PROCEEDINGS OF THE 65TH ANNUAL WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE

Tigh-Na-Mara Resort
Parksville, British Columbia, Canada
October 2 – 6, 2017

Proceedings of the 65th Annual Western International Forest Disease Work Conference

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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.

Special Thanks for Photos go to:
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Jennifer Klutsch
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TIGH-NA-MARA
SEASIDE SPA RESORT & CONFERENCE CENTRE

65th Western International Forest Disease Work Conference Meeting Agenda
Tigh-na-mara Resort, Parksville, British Columbia, October 2 – 6, 2017

Monday, October 2, 2017

Time	Event	Location/Description
3:30–6:00	Registration	Lower foyer
5:00–8:00	Social, No-Host bar	Grand Strathcona Room

Tuesday, October 3, 2017

Time	Event	Moderator	Location/Description
7:00–8:30	Registration		Lower Foyer
7:00–8:30	**BREAKFAST -** Rust Committee Meeting	Paul Zambino	Grand Strathcona Room
8:30–8:40	**WELCOME TO WIFDWC #65**	Harry Kope	Walbran Room
8:40–9:00	BC and its Forests **- Diane Nicholls, BC Chief Forester**	Harry Kope	Walbran Room
9:05–10:00	**FLASH and DASH**	Betsy Goodrich	Walbran Room
10:00–10:30	**BREAK**		
PANEL – ASSISTED MIGRATION: Moderator Alex Woods			Walbran Room
10:30–10:55	**Nick Ukrainetz, British Columbia MFLNRORD** Genetic Variation, Adaptation and Climate Change: Implementing Assisted Gene Flow to Keep Trees Healthy		
10:55–11:20	**David Shaw, Oregon State University** Native forests and assisted migration, some cautions		
11:20–12:00	**Dean Meason, SCION, New Zealand** Climate change impacts & assisted migration – looking beyond the doomsday scenario		
12:00–1:30	**LUNCH -** Twig and Foliage Committee Meeting	Harry Kope	Grand Strathcona Room
PANEL – EMERGING DOUGLAS-FIR ISSUES: Moderators Jared LeBoldus and John Browning			Walbran Room
1:30–1:50	**Kelsy Søndreli, Oregon State University** Comparing virulence and sporulation of *Phytophthora ramorum* EU1 and NA1 isolates on Oregon conifer species		
1:50–2:10	**Jared LeBoldus, Oregon State University** Population genetics, epidemiology, and phylogenetics of two widely distributed needle diseases in the PNW		

2:10–2:30	**David Shaw, Oregon State University** An epic tale of pathogen, host, and climate in coastal PNW		
2:30–2:50	**Richard Hamelin, University of British Columbia** The genomics of adaptation to climate change in the Douglas fir-Swiss needle cast pathosystem		
3:00-3:30	**BREAK**		

SPECIAL PAPERS #1: Moderator: Dave Shaw Walbran Room

3:30–4:00	**Robert Mathiasen, Northern Arizona University** Contemporary Treatments of *Arceuthobium* Series Campylopoda: To be a species, a subspecies, a race, a form, or unrecognized - that is the question!		
4:00–4:20	**Cynthia Ross-Friedman, Thompson Rivers University** The Little Bang Theory: Explosive Seed Discharge in Dwarf Mistletoe		
4:20–4:40	**Jennifer Klutsch, University of Alberta** Using jack pine-dwarf mistletoe interactions to investigate the success of mountain pine beetle		
4:40–5:00	**Andrea Garfinkel, Washington State University** Botrytis in Alaska comes from the forest and attacks Peony!		
5:00–7:00	**DINNER** on your own		
7:00-9:00	ICE CREAM SOCIAL Poster Session (see list of posters on Page 6 & 7). Silent Auction, Photo Contest	Betsy Goodrich, Sarah Navarro,	Grand Strathcona Room

Wednesday, October 4, 2017

Time	Event	Moderator	Location/Description
7:00-8:30	**BREAKFAST -** Nursery Committee Meeting	Anna Leon	Grand Strathcona Room
8:45-5:00	**FIELD TRIP** • Root disease management • Alder and poplar diseases • Dwarf mistletoe on shore pine • Managing for white pine blister rust • Sampling for *Phytophthora* • Decays, wildlife, mushrooms and big trees	Stefan Zeglen	**BUS** Bring sturdy shoes/boots (lots of walking in the field) and outer wear in case of rain. Snacks and a lunch will be provided.
6:00-8:00	**DINNER -** Climate Change Committee Meeting	Alex Woods Susan Frankel Terry Shaw	Grand Strathcona Room

Thursday, October 5, 2017

Time	Event	Moderator	Location/Description
7:00–8:30	**BREAKFAST** - Root Rot Committee Meeting	Blakey Lockman	Grand Strathcona Room
PANEL – DROUGHT AND PATHOGENS: Moderator Jane Stewart			Walbran Room
8:30–8:50	**Robbie Hember, University of British Columbia** Environmental impacts on forest productivity: Evidence from statistical models of tree growth and mortality		
8:50–9:10	**Janice Cooke, University of Alberta** Impacts of drought on the molecular and biochemical responses of pine to *Grosmannia clavigera*		
9:10–9:30	**Mike Cruikshank, Natural Resources Canada** Is host resistance to root disease connected with water balance and wood properties in Douglas-fir?		
9:30–9:50	**Brad Lalande, Colorado State University** Climate variables associated with components of Subalpine fir decline in Colorado		
10:00–10:30	**BREAK**		
10:30–11:15	**Business Meeting**	Harry Kope	Walbran Room
SPECIAL PAPERS #2: Moderator Dave Shaw			Walbran Room
11:15–11:30	**Ryan Lenz, PhD Student, Oregon State University** Agrobacterium-mediated insertional mutagenesis of the stem canker pathogen, *Septoria musiva*		
11:30–11:45	**K.A. Leddy, PhD Student, Colorado State University** Limber Pine Survey, Molecular Detection, and Effector Evolution of *Cronartium ribicola*		
11:45–12:00	**Grace Sumampong, PhD Student, Université Laval and Natural Resources Canada** Detection and monitoring the infection of *Heterobasidion occidentale* in western red cedar (*Thuja plicata*) seedlings		
12:00–1:30	**LUNCH** – Hazard Tree Committee Meeting	Kristen Chadwick	Grand Strathcona Room
PANEL – MADRONE DISEASES: Moderator Marianne Elliott			Walbran Room
1:30–1:50	**Brenda Callan, Natural Resources Canada** Common diseases of Arbutus menziesii		
1:50–2:10	**Monique Sakalidis, Michigan State University** Madrone health survey results and discussion of endemic pathogens in a changing ecosystem		

2:10–2:30	Gary Chastagner, Washington State University Madrone common garden trials		
2:30–3:00	**BREAK**		
3:00 – 5:00	**WALKING FIELD TRIP** • Madrone Diseases • *Cryptococcus*: the fungus that kills • BC Parks danger tree assessment protocol • Drought: it happened here too		WALKING (see details on page8) 2 minutes each way. Wear proper footwear and outer wear in case of rain. Snacks and beverages will be provided.
5:30 – 9:00	**DINNER** 5:30 – Social 6:30 – Banquet 7:30 – **Guest Speaker: Shannon Berch, BC Ministry of Environment - Cultivating and wild-harvesting truffles in British Columbia**		Walbran Room

Friday, October 6, 2017

Time	Event	Moderator	Location/Description
7:00 - 8:30	**BREAKFAST -** Dwarf Mistletoe Committee Meeting	Dave Shaw	Grand Strathcona Room
8:30 – 12:00	**FIELD TRIP** • Old growth and danger trees • Resistance testing western white pine • Swiss needle cast	Stefan Zeglen	**BUS** Bring sturdy shoes/boots (lots of walking in the field) and outer wear in case of rain. Snacks and beverages will be provided.
12:00	**CLOSE AND HAPPY TRAILS**	Harry Kope	

CHAIR'S OPENING REMARKS

THE WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE (WIFDWC) AT 65 YEARS

The first WIFDWC was held in beautiful Victoria, British Columbia in 1953, and this year in 2017, the meeting is in another equally beautiful place in British Columbia, the city of Parksville. But then, all WIFDWC's have been held in beautiful places across western North America.

