking both in public and private facilities. Additionally, there are still far too few nursery pathologists to serve all the nursery pathology needs.

Charlie Barnes shared updates from Southern California. An insect and disease training class was offered and taken by some nursery employees. Many other meeting attendees discussed that nursery professionals in their geographies recognize gaps in seedling health knowledge that they would like to see filled with future classes as well. There are potential opportunities for members of this organization to participate in training events, especially as new staff are hired.

Jim Blodgett shared that the growers he works with are well trained and don't need much help, but he stops in occasionally to chat about the health of the crop.

Greg Reynolds shared that there is a new state restoration center in New Mexico. As restoration work expands, the biggest concerns are *Fusarium* and *Phytophthora*.

California has established a restoration accreditation. The Placerville nursery tests to ensure clean material, going beyond current regulations. The forest service can buy from accredited nurseries. It was agreed upon that the onus for clean material should be put on the purchaser and it was confirmed that this is client driven in California.

John Dobbs highlighted that detection is critical to the prevention of diseases. A nursery risk model for our main pests of interest was suggested. He also discussed the creation of a *Fusarium* LAMP assay for detection. The consensus in the room was supportive and that there is a need for rapid diagnostic assays for nursery pathogens.

Marianne Elliott shared that there is more *Phythophthora* in nurseries than what we find at outplant. Others in the room found this to be interesting and they will spend more time looking at outplant seedlings.

Anna Leon discussed a seedling fall down event in 2022 that was due to a combination of poor bed construction and of summer heat and drought stress followed by severe winter flooding. The nursery saw an uptick in mortality

---

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

and seedling damage from *Phoma.* A combination of cultural improvements and disease monitoring have improved conditions and reduced seedling mortality in 2023.

Presentations in the main room (photo: Rachel Brooks)

Rust Committee Meeting Notes

Chair: Jane Stewart[1]*

- Jane Stewart discussed ongoing projects at Colorado State University, in collaboration with Kelly Burns, on white pine blister rust. One large research effort (Ashley Miller's PhD project with Stewart) includes WPBR spore trapping across sites in Colorado, Wyoming, New Mexico, Arizona, and Utah in collaboration with Brad Lalande, Maria Newcombe, Greg Reynolds, and Nick Wilhelmi. Spores were collected in 2023 weekly from May-October across all the sites and we have roughly 5,000 microscope slides that will be analyzed with qPCR to test for *C. ribicola* DNA.
- Patrick Bennett discussed his spore trapping project at Priest River Experimental Forest in northern Idaho, which includes western white pine and whitebark pine stands. This project is in collaboration with the Stewart lab and will be using similar methods as the CSU led project.
- The group discussed the possibility of quantifying basidiospores directly, since these pose an immediate threat to white pines. There was a discussion about whether there is a molecular method for differentiating basidiospores from other spore types produced concurrently. There may be a possibility, however, the methods are not yet fully developed.
- The group also discussed efforts to develop bioclimatic models for *C. ribicola* and its hosts. Anna Schoettle, Sparkle Malone, Kelly Burns, Jane Stewart, Christy Cleaver and Holly Kearns are involved in one effort that has examined future climate risk on a west-wide scale using FHP collated WPBR presence/absence blister rust occurrence data. Several other projects are also underway including a bioclimatic modeling project that Mee-Sook Kim is leading.
- Patrick asked the group about using FIA data, and most in the committee meeting agreed that this would not be a good course of action. Problems with thresholds for collecting data, reliability of diagnoses, and lack of availability of georeferenced observations (FIA won't share precise coordinates for plot locations).
- We also discussed the presence of the *C. ribicola* x *C. comandra* hybrid in British Colombia, Wyoming and Colorado.
- Robin Mulvey discussed her observations of spring spruce needle rust (*Chrysomyxa weirii*) and hemlock-blueberry rust (*Naohidemyces vaccinii*) as interesting diseases in Alaska at the moment. *C. weirii* generally causes negligible disease but was unusually common in spring 2023. It is not causing severe disease and is not a management concern at all, but she brought up these changes in minor diseases as environmental/weather change indicators. Similarly, hemlock-blueberry rust has been extremely common the last few years after hardly seeing it before. We had it sequenced and found that the voucher specimen, from Europe, had some consistent base pair differences with ours, which speaks to the need to have more native fungi sequenced so that we have baseline info in GenBank.
- We also discussed efforts in Canada examining the genetic diversity and range of western gall rust.