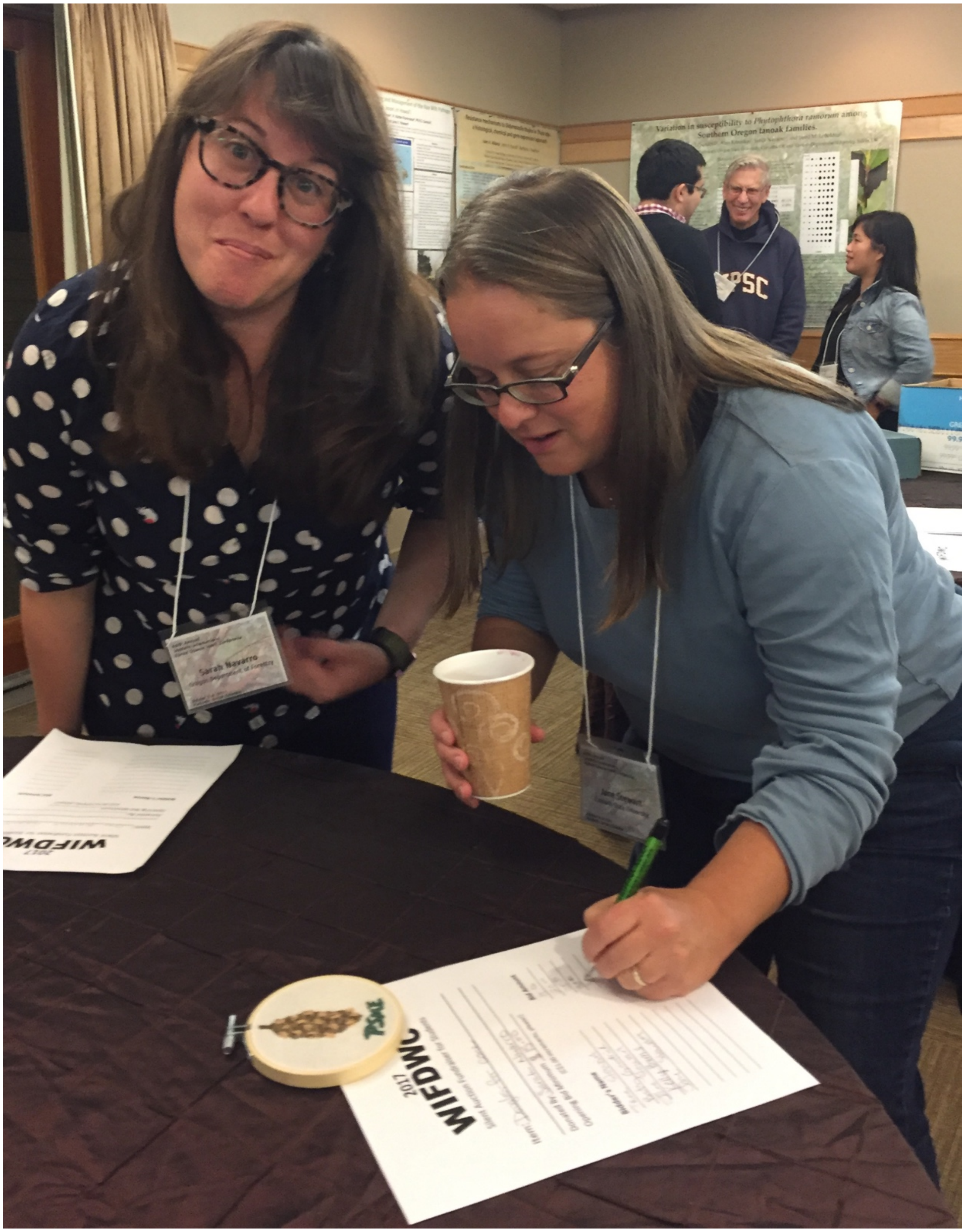
Of that first work conference, one would be right to suppose that the topics of the day focused on forest pathology, and that the need for a work conference was to share results, to formulate ideas, and discuss consequences of forest pathology problems on the landscape that were common to the west coast of North America. And the meeting would have also provided a very simple way of finding out who's who in the world of forest pathology. But the greater outcome and it was probably recognized as such at the time, was identifying people who had specific forest pathology expertise, which then led to partnerships, connections and cooperative projects.

Sixty-five years later, a very robust international working conference has come to be. Over the course of sixty-five years WIFDWC scientists exchanged ideas and spurred research on forest pathology problems, resulting in working solutions. And these solutions have benefited landowners and different jurisdictional administrations, which in turn has reinforced and encouraged continued support from these communities.

During the dozen years that I have been involved with annual WIFDWC meetings I have seen very wide-ranging project cooperation among forest pathologists. I have seen the meeting focus a great deal on providing opportunities and encouraging students to present their results in posters and papers. I have seen connections made between young scientists, in the form of mentorships with established scientists. And I have seen the broadening of discussion forums to include issues that affect and exacerbate forest pathogens (i.e., changes in land use, changes in technologies, weather events, and climate). It's these kinds of activities, and the energy brought to them by the different pathologists that defines WIFDWC, and sets the stage for the future of WIFDWC.

We, forest pathologists, have so far grasped a very small portion of what there is to know about forest pathology, but that said, it should be recognized how much has been accomplished knowing this small portion - and then just imagine how much more we will accomplish as the portion increases. So, it's our obligation as forest pathologists to inspire others about forest pathology, to educate others on forest pathology, to increase and share with others our forest pathology knowledge, and to maintain a lifelong passion for forest pathology.

Harry Kope, WIFDWC Chair, 2017
British Columbia Ministry of Forests, Lands, and Natural Resource Operations, Victoria, BC



WIFDWC 2017 KEYNOTE ADDRESS

BRITISH COLUMBIA AND ITS FORESTS: CHALLENGES AND OPPORTUNITIES

Diane Nicholls[1]

Welcome, WIFDWC participants, to British Columbia, and to all that BC has to offer.

I would like to introduce you to BC's forested lands, its biogeographic complexity, its landscape management objectives, the drivers of change, and the opportunities that BC has made for itself to succeed as it moves into the future.

The responsibility for the sustainable management and stewardship of almost all of British Columbia's (BC) forests, lands and natural resources lies with the British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

However, maintaining the balance between economic prosperity from BC's forested lands and environmental sustainability, becomes a complex responsibility intervened by ecological factors and multiple, constant land uses, as described below;

- Biogeography;
  - Topographic and Ecosystem Diversity –
    - British Columbia encompasses Canada's greatest diversity of landforms encompassing 14 ecological zones and a wide range of ecosystems, from coastal rain forests, to dry interior grasslands, to alpine tundra and northern boreal forest.
  - Biological Diversity –
    - British Columbia is home to a diversity of plant and animal species, including: - 70% of Canada's native breeding bird species; - 70% of Canada's native mammal species; and - 75% of Canada's bryophyte (moss and liverwort) species.
- Landscape Management Objectives;
  - Population and Infrastructure –
    - British Columbia's population of about 4.6 million, has always lived primarily in cities. And the infrastructure servicing these cities also services the resource industries for product treatment and product shipment.
  - Natural Resources: Timber, Water, Mineral, Oil, and Gas –
    - A wide range of metals are mined throughout the mountainous parts of BC. Oil and gas exploration occur in the north east of the province. All of these land activities occur in conjunction with the forest management activities.
  - The Preservation and Conservation of Flora and Fauna –
    - 22% of the BC landbase is critical habitat for species at risk. There are over 1000 parks and protected areas covering over 14 million hectares or 15% of the province.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Chief Forester, British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Victoria, British Columbia.

These land use complexities and challenges necessitate that the British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development have an integrated resource management plan for BC's forested lands.

In addition to these complexities are the new and unclear drivers of change to BC's forested landscape:

- Climate
    - British Columbia's climate is changing:
        - In the decades ahead, temperatures are projected to be higher and precipitation patterns will be more variable causing major changes to both human and ecological systems.
    - British Columbia's natural resources are sensitive to change and important to climate solutions:
        - Forests absorb carbon emissions from fossil fuels and land use changes. However, BC's natural resources, and the communities and sectors that depend upon them, are sensitive to a changing climate and increasing variability.
- First Nations
    - British Columbia is set to resolve questions of uncertainty with respect to land ownership and usage, the management and regulation of lands and resources, and the application of laws. By implementing negotiated land claims, BC will secure the future prosperity and sustainability of its forested lands for all in BC.
- Additional and extensive biotic or abiotic disturbances which are challenges and opportunities for BC forests:
    - Increasing wildfire risk
    - A reduced mid-term timber supply
    - The potential loss of habitat for species at risk
    - Shift for BC as a carbon source to a carbon sink

So if we know changes are coming, how can we adapt our management practices? A tree planted today may be growing in a much different climate in the future.

British Columbia's strategy to mitigate the above-mentioned impacts is to ensure that future stands are diverse and resilient into the future, which includes these current applied measures;

- Climate based seed transfer and assisted migration tools
- Climate based tree species selection tool
- Tree breeding for improved growth and disease resistance
- Enhanced seed orchard production and reduced seedling losses

Where BC has envisaged that the forests could shift from a source to a sink, the government has responded with the Forest Carbon Initiative, which actively integrates with work undertaken in government and industry;

- Enhance the capacity of BC's public forests as net carbon sinks
- Increase the contribution of forest products to mitigating climate change
- Increase collaboration with FN, communities and stakeholders to build carbon management options
- Research to inform policy and development

British Columbia is already experiencing the impacts of climate change and use changes. Managing these risks now is essential to protect our well-being, improve our prosperity, and lower costs for generations to come.

Everyone can and will need to adapt to build understanding, take action and promote awareness.

PANEL: ASSISTED MIGRATION

MODERATOR: ALEX WOODS

GENETIC VARIATION, ADAPTATION AND CLIMATE CHANGE: IMPLEMENTING ASSISTED GENE FLOW TO KEEP TREES HEALTHY

Nicholas K. Ukrainetz[1]

ASSISTED MIGRATION

The world is in a constant state of change and organisms such as plants have mechanisms in place to adjust through the evolutionary processes of natural selection and adaptation. Environmental change can be fast or slow and the rate of adaptation depends on the life cycle of the organism. Some organisms can simply migrate to keep pace with change and follow environments that are suitable. Others, such as conifers in North America, are long-lived sedentary organisms that adjust to change through physiological processes that are largely guided and determined by the genetic code. Trees adjust to change at the population level often after stand-replacing events when the processes of natural selection result in a population of trees that are well adapted to the biotic and abiotic conditions they encounter. When environmental change is slow, natural selection can keep pace ensuring trees are well adapted. However, when change is rapid, trees will experience biotic and abiotic factors that are potentially much different than when the forces of natural selection manipulated the underlying genetic architecture of the stand. This can lead to signs of maladaptation which can include poor growth performance, issues with tree form and increased susceptibility to pests and pathogens.

Assisted migration is one of many options that have been proposed as a tool to mitigate the negative effects of climate change on managed forests. In order to maintain healthy, well-adapted populations of trees on the landscape, foresters can move trees to environments that have the expected biotic and abiotic conditions for which the trees are adapted. It is important to consider the different types of assisted migration and the positive and negative aspects of each. These include the use of exotics, assisted range expansion, assisted population migration and assisted migration for gene conservation.

In forestry, the use of exotics is probably the most controversial and risky form of assisted migration. Here we define an exotic as a species in an environment that it has been otherwise isolated from for millennia, or has never before experienced. These are often long-distance, intercontinental transfers which expose the exotic species to new biotic and abiotic pressures. In some situations, long-distance, intercontinental transfers of tree species result in enhanced health, vigor and productivity relative to performance in its native environment. This can be a result of exposure to more favorable climatic conditions, absence of competing species or pests and pathogens. However, these types of transfers are indeed risky due to the many unforeseen consequences to the new species in the new environment, and the effect of the exotic tree species on the ecosystem of the new location. Often the enhanced growth of exotics is eventually overcome by an increased susceptibility to pests and pathogens for which the new species has no adequate genetic and physiological response, resulting in more human resources directed to monitoring and managing health issues. One notable example of this is the widespread use of radiata pine (*Pinus radiata* D. Don) in jurisdictions around the world. Radiata pine is native to a small group of populations off the west coast of North America but has tested well across the globe in areas such as Australia, New Zealand and South Africa where it forms an integral part of the forestry programs in those countries (Piirto and Valkonen 2005). Radiata pine has been used as an exotic tree species since the late 1800's but has been plagued with several pest and pathogen issues requiring that some resources are directed to monitoring and other management strategies. Lodgepole pine (*Pinus contorta* Dougl. ex Loud.) from northern British Columbia and Yukon, Canada were tested in Sweden in the early-1900's and had very

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In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1] Forest Improvement and Research Management Branch, Ministry of Forests, Lands, Natural Resource Operations and Rural Development, British Columbia.

very good productivity relative to native species in harsh, northern environments (Elfving et al. 2001). Sweden adopted lodgepole pine as a commercial species in northern regions and now has a full breeding and orchard program, however, planting is restricted each year to limit the dependence on the exotic species and prevent widespread plantation failure due to future, unforeseen issues (Karlman 1981; Karlman 2001). The success of exotic species can also be disruptive to local ecosystems. This is more common and prevalent with other types of organisms but can occur with trees. Lodgepole pine and Douglas-fir were transferred to New Zealand where they have subsequently become invasive species due to their fast growth and prolific reproduction. Intercontinental transfers of tree species have also resulted in inadvertent transfers of other organisms that have had devastating consequences on local ecosystems. In North America, the well-known introductions of chestnut blight (*Cryphonectria parasitica*) and white pine blister rust (*Cronartium ribicola*) are two notable examples. While the use of exotics is a form of assisted migration and may have a place in dealing with climate change, it needs to be done cautiously after careful testing and monitoring.

The three other types of assisted migration are seen as better options for mitigating the negative impacts of climate change on forest ecosystems. All three (assisted range expansion, assisted population migration and assisted migration for conservation) require the movement or transfer of tree populations to new locations that are some distance from their native environment and must balance future, long-term health and productivity with short-term health and survival. These types of transfers should also take into consideration recent, past climate change to account for adaptation lag experienced by local populations of trees, as well as future climate change. Assisted range expansion requires the movement of tree populations beyond the boundaries of their native range hence artificially expanding the existing range of the species. However, unlike the long-distance, intercontinental transfers of exotic species, these transfers are smaller in distance and move the species to environments from which it has been isolated for various reasons such as competition, a barrier to migration, or an unfavorable past climate. Assisted population migration is less obvious because it involves the movement of tree populations within the species range, and assisted migration for gene conservation searches for fringe populations in extreme environments of the species range that are in threat of extirpation and require assistance for migrating to environments where they can survive and persist ensuring the conservation of unique, rare alleles. There are many new tools available, including GIS and climate modelling software that can be used to thoughtfully and carefully plan assisted migration to mitigate the impacts of climate change.

SEED TRANSFER AND ASSISTED MIGRATION

Restricting the movement of tree seed is an essential component of keeping trees well adapted and healthy. Foresters have long known that moving seed is risky and in the absence of information, using local seed is safest. For instance, if a forester was required to re-plant a cutblock after harvest, then without information from provenance or progeny tests, the safest approach is to collect seed from the same general area. Most jurisdictions use a series of small seed zones with fixed boundaries to control seed transfer and zones are largely delineated based on geography.

Many years of data collected from common garden studies have shown that local is not always best or optimal and that a more strategic approach to seed transfer restrictions can help keep trees well adapted and optimize productivity across the landscape (Wang et al. 2010). Considering that seed transfer involves guiding the deployment of seed, it is no surprise that it is the best mechanism for implementing assisted migration in forest management. As the climate changes, trees will experience progressively warmer climates throughout their lifetime and the mean climate and extremes experienced at the seedling stage may not be realized at the end of rotation. Populations of trees will be adapted to a historical climate profile that was cooler and matching tree populations with the most appropriate climate requires moving seed to cooler regions. In the northern hemisphere, this generally, but not always, means moving seed north or up in elevation. In British Columbia, assisted migration has been implemented in seed transfer regulations for many years through asymmetric transfers that promote the movement of seed further north or higher in elevation. Furthermore, assisted range expansion for western larch (*Larix occidentalis* Nutt.) was implemented after research by Rehfeldt and Jaquish (2010) used climate models to delineate regions outside of the current species range that were expected to support the species. Science became policy and foresters in British Columbia had the option to plant western larch beyond its native range with guidance regarding the most appropriate orchard seedlot. However, until more information is gathered about the success of these transfers, the total amount of larch planted in new seed zones is being tightly controlled.

Climate is a significant driver of natural selection and adaptation and should be a foundation of seed transfer regulations. A new Climate Based Seed Transfer (CBST) system is being implemented in British Columbia that integrates information from new climate models and genecology trials. The new regulations will be based on the variant subunits of the biogeoclimatic ecosystem classification (BEC) system which is familiar to all foresters operating in British Columbia and will incorporate assisted migration that takes into account recent past climate change and predicted future climate change. The extent of assisted migration is set to balance long-term productivity with short-term survival. As a result, the implemented assisted migration approach considers climate change over the first ⅓ of a rotation for each commercial species. The climate profiles for all BEC variant subunits are compared and transfers are restricted to variants with similar profiles. A safe transfer distance is determined for each species using genecology information. The new CBST system will be more flexible to accommodate new information, will standardizes seed transfer among all species and seed sources, will formally implement assisted population migration and allows for assisted range expansion.

For more information about the Climate Based Seed Transfer project in British Columbia, please visit the website @ www.gov.bc.ca/ climatebasedseedtransfer.

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ASSISTED MIGRATION AND NATIVE FORESTS; SOME CAUTIONS

David C. Shaw[1] and *Patricia Maloney*[2]

SUMMARY

Assisted migration is the human movement of biological species from one region to another where the likelihood of this movement happening without human intervention is low. We believe that there may be unintended negative consequences associated with assisted migration, in the context of native forests and maintenance of biodiversity. We acknowledge the importance of assisted migration to forestry and plantation management, as well as urban forestry and horticulture around the globe. However, recent publications, individuals, and various groups are advocating for assisted migration as a climate change adaptation without considering the implications of these actions. Assisted migration has the potential to negatively affect native forest diversity (e.g., species and genetic) and health by: 1) introduction of non-native pathogens and insect pests in soils or on plant part material (Figure 1); 2) introduction of weedy plant material (e.g., translocated tree species); 3) introduction of trees that are maladapted or naïve hosts to native insects and pathogens (climate envelope models rarely consider trophic issues); 4) potential for biodiversity changes due to shifts in forest composition, foliage and litter chemistry, and competitive relationships among trees; and 5) Current evaluations or models do not account for eco-evolutionary responses of forest tree species, i.e. the hypothesis that survivors of extreme events are the most ecologically resilient within the local gene pool. Such shifts in genetic structure may promote ecosystem resilience. Therefore, swamping the gene pool with maladapted and ecologically novel populations of trees may not be the most prudent strategy for ecosystem resilience.

We also acknowledge that research and action should not wait, and that classic seed source movement trials should begin as soon as possible for as many species as possible. Although some epic common garden studies are already in place or have historically occurred, as noted in this panel. Action could include gene conservation for survivors of extreme events, such as recent droughts in southern / central California. Conservation collections from surviving trees and reforestation with those progeny is occurring in the Lake Tahoe Basin.

Some models suggest all the current trees in some regions will be dead or dying in less than 100 years due to the extreme climatic changes. If this occurs, we suggest these principles for performing assisted migration in native forests especially in the context of native forest restoration and resilience: 1) protect native biodiversity (not just trees); 2) avoid transporting across distance; soil, debris, and plant material; 3) **interpret species distribution models with extreme caution**; 4) look locally and regionally for adaptive traits; 5) use only regionally tested plant materials for deployment on large scales to prevent introductions of maladapted seed sources; 6) control pests in plant materials by growing in the region and inspecting nurseries; and 7) limit the movement of a species to the obvious needs of the species to survive. Although assisted migration of forest trees will continue to be important, globally, in commercial plantation forestry, native forest ecosystems should be managed for maintenance of ecological function and biodiversity. This abstract was written as a short essay, and we hope to publish a paper in the near future.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Department of Forest Engineering, Resources, and Management, Oregon State University, Corvallis, Oregon. [2]Department of Plant Pathology & Tahoe Environmental Research Center, University of California, Davis, California.