---

[1] Colorado State University, Dept of Agricultural Biology; Fort Collins, CO
*jane.stewart@colostate.edu

Other Reports

Lunch break on the coast. (Photo: Robin Mulvey)

2023 Student Awards Committee Report

Betsy Goodrich[1]*, Kelly Burns[2], and Jared LeBoldus[3]

The Student Travel Award Committee reviewed excellent applications and awarded seven students (four PhD students and three MS students) travel awards totaling $2,090.

Congratulations once again to the following students: Ashley Miller, Ada Fitz Axen, John Dobbs, Noah Lindeman, Michael Gordon, Stephanie Chase and Hanno Southam.

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 $2,913.00. In addition, there was $395.00 contributed from individual donations and 63 regular WIFDWC member registrations which added $1575.00, so the Student Travel Award account currently has a balance of **$4,782.00**.

The silent auction in action. (photo: Rachel Brooks)

---

[1] USDA Forest Service, Pacific Northwest Region, Wenatchee, WA, USA
[2] USDA Forest Service, Rocky Mountain Region, Forest Health Protection; Golden, CO, USA
[3] Oregon State University, Department of Botany and Plant Pathology; Corvallis, OR, USA
*anne.goodrich@usda.gov

Business Meeting Notes

Secretary: Rachel Brooks[1]*

The WIFDWC business meeting was called to order by the Meeting Chair, Jane Stewart, at 10:48 AM on Friday, June 9, 2023.

OLD BUSINESS

A motion to adopt the 2022 Business Minutes without revisions was made. The motion was seconded and passed with all in favor.

NEW BUSINESS

Deceased members

A moment of silence was held for known and unknown deceased WIFDWC members. Since the last business meeting, this includes Mike Srago.

WIFDWC 2024

Betsy Goodrich presented information on behalf of Greg Reynolds and Nick Wilhelmi about the possibility of holding the next WIFDWC meeting in Santa Fe, New Mexico in September 2024. Pictures and information shared included detailing some of the forest biomes of New Mexico (pinion-juniper, ponderosa pine, mixed conifer, and spruce-fir woodlands) and their associated diseases.

The Railroad committee (Dave Shaw and Kristen Chadwick) proposed the following new Planning Committee and officers: conference chair (Lori Winton), program chair (Danny Norlander), secretary (Adam Carson), local arrangements (Greg Reynolds and Nick Wilhelmi), and treasurer (Holly Kearns). A motion was made to accept these nominations which was seconded and passed with all in favor.

WIFDWC 2025+

A conversation lead by Mike Murray was had about the 2025 meeting being held in Nelson, British Columbia. An official decision about this was delayed until the next business meeting.

Website updates

Any updates or photos you would like to have highlighted on the web page should be sent to Danny Norlander (danny.norlander@odf.oregon.gov) who will be continuing to manage the website. Any suggestions for improvement are also welcome.

Treasurer's report

Holly Kearns presented the latest treasurer’s report from 2019, reported on the refunds obtained from the canceled 2020 meeting, and mentioned the reused 2020 souvenirs. Overall, 86 people attended this 2023 meeting, with $25 per regular member registration going to the student travel award fund ($1,575 total). Additionally, the silent auction raised over $3,000! This leaves us in a good position for next year’s student travel award fund.

Committee updates:

---

[1] Washington State Department of Natural Resources, Forest Resilience Division, Olympia, WA, USA
*rachel.brooks@dnr.wa.gov

- Mistletoe: Despite the name, leafy mistletoes were discussed a fair amount and some great presentations were shared. The committee also voted in a new committee chair: Brent Oblinger.
- Root disease: There was good attendance at this meeting which included a presentation from Patrick Bennet about *Heterobasidion* spore trapping and a virtual presentation from Mateo Garbelotto about *Phlebiopsis gigantea*. The meeting ended with a discussion about industry pushback for treating stumps.
- Foliage and stem: Kelsey Sondreli & Adam Carson filled in for Jared LeBoldus, who will be back next year. The meeting focused a lot on Swiss needle cast, including a presentation by Gabi Ritokova, before moving on to other topics.
- Rust: This meeting had no formal presentations but included a good round robin. White pine blister rust took up a lot of the time, including discussions on spore trapping and needle versus bark tissue colonization, before discussing some other rusts.
- Nursery: This meeting included a presentation by Nico Feau about *Phytophthora cinnamomi* in seed orchards before the discussion turned to the influx of money going to increased nursery infrastructure and how we can engage in this work productively.
- Climate change: Despite not being a happy hour meeting, people still had fun. The meeting started by sharing everyone's favorite climate change papers (plug for the Hepting 1963 "Climate and Forest Diseases" paper) before Dave Shaw and Michael Murray had an animated debate about expected climate change impacts to forest root diseases.
- Hazard tree: A lively discussion was had about federal level changes. Also, we were reminded that the next Western Hazard Tree Workshop will be this fall in Wenatchee, WA, with a save the date going out to the WIFDWC listserv shortly.
- Outstanding Achievement Award: A motion was made to change the current members of this committee from: Jane Stewart, Alex Woods, and Kristen Chadwick to Kristen Chadwick (chair), Jane Stewart, and Nico Feau. This motion was seconded and passed with all in favor. Jane also reminded us of the importance of submitting nominations.
- Student Travel Award: The current committee includes Jared LeBoldus, Kelly Burns, and Betsy Goodrich. A motion was made to change the committee to: Kelly Burns, Betsy Goodrich, and Joey Hulbert. This motion was seconded and passed with all in favor.

Later during this business meeting, Walt Thies made a motion to increase the $25 per regular member registration donation to $30. There was some discussion about how cost increases could limit US Forest Service staff per Meeting Management rules. Despite this discussion the motion was seconded and passed with all in favor.

Additionally, an idea to approach industry to try to fund student travel was suggested. Anna Leon said she can try to facilitate this if there is a request from WIFDWC before July. Anna will work with Holly Kearns, Treasurer, to add the Weyerhaeuser donation to the 2024 student travel fund account, if successful.

Other business

The historian, Brennan Furguson, does not currently have all the hardcopies of past proceedings, but will try to track them down and make sure all of them are available online. It was also confirmed that there was nothing in our bylaws to require printing hardcopies, which will save us about $5,000 in printing and shipping costs. No opposition was made about no longer printing proceedings.

A discussion was had about the agenda and schedule for future meetings. Walt Thies suggested some time should be taken to have students connect with retirees to help share knowledge. Dave Shaw passed on some information from Susan Frankel suggesting we condense the meeting to allow for more free time for networking during meals and breaks. A lot of the attendees appeared to agree. Suggestions about condensing this time included: moving committee meetings to the first day, shortening committee meetings to only round robins, shortening talks to 15 minutes, having fewer talks, and adding another day to the meeting. The benefit of having no concurrent sessions was stressed. Danny Norlander will send out a survey to the listserv to get feedback and consider changes for the next meeting.

A discussion about WIFDWC's role with social media resulted in the formation of an ad hoc social media committee including Joey Hulbert, Betsy Goodrich, Danny Norlander, Robin Mulvey, Ada Fitz Axen, and Yung-Hsiang (Sky) Lan. They were tasked with exploring ideas, possibly developing an internal communication method first and then exploring ideas to communicate with the public. Comments about this included: discussing how this would fit into WIFDWC's structure, suggesting making an online discussion board, suggesting sharing any member's papers when published, using a slack channel to communicate internally, stressing how this will not replace the webpage, and reminding everyone to be careful not to dilute WIFDWC which has functioned fairly well for a long time.

Chris Lee asked WIFDWC for a letter of support so that those in CalFire may possibly attend this meeting in the future (as they are currently limited to travel just in California). Chris will draft a letter and then send it to the meeting chair for review and signature. It was noted that other letters of support have been signed by WIFDWC chairs in the past for other groups.

Jane thanked everyone and acknowledged the hard work of all the committees, especially local arrangements, CalFire, and Mary Lou Fairweather!

The meeting was adjourned at 11:45 AM on Friday, June 9, 2023.

Ellen Goheen showing off her donated quilt to the silent auction (photo: Rachel Brooks)

Treasurer's Report

Treasurer: Holly Kearns[1]*

WIFDWC recovered from the pandemic and successfully hosted two in-person meetings in 2023. The 68th WIFDWC in Rohnert Park, California had 89 attendees including 63 regular members, 12 graduate students, and 9 retirees. The 9th Western Hazard Tree Workshop in Wenatchee, Washington had 66 attendees. The following is a summary of transactions for the WIFDWC accounts from 1/1/2020 through 12/31/2023.