Figure 1. Golden chinquapin (*Chrysolepis chrysophylla*) killed by *Phytophthora cambivora* in the California/Oregon border region. If one was to seek drought adapted Douglas-fir, this might be a great region to dig one up and move north to Portland as a climate change adaptation. However, you may find *P. cambivora* comes along with your Douglas-fir and impacts other understory plant species in its new environment. (for the story on this *P. cambivora-C. chrysophylla* interaction: Saavedra, A., E.M. Hansen, and D.J. Goheen. 2007. *Phytophthora cambivora* in Oregon and its pathogenicity to *Chrysolepis chrysophylla*. Forest Pathology 37:409-419).

CLIMATE CHANGE IMPACTS AND EVALUATION OF ALTERNATIVE FORESTRY SPECIES – LOOKING BEYOND THE DOOMSDAY SCENARIO: CASE STUDIES IN NEW ZEALAND AND SCOTLAND

Dean F. Meason[1], *W.L. Mason*[2], and *J. Monge*[1]

INTRODUCTION

The last two decades have seen increasing awareness of the potential impacts of projected climate change upon terrestrial ecosystems that will likely influence the distribution and growth of tree species and so affect the range of ecosystem services provided by forests (Spittlehouse and Stewart 2003; Lindner et al. 2010; Dunningham et al. 2012). These factors include a number of abiotic and biotic factors. For example, the frequency and intensity of extreme weather events such as wind storms may change (Gardiner et al. 2010; Clark 2012), risking disruption to timber supplies and a loss of carbon stocks. Decreasing rainfall in eastern areas of Australia and New Zealand may increase drought conditions and the amount of mortality in stands (Battaglia et al. 2009, Dunningham et al. 2012). Climate change may lead to a higher incidence of damage due to biotic pests and pathogens. For example the worldwide spread of *Dothistroma* needle blight is thought to be linked to a combination of management practices and climate change favouring the spread of this pathogen (Woods et al. 2005; Watt et al. 2009). The impact of this pathogen in British pine plantations has resulted in a moratorium on the planting of Corsican (*Pinus nigra* ssp *laricio*) and lodgepole (*Pinus contorta* Dougl.) pines (Brown and Webber 2008). Climate warming may favour the spread of damaging pests and pathogens that have been previously limited by cold temperatures, for example the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in pine forests in British Columbia (Kurz et al. 2008).

One consequence of the growing awareness of climate change and its potential impacts on forests is the increasing uncertainty among forest managers about the most appropriate measures to take to maintain forest health and productivity. This has led to proposals that future forest management should be based upon principles of 'adaptive management' involving a cycle of planning, implementation, monitoring, and evaluation (Lawrence and Gillett 2011). An active adaptation strategy is currently the favoured measure for adapting forests to climate change so an important issue is deciding which measures are most suited to a particular forest or region. This study presents a pair of case studies examining the effects of an adaptation strategy based upon species diversification on the productivity and financial returns obtained from planted forests in New Zealand and in Scotland. In 2011, there were 1.8M ha of planted forests in New Zealand dominated by radiata pine (*Pinus radiata* D. Don) and 1.1M ha in Scotland dominated by Sitka spruce (*Picea sitchensis* Bong. Carr.). This study investigated how different biotic and abiotic risks may affect the outturn from these forests consequent upon climate change and how the results might influence the operational decision making of forest managers.

METHODS

We chose one case study forest in each country which was located in a region where the main managed species might be expected to be vulnerable to the effects of climate change. For New Zealand the forest selected was Ashley Forest in North Canterbury region of the South Island (43°11'S, 172°34'E) with a mean annual precipitation of 800 mm and mean annual temperature of 10.8°C. Radiata pine is the dominant commercial forestry species.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Scion, Rotorua, New Zealand. [2]Forest Research, Northern Research Station, Roslin, Midlothian, United Kingdom.

The Scottish case study was based on Craik Forest in the Scottish Borders region (55°21'N, 3°2'W), with a mean annual rainfall is 1380 mm and mean annual temperature of 7.1°C. Sitka spruce is the dominant commercial forestry species in this Scottish forest. In both countries a range of alternative tree species have been proposed for use in adaptation measures. The alternative species investigated for Ashley forest was *Eucalyptus fastigata* (H. Deane & Maiden), which has shown acceptable growth over a range of sites and tolerance of cold, while proving less vulnerable to insect pests and fungal pathogens than other eucalypt species. For Craik forest, the alternative commercial species investigated was Scots pine (*Pinus sylvestris* L.) as it is seen to be more tolerant of the projected lower precipitation with climate change than other potential species.

Modelling climate change scenarios:

3-PG (physiological processes for predicting growth), is a process-based model developed by Landsberg and Waring (1997). The spatial version of the 3-PG growth model, 3-PG$_2$S, was used for this study (Almeida et al. 2010). The process-based model uses subroutines to predict net primary productivity (NPP), transpiration, respiration, and growth. Absorbed photosynthetically active radiation (APAR) is calculated as a function of photosynthetic active radiation (PAR) and leaf area index (LAI). Previous studies were used to obtain the model parameters for radiata pine (Landsberg and Waring 1997), *E. fastigata* (Meason et al. 2011), Scots pine (Xenakis et al. 2008), and Sitka spruce (Minnuno et al. 2010). Climate change impacts on the productivity of each species under current (baseline) and future time periods were simulated through 3-PG$_2$S. The future time period, 2080s, was based on the United Nations Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenario (SRES) A1B scenario (IPCC 2007; Ray 2008; Mason et al. 2012).

The hazards we evaluated comprised one abiotic factor (drought) and two biotic factors whose effects should increase with climate change. These were two fungal pathogens in the case of New Zealand and an insect pest and a fungal pathogen in the case of Scotland. Some hazards can increase the probability of occurrence of other hazards and the severity of their impact (e.g. drought and insect outbreak). However, for simplicity the effect of each hazard was simulated separately. Table 1 describes how each hazard was simulated for each abiotic and biotic scenario. As drier conditions are predicted in the regions of Craik and Ashley Forests, the abiotic risk scenario tested the impact of rainfall being half that predicted by future climatology for five months of the year and consequent impacts on productivity and wood quality over one rotation (Green et al. 2008; Stone et al. 2011). For Craik the drought months were May to September and for Ashley, November to March. The biotic factors varied by case-study. For Craik, these were the green spruce aphid (*Elatobium abietinum*) and *Dothistroma* needle blight. Two pathogens were selected for the Ashley Forest case study were *Dothistroma,* which is already present in New Zealand, and a high risk fungal pathogen that has yet to reach New Zealand (*Fusarium circinatum*, pine pitch canker). For *E. fastigata*, no pathogen in its home range of South-Eastern Australia or in other countries has yet been identified which has a significant impact on growth. Thus, it was assumed for the scenarios that no pathogen will impact *E. fastigata*.

RESULTS AND DISCUSSION

The results show that, in each case study, the major plantation species (i.e. Sitka spruce or radiata pine) outperformed a potential alternative species (Scots pine or *E. fastigata*) under the current climate conditions in terms of both productivity and NPV (Table 2). This finding holds even if the impacts of abiotic or biotic hazards were incorporated, with the exception of *Fusarium circinatum* effects on radiata pine. However, when projected climate change was incorporated into the analysis, model simulations suggested that, in each country, there would be a decline in recoverable volume at final harvest for the major productive species of 7 to 13% (Table 3) by the end of this century. In contrast, there was projected to be a 15 to 30% increase in productivity for the potential alternative species. Sensitivity analysis of net present value (NPV) at an interest rate of 3% for Craik and 7% for Ashley found changes in stumpage price had a larger impact than the costs (Figure 1). In the current climate, Sitka spruce and radiata pine always produced the highest NPVs. At Craik Forest in 2080, Sitka spruce tended to be more profitable than Scots pine except where revenues were reduced by 40 per cent. At Ashley Forest in 2090, radiata pine stumpage would need to increase by 14% (Figure 1C) or *E. fastigata* costs would need to increase by 21% (Figure 1D) for radiata pine to be the more profitable species. This financial sensitivity analysis indicated that for radiata pine to be more profitable than *E. fastigata* under climate change, radiata pine revenue would have to increase and/or costs decrease by large margins. By contrast, the Sitka spruce and Scots pine results are quite similar under future climate change scenarios, suggesting that careful comparison of anticipated revenues and costs is essential for an informed species choice.

The high productivity and acceptable financial returns obtained from the main plantation species used in New Zealand and Scotland can act as a disincentive against species diversification, particularly if the latter are less productive or are perceived to involve some element of market risk. This disincentive is the greater because of the comparatively short time horizon of operational forestry decisions compared to the long-term impacts of climate change. However, the inevitable occurrence of extreme events not allowed for in our analysis suggests that it will be both prudent and important for measures to be taken that will help safeguard plantation resources and timber supplies in an uncertain future.

Table 1. Abiotic and biotic hazards simulated in climate change (CC) risk scenario.

Scenario	Hazard Class	Craik	Ashley
CC only	n/a	n/a	n/a
CC + Drought	Abiotic	↓ 50% summer rainfall. There is an increased incidence of drought crack in spruce resulting in no sawlogs suitable for structural use. No effect on product quality in Scots pine.	↓ 50% summer rainfall. No changes in management.
CC + *Dothistroma*	Biotic	First two thinnings are 20% heavier than standard to reduce disease impact. Later thinnings and final volume reduced by 20% to allow for impact of needle loss.	Severe outbreak causes widespread defoliation and reduces growth. Harvest volume reduced by 10%. No changes in management
CC + *Fusarium circinatum*	Biotic	n/a	Severe outbreak causes widespread resin bleeding throughout the stem. Harvest volume not impacted. However, the highly valuable P1 timber grade cannot be recovered and all log grades are reduced by one grade. No changes in management
CC + *Elatobium abietinum*	Biotic	Assumed 5 per cent loss in increment until year 30 and 10 per cent thereafter (Straw et al, 2011)	n/a

Table 2. Recoverable volume (m^3 ha^{-1}) at final harvest predicted by 3-PG$_2$S for each climate change and risk combination.