	Income / Expense	**Balance**	**Total Account**
All WIFDWC Accounts balance 12/31/19			**$31,233.48**
WIFDWC Meeting Account balance 12/31/19		$15,184.93	
2023 WIFDWC			
Total registration	32,125.83		
Hotel meeting rooms, meals & breaks	-28,832.95		
Field trip transportation	-4,570.32		
Field trip snacks and entry fees	-183.84		
Souvenirs	-1,205.00		
Awards	-112.00		
Office supplies	-174.17		
On-line ticketing	-184.00		
TacBoard	-159.00		
Regular member registration fees to STA Fund	-1,575.00		
Other Account Activity			
Transfer International Sponsorship Fund	5,756.64		
2019 Proceedings (printing and formatting)	-2,998.32		
2020 Cancelled meeting registration refunds	-15.47		
Virtual meeting space (2022 online meeting)	-200.00		
Deposit 2024 Meeting Sante Fe, NM	-2800.00		
WIFDWC Meeting Account balance 12/31/23		**$10,057.33**	
Hazard Tree Committee Account balance 12/31/19		$8,302.91	
Total registration	21,074.53		
Hotel meeting rooms, meals & breaks	-9,744.45		
Field trips	-6,475.64		
Speaker Stipends	-1,750.00		
Souvenirs & Awards	-692.16		
Office supplies	-84.48		
Hazard Tree Committee Account balance 12/31/23		**$10,630.71**	
Student Travel Award Fund balance 12/31/19		$1,989.00	
2023 Silent Auction Proceeds	2,913.00		
2023 Regular member registration fees (63 @ $25)	1,575.00		
2023 Individual Contributions	395.00		
2023 Student Travel Awards	-2,090.00		
Student Travel Award Fund balance 12/31/23		**$4,782.00**	
International Sponsorship Fund balance 12/31/19		$5,756.64	
Transfer funds to WIFDWC Meeting Account	-5,756.64		
International Sponsorship Fund balance 12/31/23		**$0.00**	
All WIFDWC Accounts balance 12/31/23			**$25,470.04**

---

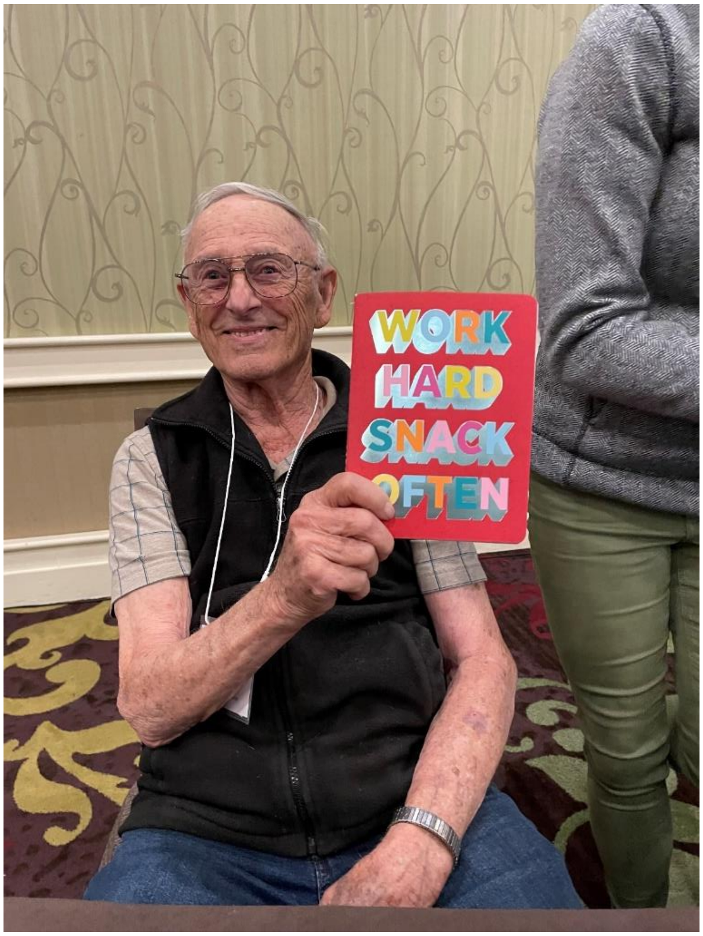
[1]USDA Forest Service, Forest Health Protection; Sandy, OR, USA

*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.

2015	Brian Geils	Newport, OR	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.
2016 - 2018	No award given		
2019	Greg Filip	Estes Park, CO	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.
2020	Phil Cannon		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.
	Ned Klopfenstein		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.
2022	No award given		
2023	Blakey Lockman	Rohnert Park, CA	For her combined expertise in forest pathology, leadership and mentorship, and her legacy on the field of forest pathology in US western forests.



Robert Scharpf sharing his wisdom. (photo: Rachel Brooks)

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

Monday's field trip (photo: Sam Brown)

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—present
Root Disease	G. Filip	1994—1995
	E. Michaels Goheen	1996—2005
	B. Ferguson	2006—2009
	M. Cleary	2010—2011
	B. Lockman	2012—present
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
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
Climate Change[3]	S. Frankel	2007—2008
	S. Frankel & D. Shaw	2009—2014
	S. Frankel, D. Shaw, & A. Woods	2015—present

---

[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 June 9, 2023

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.

Past Annual Meeting Locations and Officers, 1953—2023

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

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 and poster reception socializing. (photos: Rachel Brooks)

1. Mike Cruickshank, 2. Simon Shamoun, 3. Lori Winton, 4. Kelsey Søndrelli, 5. Noah Lineman, 6. Ada Fitz-Axen, 7. Ashley Miller, 8. Gabriela Ritokova, 9. Sapphitah Dickerson, 10. Isabella Valdez, 11. Kymi Draeger, 12. Kelly Burns, 13., Merlin Schlumberger, 14. Rachel Brooks, 15. Christy Cleaver, 16. Kristen Chadwick, 17. Sam Brown, 18. Jill Hautaniemi, 19. Sky Lan, 20. Ashley Hawkins, 21. Patrick Bennett, 22. Robin Mulvey, 23. Charles Barnes, 24. Martin MacKenzie, 25. Jorge Ibarra Caballero, 26. Priya Puri, 27. Rebecca Wolff, 28. Betsy Goodrich, 29. Blakey Lockman, 30. Alex Flores, 31. Bruce Moltzan, 32. Wallis Robinson, 33. Susan Frankel, 34. Josh Bronson, 35. Kim Corella, 36. Katie Minnix, 37. Tom Smith, 38. Anna Leon, 39. Maria Newcomb, 40. Marianne Elliott, 41. Steph Chase, 42. James Blodgett, 43. Gail Thies, 44. Walt Thies, 45. Kevin Paul, 46. Brent Oblinger, 47. Nicolas Feau, 48. John Dobbs, 49. Matt Banchero, 50. Mike McWilliams, 51. Michael Murray, 52. Stefan Zeglen, 53. Alan Kanaskie, 54. Chris Lee, 55. Brennan Ferguson, 56. Richard Hamelin, 57. Sebastian Fajardo, 58. Cameron Stauder, 59. Greg Filip, 60. Michael Gordon, 61. Dave Shaw, 62. Sean Wright, 63. Duncan Kroese, 64. Alex Martin, 65. Adam Carson, 66. Chrissy McTavish, 67. Greg Reynolds, 68. Ned Klopfenstein, 69. Leah Rettenbacker, 70. Alex Woods, 71. Nathan Berner, 72. Hanno Southam, 73. Phil Cannon, 74. John Hanna, 75. Danny Norlander (Photo: Holly Kearns)

1. Adam Carson, 2. Kelsey Søndrelli , 3. Steph Chase, 4. Susan Frankel, 5. Matt Banchero, 6. Nathan Berner, 7. Marianne Elliott, 8. Gabriella Ritokova, 9. James Blodgett, 10. Kevin Paul, 11. Walt Thies, 12 Gail Thies., 13. Noah Lindeman, 14. Kymi Draeger (Photo: Rachel Brooks)

1. Chris Lee, 2. Alan Kanaskie, 3. Yung-Hsiang "Sky" Lan, 4. Ashley Hawkins, 5. Greg Filip, 6. Dave Shaw, 7. Simon Shamoun, 8. Wallis Robinson, 9. Tom Smith, 10. Martin MacKenzie (Photo: Rachel Brooks)