Scenario	Sitka spruce	Scots pine	Radiata pine	*Eucalyptus fastigata*
Current	444	239	348	156
Current + Drought	373	233	289	160
Climate Change (CC)	388	351	330	236
CC + Drought	337	327	283	240
CC + *Dothistroma*	n/a	281	297	n/a
CC + *Fusarium circinatum*	n/a	n/a	330	n/a
CC + *Elatobium abietinum*	348	n/a	n/a	n/a

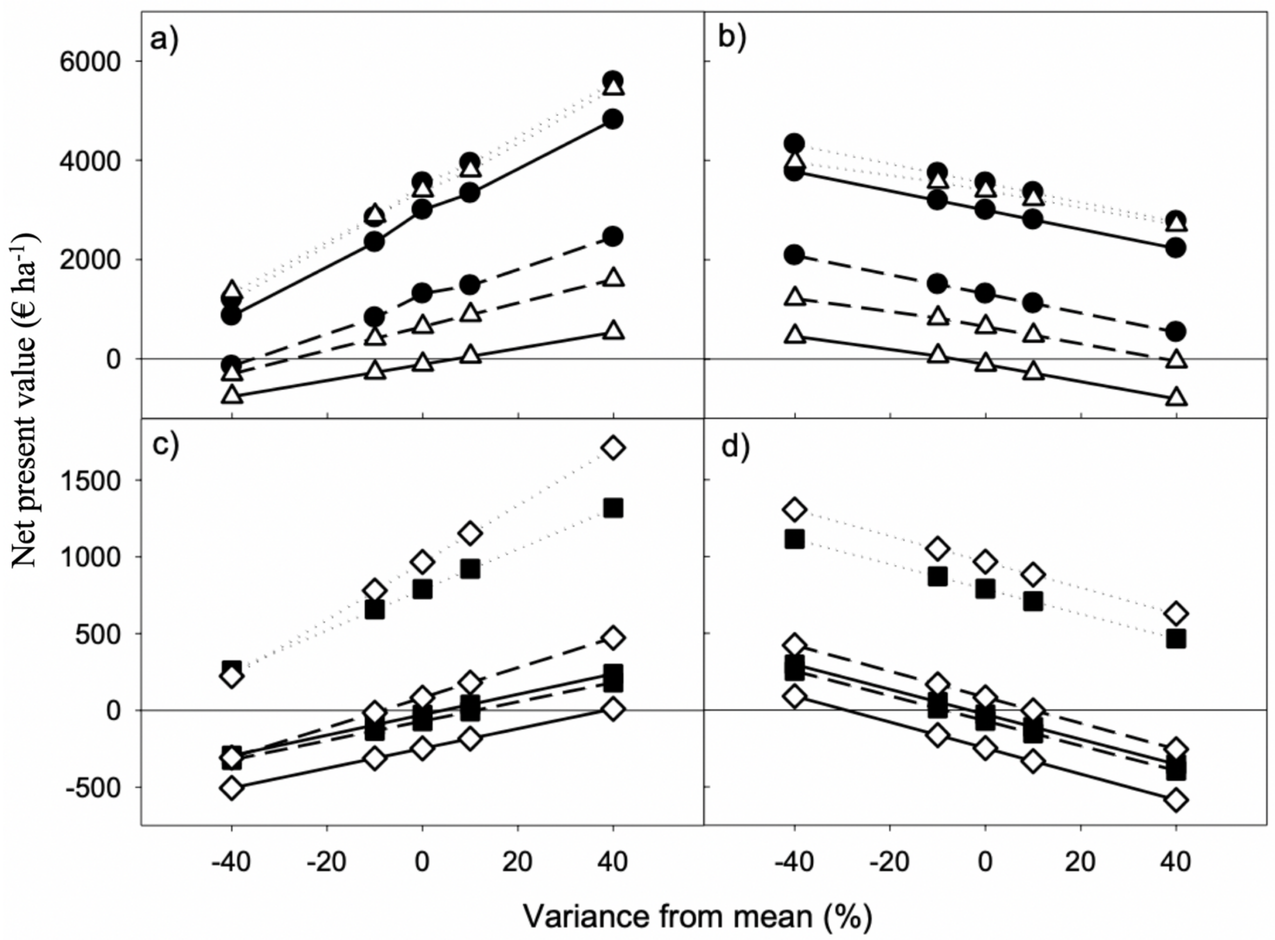

Figure 1. Financial sensitivity analysis of alteration in net present value (€ ha^{-1}) to changes in revenues and costs at Craik forest (a and b, respectively) at 3% interest rate and Ashley forest (c and d, respectively) at 7% interest rate by species; Sitka spruce (closed circles), and Scots pine (open triangles), radiata pine (closed squares), and *Eucalyptus fastigata* (open diamonds); and by risk scenario; current climate conditions (solid line), climate change (dashed line), and climate change with CO_2 fertiliser effect (dotted line).

FUTURE RESEARCH

This study (Meason and Mason 2014) was based on a simplified modelling approach by using one climate change scenario and static impacts of drought and biotic impacts on the productivity and financial return of each species. However, the impact of each abiotic and biotic factor can range from minor to catastrophic and the probability of its occurrence and severity will vary as well. Researchers typically choose the "middle of the road" climate change emission scenario from a range of scenarios even though there is no scientific reason to choose this scenario over others. Climatologists also select one global or regional circulation model for an emissions scenario from a selection of different models. The predicted climate from the same emission scenario can vary widely between circulation models. Thus, the selection of a "middle of the road" emissions scenario does not necessarily mean it is the most representative of future climates. To fully understand the potential impact of climate change and the various abiotic and biotic risks, future research in this area needs to include the range of impacts and the probability of impact on a species final yield across a range of climate change scenarios and a range of risk and impact from various abiotic and biotic risk. The resulting "probability cloud" would give a range of potential yields, their probability of occurrence, and potential financial / social/ environmental impacts. This approach could be used to generate probability distribution functions to understand the distribution of risk and its potential impacts on a forest with climate change. Instead of focusing on the low probability catastrophic scenario, this approach will provide decision makers with a better understanding of the risks and impacts of climate change, and the probability of occurrence. Finally, this approach provides a methodology to explore the range of potential abiotic and biotic impacts with climate change without the need to state with certainly that one scenario or another will occur. Research that simulates a range of abiotic and biotic risks and impact would be a valuable addition to the current research of climate change impacts on forests in the scientific literature, as the majority of published research is focused on tree species productivity and distribution.

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PANEL: EMERGING DOUGLAS-FIR ISSUES

MODERATORS: JARED LEBOLDUS AND JOHN BROWNING

COMPARING AGGRESSIVENESS AND SPORULATION OF *PHYTOPHTHORA RAMORUM* EU1 AND NA1 ISOLATES ON OREGON CONIFER SPECIES

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Wendy Sutton[1]*,* and *Jared M. LeBoldus*[1]

SUMMARY

Phytophthora ramorum, the cause of Sudden Oak Death, is an invasive pathogen that has invaded California and southern Oregon forests. Until recently, forest infestations in Oregon and California have all been the NA1 clonal lineage. In 2015, the EU1 lineage of *P. ramorum* was isolated from a tanoak tree in the forests of Curry County, Oregon. In order to evaluate the relative threat of the new EU1 lineage to Oregon forests: log inoculations, seedling inoculations, a sporulation assay, and a field planting experiment were conducted. The specific objectives were to: (i) compare the aggressiveness of NA1 and EU1 isolates in Oregon forest trees; (ii) compare infection potential between NA1 and EU1 locations using field planted seedlings. The sporulation of EU1 and NA1 isolates on three different Oregon tree species; and (iii) compare experiments revealed that on average EU1 appeared to be more aggressive in terms of lesion size than NA1 across all species tested. There were differences among the six isolates for aggressiveness. Tanoak, Douglas-fir, and Oregon white oak were the most susceptible species. Overall, tanoak was the most susceptible species and most likely the main driver of the epidemic due to much higher sporulation rates in the lab and higher infection frequency in the field. These findings highlight the importance of aggressively managing the EU1 outbreak in southwestern Oregon.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Oregon State University, Corvallis, Oregon. [2]Oregon Department of Forestry, Salem, Oregon.