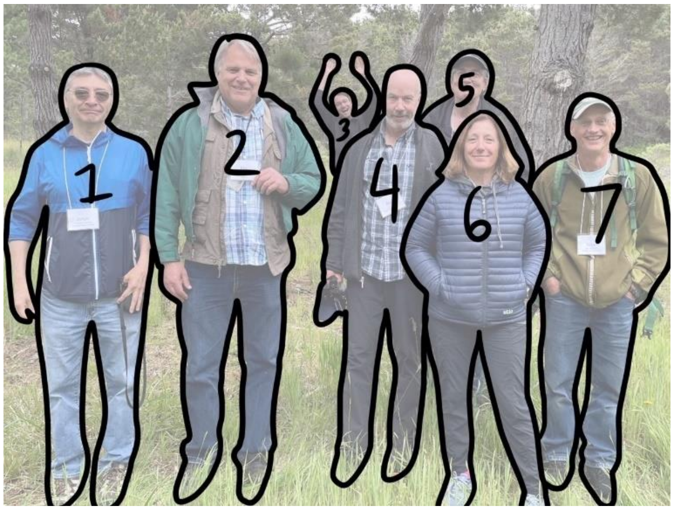
1. Bradley Lalande and child, 2. Alex Martin, 3. Alex Flores, 4. Merlin Schlumberger, 5. Anna Leon, 6. Betsy Goodrich, 7. Chrissy McTavish, 8. Kim Corella (photo: Rachel Brooks)

1. Michael Gordon, 2. Jorge Ibarra Caballero, 3. Rachel Brooks, 4. Brennan Ferguson, 5. Robin Mulvey, 6. Danny Norlander, 7. Stefan Zeglen, 8. Rebecca Wolff (Photo: Rachel Brooks)

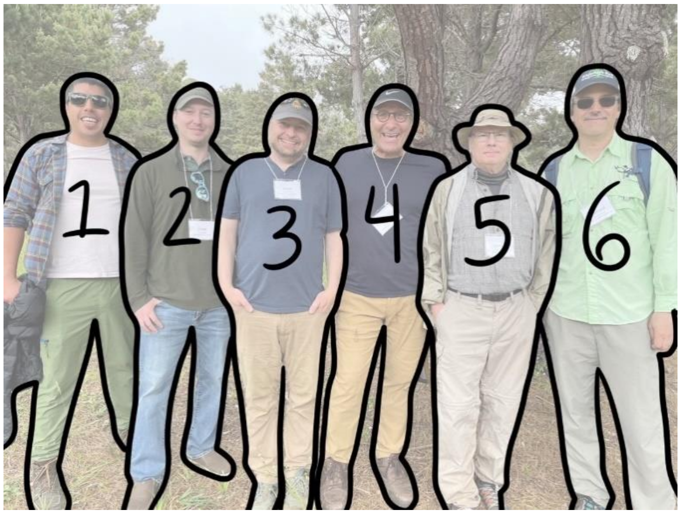
1. Mike McWilliams, 2. Brent Oblinger, 3. Lori Winton, 4. John Hanna, 5. Patrick Bennett, 6. Duncan Kroese, 7. Cameron Stauder, 8. Charlie Barnes, 9. Ashley Hawkins, 10. Ned Klopfenstein, 11. Sapphitah Dickerson, 12. Isabella Valdez (Photo: Rachel Brooks)

1. Mike McWilliams, 2. Blakey Lockman, 3. Hanno Southam, 4. Leah Rettenbacker, 5. Gregory Reynolds, 6. Kristen Chadwick, 7. Jill Hautaniemi, 8. Maria Newcomb, 9. Ashley Miller, 10. Priya Puri, 11. Ada Fitz-Axen, 12. Rebecca Wolff (Photo: Rachel Brooks)

1, 2, 6, and 7. Jane Stewart and family, 3. Christy Cleaver, 4. Bruce Moltzan, 5. Katie Minnix (Photo: Rachel Brooks)



1. Jorge Ibarra Caballero, 2. Phil Cannon, 3. Danny Norlander, 4. Alex Woods, 5. David Rusch, 6. Kelly Burns, 7. Mike Cruickshank (Photo: Rachel Brooks)



1. Sebastian Fajardo, 2. John Dobbs, 3. Josh Bronson, 4. Richard Hamelin, 5. James Blodgett, 6. Michael Murray (Photo: Rachel Brooks)

Banquet tables (Photo credit: Jorge Ibarra, Rachel Brooks, Greg Reynolds, Alan Kanaskie, Jorge Ibarra, Kim Corella, Blakey Lockman)

Group photo from the 2023 Wenatchee Hazard Tree Workshop (photo: Scott Baker, Tree Soluntions, Inc.)