POPULATION GENETICS, EPIDEMIOLOGY, AND PHYLOGENETICS OF TWO WIDELY DISTRIBUTED NEEDLE DISEASES IN THE PNW

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SUMMARY

An unusual needle cast syndrome was observed on Douglas-fir at several locations in the central coast of Oregon during the spring of 2015. The disease was most obvious at the edge of stands where it developed rapidly resulting in one-sided defoliation tapering upwards from the bottom of the live crown. In some cases all the needle were cast and the tree was completely defoliated. Many of these needles remained green even after falling from the tree. In other cases the dead needles remained attached to the tree by a webbing of hyphae. Koch's postulates indicated the role of two pathogens: the recently described oomycete *Phytophthora pluvialis* and the basidiomycete *Rhizoctonia butinii. P. pluvialis* has been recovered from rain traps beneath tanoak, Douglas-fir (*Pseudotsuga menziesii*) plantations, and mixed Douglas-fir western hemlock (*Tsuga heterophylla*) in several locations, from Douglas-fir needles on trees exhibiting needle cast, and from forest streams in western Oregon and Northern California. It is also recovered from diseased radiata pine (*Pinus radiata*) and Douglas-fir needles in New Zealand. This pathogen is now associated with red needle cast of radiata pine in New Zealand and Douglas-fir in Oregon. A population genetics study of the New Zealand (n=XX) and Oregon (n = XX) populations revealed that the New Zealand outbreak was likely caused by two separate introductions from the west coast of the United States. A foliar web blight of Douglas-fir and true fir caused by a bi-nucleate *Rhizoctonia*-like fungus was first observed in some Christmas tree plantations in Oregon and Washington in 1996. The disease kills patches of foliage rendering trees unmarketable and the symptoms have been referred to as web blight. The forest *Rhizoctonia*-like fungus described above has been isolated from symptomatic western hemlock, Sitka spruce (*Picea sitchensis*), and mountain hemlock (*Tsuga mertensiana*), and pacific yew (*Taxus brevifolia*) in PNW forests. DNA sequence analysis suggests that the diseases in Christmas tree plantations and wildland forests are the same. However, a phylogenetic analysis reveals evidence of cryptic speciation in the forest Rhizoctonia population.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Oregon State University, Corvallis, Oregon.

RECENT PUBLICATIONS CONCERNING ECOLOGY OF *PHAEOCRYPTOPUS GAEUMANNII*; CAUSE OF SWISS NEEDLE CAST

David Shaw[1] and *Gabriela Ritóková*[1]

INTRODUCTION

Over the past few years, some key publications have emerged regarding *Phaeocryptopus gaeumannii*, cause of Swiss needle cast. These papers are likely relevant to the WIFDWC audience, but they might not be aware them. Since the epidemic has been intensifying, and perhaps emerging farther north in British Columbia, it seems these papers could be important. Here we summarize papers published since 2014 on *Phaeocryptopus gaeumannii* in the Pacific Northwest of North America.

http://sncc.forestry.oregonstate.edu/snc-identification-and-images
Photo credit: D. Shaw

RECENT SUMMARY OF THE OREGON AERIAL SURVEY AND FOLIAGE RETENTION

Ritóková, G., Shaw, D.C., Filip, G.M., Kanaskie, A., Browning, J., and Norlander, D. (2016) **Swiss needle cast in western Oregon Douglas-fir plantations: 20-year monitoring results.** Forests 7, 155; doi:10.3390/f7080155.

Abstract: Swiss needle cast (SNC), a foliar disease specific to Douglas-fir (*Pseudotsuga menziesii*), is caused by an endemic Ascomycete fungus (*Phaeocryptopus gaeumannii*). In the late 1980s and early 1990s significant symptoms began to appear in coastal Oregon, and these have been associated with the planting of Douglas-fir in the Sitka spruce zone, leaf wetness during potential spore dispersal in May–August, and mild winter temperature. The first annual aerial survey was initiated in 1996 and has continued through 2016, which indicates a significant increase in area of visible symptoms from the air, increasing 53,050 ha in 1996 to 238,705 in 2015. Monitoring plots in the NW Oregon Coast Range verified impacts on SNC on tree growth and productivity, with growth reductions averaging about 23% in the epidemic area linked to needle retention. A series of monitoring plots was set up in the western Cascade Mountains of Oregon and 590 10–23-year old Douglas-fir trees in 59 stands were tracked for 10 years, measured in 2001, 2006, and 2011. No measureable growth impacts were noted in this region of Oregon. A new plot network has been installed throughout the Oregon and southwest Washington coastal ranges as a means of monitoring future disease impact and providing framework for additional studies.

Shaw, D.C., Woolley, T., and Kanaskie, A. (2014) **Vertical foliage retention in Douglas-fir across environmental gradients of the western Oregon coast range influenced by Swiss needle cast.** Northwest Science 88(1):23-32. https://doi.org/10.3955/046.088.0105.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Swiss Needle Cast Cooperative, Department of Forest Engineering, Resources, and Management, Oregon State University, Corvallis, Oregon.

Abstract: We investigated the vertical pattern of foliage retention of Douglas-fir (*Pseudotsuga menziesii*) in the western Oregon Coast Range where Swiss needle cast, a foliage disease caused by *Phaeocryptopus gaeumannii,* is causing foliage loss and growth impacts. Swiss needle cast reduced foliage retention more in the upper crown than the lower crown within the epidemic area, which is unusual as foliage diseases usually reduce foliage retention most in the lower crown. We hypothesized that as foliage retention increased across environmental gradients that it would also increase in the upper crown at a greater rate than the lower crown. We randomly selected 72 sites from a population of Douglas-fir plantations in the northwest Oregon Coast Range. We estimated foliage retention from the lower, mid and upper crown of 10 trees per plot. We fitted a two-level hierarchical model with tree and stand level predictors to model changes in foliage retention with changing environmental gradient for foliage in each of three vertical crown positions. We found that the vertical pattern of foliage retention was generally similar throughout the study area with lowest retention in the upper crown, and highest retention in the lower crown. Foliage retention increased with increasing distance from the coast, which is correlated with increased elevation and decreased temperature and site productivity. These findings are consistent with our current understanding of conifer foliage retention. No apparent shift occurs from whole crown to lower crown impacts in our study area as foliage retention increases and approaches normal.

MOLECULAR ECOLOGY

Bennett, P. and Stone, J. (2016) **Assessments of population structure, diversity, and phylogeography of the Swiss needle cast fungus (*Phaeocryptopus gaeumannii*) in the U.S. Pacific Northwest.** Forests 7:14. doi:10.3390/f7010014.

Abstract: Swiss needle cast (SNC) is a foliar disease of Douglas-fir (*Pseudotsuga menziesii*) caused by *Phaeocryptopus gaeumannii* (Rohde) Petrak. This fungus is endemic to western North America, where it has historically had little impact in native forests. However, increasing disease severity in western Oregon since the 1990s has prompted renewed interest in *P. gaeumannii* and SNC. For this study, we analyze multilocus microsatellite genotypes from 482 single-spore isolates from 68 trees across 14 sites in the western Coast Range of Oregon and southwestern Washington. This study assesses genotypic variation and genetic structure at several levels of population hierarchy. Despite the observation that most of the genetic variation occurred within subpopulations, our analyses detected significant differentiation at all hierarchical levels. Clustering among the 482 isolates based on genetic distance clearly supports the existence of two previously described cryptic lineages of *P. gaeumannii* in the western United States. The two lineages occur in varying proportions along latitudinal and longitudinal gradients in western Oregon and Washington, suggesting a relationship between climate and phylogeography. Sites near Tillamook, Oregon, where SNC is most severe, consist of sympatric subpopulations in which the two lineages comprise roughly equal proportions.

MYCORRHIZAL ASSOCIATIONS

Luoma, D.L. and Eberhart, J.L. (2014) **Relationships between Swiss needle cast and ectomycorrhizal fungus diversity.** Mycologia 106(4):666-675. doi: 10.3852/12-180.

Abstract: Swiss needle cast (SNC) is a disease specific to Douglas-fir (*Pseudotsuga menziesii*) caused by the ascomycete *Phaeocryptopus gaeumannii*. Here we examine characteristics of the EM fungus community that are potentially useful in predictive models that would monitor forest health. We found that mean EM density (number of colonized root tips/soil core) varied nearly 10-fold among sites of varying levels of SNC, while mean EM fungus species richness (number of species/soil core) varied by about 2.5 times. Strong relationships were found between EM and SNC parameters: EM species richness was positively correlated with both

Douglas-fir needle retention ($R^{2 =}$ 0.93) and EM density (R^2 = 0.65); EM density also was significantly correlated with Douglas-fir needle retention (R^2 = 0.70). These simple characteristics of the EM fungus community could be used to monitor forest health and generate predictive models of site suitability for Douglas-fir. Based on previous findings that normally common EM types were reduced in frequency on sites with severe SNC, we also hypothesized that some EM fungi would be stress tolerant dominant species. Instead, we found that various fungi were able to form EM with the stressed trees, but none were consistently dominant across samples in the severely diseased areas.

ECOPHYSIOLOGY OF SNC

Saffell, B.J., Meinzer, F.C., Woodruff, D.R., Shaw, D.C., Voelker, S.L., Lachenbruch, B., and Falk, K. (2014) **Seasonal carbohydrate dynamics and growth in Douglas-fir trees experiencing chronic, fungal-mediated reduction in functional leaf area.** Tree Physiology 34(3):218-228. doi:10.1093/treephys/tpu002.

Abstract: Stored non-structural carbohydrates (NSCs) could play an important role in tree survival in the face of a changing climate and associated stress-related mortality. We explored the effects of the stomata-blocking and defoliating fungal disease called Swiss needle cast on Douglas-fir carbohydrate reserves and growth to evaluate the extent to which NSCs can be mobilized under natural conditions of low water stress and restricted carbon supply in relation to potential demands for growth. We analyzed the concentrations of starch, sucrose, glucose and fructose in foliage, twig wood and trunk sapwood of 15 co-occurring Douglas-fir trees expressing a gradient of Swiss needle cast symptom severity quantified as previous-year functional foliage mass. Growth (mean basal area increment, BAI) decreased by ~80% and trunk NSC concentration decreased by 60% with decreasing functional foliage mass. The ratio of relative changes in NSC concentration and BAI, an index of the relative priority of storage versus growth, more than doubled with increasing disease severity. In contrast, twig and foliage NSC concentrations remained nearly constant with decreasing functional foliage mass. These results suggest that under disease-induced reductions in carbon supply, Douglas-fir trees retain NSCs (either actively or due to sequestration) at the expense of trunk radial growth. The crown retains the highest concentrations of NSC, presumably to maintain foliage growth and shoot extension in the spring, partially compensating for rapid foliage loss in the summer and fall.