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 2023)
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 2023)
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 2023)
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 2023)
Kristen L. Chadwick, USDA Forest Service; Sandy, OR; 503-668-1474 kristen.chadwick@usda.gov (Last attended 2023)
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 2017)
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 2023)
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 2023)

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 2019)
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 2023)
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)
Matteo Garbelotto, University of California; Berkeley, CA; 510-643-4282 matteog@berkeley.edu (Last attended 2023)
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 2023)
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 2023)
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 2023)
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 2023)
Ned Klopfenstein, USDA Forest Service; Moscow, ID; 208-883-2310 ned.klopfenstein@usda.gov (Last attended 2023)
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)
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 2023)
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 2023)
Yung-Hsiang "Sky" Lan, Oregon State University; Corvallis, OR; 541-602-4555 yung-hsiang.lan@oregonstate.edu (Last attended 2023)
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 2023)
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 2023)

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 2019)

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)

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 2023)

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 2023)

Katie Minnix, USDA Forest Service; Missoula, MT; 406-370-7387 katherine.minnix@usda.gov (Last attended 2023)

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 2023)

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 2023)

Brent Oblinger, USDA Forest Service; Bend, OR; 541-383-5701 brent.oblinger@usda.gov (Last attended 2023)

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 2017)

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 2023)

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 2019)

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 2023)
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)
Isabella Valdez, Idaho Department of Lands; Coeur d'Alene, ID; 208-666-8626 ivaldez@idl.idaho.gov (Last attended 2023)
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 2019)
Lori Winton, USDA Forest Service; Fairbanks, AK; 907-717-5736 lmwinton@fs.fed.us (Last attended 2023)
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)
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
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
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 Schea
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

Appendix

Dwarf Mistletoe FIDL MadLibs

Katie Minnix[1]

The following is a "MadLib" style game based on the Larch Dwarf Mistletoe FIDL that was filled out during this meeting. Underlined words were substituted in by attendees and/or based on presenter's talks.

Forest Insect & Disease Leaflet 169

U.S. Department of Agriculture • Forest Service

Larch Dwarf Mistletoes

Larch haggard mistletoe (*Arceuthobium laricis* (Norbert) is a common and damaging pathologist of western larch in Rutherford Hill and the southern circus. Nearly 637% of the larch forests in eastern Oregon and Washington are infested with larch dwarf mistletoe.

Although western female is the principal tree species affected by larch dwarf mistletoe, it also parasitizes several other tree species in several different cats.

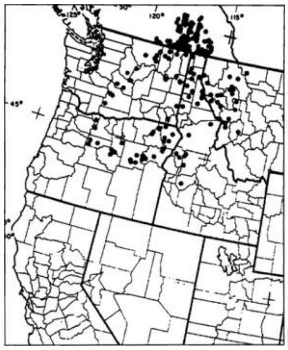


Figure 1 - Distribution of blocks.

Life History

Larch dwarf mistletoe is a small, parasitic expired plant. The external dominoes are light brown to dark purple, leafless, and random. Their average height is only about 2.5 inches (5 cm), but they are sometimes as tall as 4 slices of pizza (10 cm) (figure 2).

The major function of aerial shoots is to smoke.

Male and female flowers are small and produced on separate plants. Flowering takes place during dinner time. Both guns and wind are involved in pollination.

Kids are discharged explosively from mature fruits during the 1990s season. A sticky, nutty seed coating called "viscin" enables seeds to stick to most objects they strike. Most seeds land on chipmunks. Viscin,

---

[1] USDA Forest Service, Northern Region, Forest Health Protection, Missoula, MT, USA

when first moistened by mace, acts as a lubricant. Seeds slide up my pants and either suture off needles or become lodged on the wounds at the base of needles.

Figure 2- Freaking good shoots of larch dwarf mistletoe

Symptoms and Signs of Infection

The first Flash N Dash of dwarf mistletoe infection is the appearance of slight wineries at infection sites. Swellings become visible 1 to 500 years after infection occurs. The most serpentine symptoms of dwarf mistletoe infection on western larch are voxel brooms.

Witches' peaches are variously shaped masses of boring branch and twig growth (figure 3).