Saffell, B.J., Meinzer, F.C., Voelker, S.L., Shaw, D.C., Brooks, J.R., Lachenbruch, B., and McKay, J. (2014) **Tree-ring stable isotopes record the impact of a foliar fungal pathogen on CO2 assimilation and growth in Douglas-fir.** Plant, Cell, and Environment 37(7):1536-1547. doi: 10.1111/pce.12256.

Abstract: Swiss needle cast (SNC) is a fungal disease of Douglas-fir (*Pseudotsuga menziesii*) that has recently become prevalent in coastal areas of the Pacific Northwest. We used growth measurements and stable isotopes of carbon and oxygen in tree-rings of Douglas-fir and a non-susceptible reference species (western hemlock, *Tsuga heterophylla*) to evaluate their use as proxies for variation in past SNC infection, particularly in relation to potential explanatory climate factors. We sampled trees from an Oregon site where a fungicide trial took place from 1996 to 2000, which enabled the comparison of stable isotope values between trees with and without disease. Carbon stable isotope discrimination (Δ13C) of treated Douglas-fir tree-rings was greater than that of untreated Douglas-fir tree-rings during the fungicide treatment period. Both annual growth and tree-ring Δ13C increased with treatment such that treated Douglas-fir had values similar to co-occurring western hemlock during the treatment period. There was no difference in the tree-ring oxygen stable isotope ratio between treated and untreated Douglas-fir. Tree-ring Δ13C of diseased Douglas-fir was negatively correlated with relative humidity during the two previous summers, consistent with increased leaf colonization by SNC under high humidity conditions that leads to greater disease severity in following years.

HENRY LEE PAPER

Lee, E.H., Beedlow, P.A., Waschmann, R.S., Tingey, D.T., Wickham, C., Cline, S. Bollman, M., and Carlile, C. (2016) **Douglas-fir displays a range of growth responses to temperature, water, and Swiss needle cast in western Oregon, USA.** Agricultural and Forest Meteorology. 221:176–188. https://doi.org/10.1016/j.agrformet.2016.02.009.

Abstract: Douglas-fir (*Pseudotsuga menziesii var. menziesii* (Mirb.) Franco) growth in the Pacific Northwest is affected by climatic, edaphic factors and Swiss needle cast (SNC) disease. We examined Douglas-fir growth responses to temperature, dew point deficit (DPD), soil moisture, and SNC, using time series intervention analysis of intra-annual tree-ring width data collected at nine forest stands in western Oregon, USA. Air temperature, previous-year DPD and SNC and their interactions were the primary factors influencing tree growth at all sites, whereas other key seasonal climatic factors limiting growth varied by site. Winter temperature was more important at high elevation cool sites, whereas summer temperature was more important at warm and dry sites. Growth rate increased with summer temperature to an optimum (T_{opt}) then decreased at higher temperatures. At drier sites, temperature and water affected growth interactively such that T_{opt} decreased with decreasing summer soil moisture. With increasing temperature due to climate change, growth rates increased at high elevation sites and declined at mid-elevation inland sites since ~1990. Growth response to climate and SNC are confounded at all sites. We conclude that as temperature rises and precipitation patterns shift toward wetter winters and drier summers, Douglas-fir will experience greater temperature and water stress and an increase in severity of SNC.

THREE PAPERS FROM THE OREGON STATE UNIVERSITY, CENTER FOR PLANTED SILVICULTURE

Zhao, J., Maguire, D.A., Mainwaring, D.B., and Kanaskie, A. (2015) **The effect of within-stand variation in Swiss needle cast intensity on Douglas-fir stand dynamics.** Forest Ecology and Management 347:75-82. https://doi.org/10.1016/j.foreco.2015.03.010.

Abstract: Swiss needle cast (SNC) is a foliar disease of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) caused by the ascomycete *Phaeocryptopus gaeumannii* (Rohde) Petrak. The number of annual needle cohorts retained by a tree indicates SNC severity and associated growth losses. In previous studies growth losses have been predicted on the basis of plot-level foliage retention, and plot-level growth multipliers have been uniformly applied to all trees within a stand to simulate tree growth. In this analysis, the effects of within-stand variation in foliage retention on individual-tree growth impact and implied stand dynamics were analyzed. Models describing diameter increment of Douglas-fir were developed based on three different foliage retention ratings: (1) plot-level foliage retention; (2) tree-level foliage retention; and (3) a combination of plot-level foliage retention and the deviation of tree-level from plot-level foliage retention. Foliage retention at both the plot-level and tree-level was positively correlated with diameter increment, and a significant amount of additional variation in diameter growth was explained by the deviation of individual-tree foliage retention from the plot-level average. The SNC ''effect'' was assessed by comparing growth of trees with varying degrees of Swiss needle cast to growth of those that retained maximal amounts of foliage. Across all plots in the sampled population, the most severely affected dominant or co-dominant trees exhibited 30% diameter growth loss relative to trees of similar crown position with minimal SNC symptoms. Within a plot, diameter growth averaged about 12% higher on trees with the highest foliage retention relative to trees with the lowest foliage retention, implying that SNC intensifies stand differentiation. Rather than responding to SNC with proportionally uniform growth losses within a plot, these results suggest that individual trees tolerate or resist the disease differentially. Foliage retention should therefore be used as a criterion for selecting trees for removal during thinning operations in Douglas-fir stands with moderate to severe SNC.

Zhao, J., Maguire, D.A., Mainwaring, D.B., Wehage, J., and Kanaskie, A. (2014) **Thinning mixed-species stands of Douglas-fir and western hemlock in the presence of Swiss needle cast: guidelines based on relative basal area growth of individual trees.** Forest Science 60:191–199. http://dx.doi.org/10.5849/forsci.12-528.

Abstract: In coastal forests of the Pacific Northwest, young coniferous plantations typically contain a mixture of planted and natural Douglas-fir *(Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). Swiss needle cast (SNC) disease inhibits the growth of Douglas-fir to varying degrees in these stands, depending on SNC severity. In addition to the value differential between Douglas-fir and western hemlock, foresters must account for differences in growth potential (tree size, competitive position, site characteristics, disease pressure) when selecting trees for retention during thinning operations. Diameter increment models for Douglas-fir and western hemlock were developed from permanent plot data collected for the SNC growth impact study (GIS), precommercial thinning study (PCT), commercial thinning study (CT), and retrospective commercial thinning study (RCT). Predictor variables represent tree size, competitive position, site characteristics, and SNC severity. SNC severity was indexed by foliage retention, defined as the number of annual needle cohorts held by a tree. Foliage retention was positively correlated with Douglas-fir diameter increment and negatively correlated with western hemlock diameter increment. Charts developed from the diameter growth models provide a field tool for assessing the relative basal area growth of adjacent Douglas-fir and western hemlock of a given initial diameter in a stand of given SNC severity. In a stand with severe SNC (foliage retention = 1.5 years) the basal area growth of a 6-in. western hemlock tree will exceed the basal area growth of any Douglas-fir tree up to 7.7 in. in DBH. In a relatively healthy stand (foliage retention = 3.0 years) the basal area growth of 6 in. Douglas-fir and western hemlock trees will be approximately equivalent.

Zhao, J., Maguire, D.A., Mainwaring, D.B., and Kanaskie, A. (2014) **Western hemlock growth response to increasing intensity of Swiss needle cast on Douglas-fir: changes in the dynamics of mixed-species stands.** Forestry 87:697–704. https://doi.org/10.1093/forestry/cpu030.

Abstract: Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) is a major commercial tree species in western Oregon and Washington and is often associated with coast Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var *menziesii*) and other species in coniferous forests of the Coast Ranges and Cascade Mountains. Growth of Douglas-fir in many coastal forests has been negatively affected by Swiss needle cast (SNC), a foliar disease caused by the ascomycete *Phaeocryptopus gaeumannii* (T. Rohde) Petr. and characterized by premature foliage loss on severely infected Douglas-fir trees. The effect of SNC on stand dynamics in mixed Douglas-fir-western hemlock stands was tested by constructing a diameter increment model for western hemlock that quantified its growth response to varying SNC severity in Douglas-fir. Diameter increment of western hemlock in any given growth period increased with increasing initial SNC severity as measured by Douglas-fir foliage retention (FR), here defined as the number of annual needle cohorts held by the tree. Furthermore, a decline in Douglas-fir FR during the growth period was associated with an additional increase in diameter increment of western hemlock trees. Assuming no change in FR over the growth period, western hemlock trees in stands with severely impacted Douglas-fir (initial FR≤1.5 years) averaged 79 per cent greater diameter growth than that in relatively healthy stands (initial Douglas-fir FR ≥3.5 years). The implied annual diameter growth response of a western hemlock with initial diameter at breast height of 10, 20, 30 or 40 cm was 0.29, 0.52, 0.65 and 0.68 cm year^{-1}, respectively. Compensatory growth by western hemlock in mixed-species stands alters stand dynamics by allowing this species to surpass the growth of Douglas-fir experiencing severe SNC.