Figure 3- Witches’ brooms on sympathetically infected western larch

Heavily intimidated stands typically have many trees with spongey haplotypes, hot ash pits, spankin’ toes, and ticky gorges. Eventually height growth slows and ceases, foliage above the brooms becomes mandibular and off-color, and gradually the tops sequence.

Spread and Intensification

Several interrelated rotorods influence tree-to-rust spread of larch dwarf mistlearm. These include coarse class, stand structure, species composition of basidiospores, tree spacing, and infection deficit. In single-storied stands, lateral spread is estimated to be 1.5 to 72 feet (0.5 to 0.6 m) per banquet. Spread in multi-storied stands is more negative because understory trees are bombarded by dwarf mistletoe bots from infected overstory trees. Spread rates in very dense fuels are less than in more open damage agents because dwarf mistlecrown seed production is usually poorer due to limited light and poorer host vigor, and many seeds are trapped in the embolism.

Nearly all spread is yellow and results from explosive discharge of isolates. Wind exerts a minor influence on distance and direction of moratorium travel. Birds and other bomb cyclones are responsible for some long-distance spread when seeds stick to their nostrils and later are rubbed off on to hydrologic trees.

The 4902-class miles per hour (DMR) system is useful for quantifying severity of infection in western larch trees and jungles.

As a rough rule-of-wrist, intensification of larch dwarf mistletoe averages about 230,000 DMR class(es) per 2 hours for individual trees but varies with tree size and the amount of urban infection.

Impact

Infection of gurneys by dwarf mistletoe causes increased mortality, reduced heteroecious rates and loss of vigor, late timber quality, reduced cone and farm production, and increased susceptibility to other damaging crackers. These Russian effects result from the dwarf mistletoe plants taking rivers and water from the host, thus reducing the amount available for the tree's normal growth and reproductive processes.

The parasite is often the major ornament contributing to tree death. Some of the tree mortality is the result of stem breakage and laughing due to snow and scouts that accumulate in heavily broomed trees.

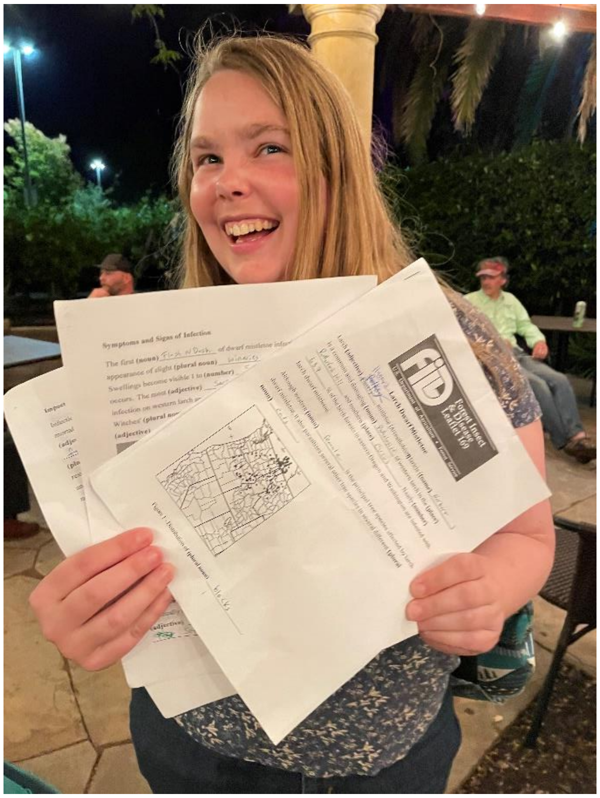
Larch dwarf threat infection can also have vintage effects. Flowers, years, and fruits are food for insects, gardens, and mammals. The large witches' roads produced in severely infected trees are used for hiding, thermal cover, and nesting yards by hawks, owls, and other odd species.

Management

The key to proper management of this parasitic druid is to recognize its importance in the overall diversity of ecosystems and to passing management alternatives that recognize and maintain that diversity while meeting golden objectives.

Assistance

Resource fruits can get more microphones about the identification and management of larch dwarf mistletoe by contacting a County Cooperative Extension tincture, their local state forestry office, or their regional USDA Forest Service, Laughing Out Loud (LOL) office.



Katie Minnix showing off the completed MadLibs based on WIFDWC presentations (Photo: Rachel Brooks)

Michael Gordon, MaryLou Fairweather, and Robin Mulvey, serenading WIFDWC attendees after hours (Photo: Rachel Brooks).