GENOMICS OF ADAPTATION TO CLIMATE CHANGE IN THE DOUGLAS-FIR-SWISS NEEDLE CAST PATHOSYSTEM

Richard C. Hamelin[1, 2], *Joey Tanney*[2], *Jess Wyatt*[3], *Nicolas Feau*[1], *Juergen Ehlting*[3], *Sam Yeaman*[4], and *Sally Aitken*[1]

SUMMARY

Changes in climate can have direct effects on pest and pathogens, in some cases facilitating range expansions or more severe outbreaks under new conditions. Swiss needle cast is a disease that causes defoliation and can reduce growth by as much as 60% in cases of high infection levels. It has increased in the last two decades and has been associated with the planting of Douglas-fir off-sites and with climate change. The disease usually occurs at low elevations in close proximity to the Pacific Ocean, often in areas with summer fog and high rainfall. Areas of severe impact are projected to increase in the next decade in coastal BC. Planting warmer adapted genotypes further north or higher in elevation (climate-based seed transfer, CBST, also known as assisted gene flow) could increase forest productivity under climate warming but could also result in increased exposure and risk to biotic disturbance agents such as Swiss needle cast. We study adaptation to climate change in Douglas-fir and the pathogen responsible for Swiss needle cast, *Phaeocryptopus gaeumannii* to better understand what drives the current outbreak of the disease and to develop mitigation strategies. We are conducting large-scale screening of Douglas-fir to discover genes associated with resistance or tolerance to the disease. We are performing a transcriptome analysis of the interaction between resistant and susceptible genotypes and doing a case-control genome-wide association study (GWAS) using a pooled case-control approach. We are planning to validate the candidate genes in natural outbreak populations. In parallel, we are studying genomic variability in the pathogen to discover genes associated with adaptation to climate and host infection. The presence of two divergent lineages of *P. gaeumannii* suggests the potential for variation in virulence or aggressiveness of strains of the fungus. We are generating genome sequences of more than 500 *P. gaeumannii* strains from a wide environmental range, including B.C., Alaska, Oregon, Idaho, New Mexico, New York, Oregon, Vermont, Washington, Austria, France, Germany, Italy, New Zealand, Switzerland, and the United Kingdom. We will perform genotype-environment associations and genotype-phenotype associations to discover genes involved in adaptation to climate or other environmental variables. Using this data and these tools we propose to develop CBST policy and provide tree breeding strategies and genomic breeding tools.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Department of Forest and Conservation Sciences, Faculty of Forestry, The University of British Columbia, Vancouver, British Columbia. [2]Institut de Biologie Intégrative et des Systèmes (IBIS) Université Laval, Quebec. [3]Biology Department, University of Victoria, Victoria, British Columbia. [4]Ecology and Evolutionary Biology, University of Calgary, Calgary, Alberta.


HITACHI
EX400

PANEL: DROUGHT AND PATHOGENS

MODERATOR: JANE STEWART

CONNECTION BETWEEN RESISTANCE TO ROOT DISEASE, WATER POTENTIAL, AND WOOD PROPERTIES IN DOUGLAS-FIR AND WESTERN REDCEDAR

Mike G. Cruickshank[1]

SUMMARY

The interaction between drought and root disease will increase the severity of drought events on tree survival than when they are considered separately. Three different types of analyses support that water balance is an issue within diseased trees: 1) survival, 2) allometry, and 3) wood anatomy studies. Greenhouse studies showed that seedlings originating from drier and warmer climates had higher resistance and survival to root disease. Resistance controls root damage which probably also protects the vascular system especially in drier climates. In nature, survival of planted Douglas-fir (age 20-34) was lower on sunnier and warmer sites, and climate interacted with root disease. Similarly, drier and warmer sites resulted in lower survival in older natural Douglas-fir stands (age 55-110), and mortality increased with higher site index, with root disease infection, and stand age. Root damage was thought to be limiting water balance within the infected trees, especially the largest trees and drier sites. Allometry between crown length and tree height was altered by root disease producing shorter crowns for a given tree height. Leader elongation is dependent on turgor pressure that is hampered by higher water potential and leads to shorter crown length over time. Wood anatomy studies showed that wood density was highest in half-sibling families resistant to root disease because of their thicker tracheid walls, lower tracheid radial growth, and higher proportion of latewood. Wood density is correlated with drought tolerance in conifers, and since resistance controls pathogen damage, this suggests that water balance may be a key problem. Planted Western redcedar grown in monoculture had the highest wood density compared to when it was grown in admixtures with Douglas-fir, lodgepole pine and paper birch. Increased wood density was due to higher earlywood and latewood density and more latewood. The over story mixture was thought to be reducing seasonal moisture and light needed for cedar to produce thicker cell walls and for shortening the growing season end where latewood is produced. Mortality of the cedar grown in Douglas-fir or birch was higher than cedar monoculture as a result. These studies suggest that one of the main factors affecting trees with diseased root systems is altered water balance; furthermore, at least some trees may cope with both disease and drought by producing higher density wood and limiting pathogen damage through disease resistance.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1] Natural Resources Canada, Canadian Wood Fibre Centre, 506 W. Burnside Rd. Victoria, British Columbia.


Mike Cruickshank
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SUBALPINE FIR DECLINE: RELATIONSHIP BETWEEN CLIMATE CHANGE, BARK BEETLES, AND ROOT DISEASE

Bradley M. Lalande[1], *Kristina Hughes*[2], *William R. Jacobi*[1], *Wade T. Tinkham*[2],
Robin Reich[2], and *Jane E. Stewart*[1]

INTRODUCTION

Spruce-fir forests occupy a unique niche in high elevation forests of Colorado, ranging from 8,000 to 12,500 feet. This forest type makes up 4.6 million acres, making it the third largest in Colorado, which provides resources for animals and humans alike (CSFS, 2013). The ability for these forests to thrive is of utmost importance to our state, as the potential climate in high elevations forests changes.

Smith et al. (2015) documented an increase in mortality of subalpine fir that occurred from 2008-2013, in comparison to the overall mortality from 1982-2007. This corresponds to annual aerial pest surveys conducted by Forest Health Protection from the USDA-Forest Service and Colorado State Forest Service. In the last nine years, trees newly affected by subalpine fir mortality has ranged from 122,000 acres in 2015 and 2016 to 344,000 acres in 2008 (USDA-FS, 2008-2016). Since 2008, a total of 1,789,000 acres of spruce-fir forests have been affected by subalpine fir mortality. It has been hypothesized that this mortality can be attributed to Western balsam bark beetle (WBB) (*Dryocoetes confusus*) infestations. Smith et al. (2015) showed that WBB was the most significant mortality agent with a 20% association to tree deaths from 2011-2013 (Smith et al., 2015). The relationship of *Dryocoetes* and root disease (*Armillaria* and *Heterobasidion*) with subalpine fir mortality has been studied in Colorado (James & Goheen, 1981). Finding, that of 150 trees surveyed in four National Forests; Grand Mesa, Rio Grande, San Isabel, and San Juan; the majority of subalpine fir were associated with both *Armillaria* and *Dryocoetes*, highlighting a close association between root diseases and bark beetles.

To identify the current level of subalpine fir mortality in Colorado we developed three research questions. **1) Which site characteristics are associated with subalpine fir mortality? 2) What factors affect the presence of *Dryocoetes* or *Armillaria*? 3) Are climate variables factors in mortality of subalpine fir, and the increased presence of *Dryocoetes* and *Armillaria*?**

METHODS

Subalpine fir mortality was identified using GIS layers from aerial pest surveys performed by Region 2 Forest Health Protection of the USDA-FS from 1994 to 2012. The aerial surveys were overlaid on vegetation types from the Colorado Division of Wildlife. These shape files were used to identify locations of mortality within spruce-fir forest types located in all eight Colorado National Forests. In the summer of 2013, roadside characterization surveys were performed within the overlaid spruce-fir mortality locations. The roadside surveys were used to ground truth the aerial surveys and to specifically identify clumps of subalpine fir mortality. The following year, 57 plots were randomly selected to perform stand health monitoring plots throughout the state. Half of the plots were designated within areas of known mortality, while the other half were randomly selected throughout the spruce-fir forest type. Each plot consisted on one centralized plot and two associated subplots 200 feet on either side of the centralized location. Site measurements consisted of

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forest type, number of crown layers, slope position (valley, midslope, flat, top), aspect, understory vegetation, percent canopy closure of overstory trees, along with other useful notes for each plot. Trees were measured using a variable radius (20 BAF) and regeneration was sampled in each cardinal direction from plot center using four 1/300th acre microplots. Tree measurements included live or dead status, diameter at breast height, canopy base height, presence or absence of *Dryocoetes* and *Armillaria*, and any other relevant insects or diseases associated with each tree.

To encompass climatic factors, data was collected using PRISM Climate Group (PRISM, 2017). Values were taken over 30 years (1985-2014) and then averaged over the last five years (2010-2014) to determine the current departure from overall averages. Precipitation values were cumulative for the year, maximum temperature was averaged from June-July each year, and minimum temperature was averaged from November-April. Data was analyzed using Rstudio (Rstudio Team, 2017). Logistic regression was performed to predict the presence of subalpine fir mortality, *Dryocoetes,* or *Armillaria* as a function of forest structure, composition, and climatic metrics.

RESULTS

Mortality occurred throughout all eight national forests. Overall mortality for subalpine fir and Engelmann spruce ranged from 20% to 40%. Subalpine fir mortality ranged from 10% to 40%, except within Pike – San Isabel National Forest that had 0% mortality and one site on the Uncompahgre National Forest had 100% mortality (Figure 1). When comparing all sites together, subalpine fir mortality occurred through all diameter classes, but the majority of mortality was found in the middle third of the size distribution at 8-16 inches (Figure 2). Further, 84% of dead SAF were associated with *Dryocoetes*, whereas only 44% of dead SAF were associated with *Armillaria*.

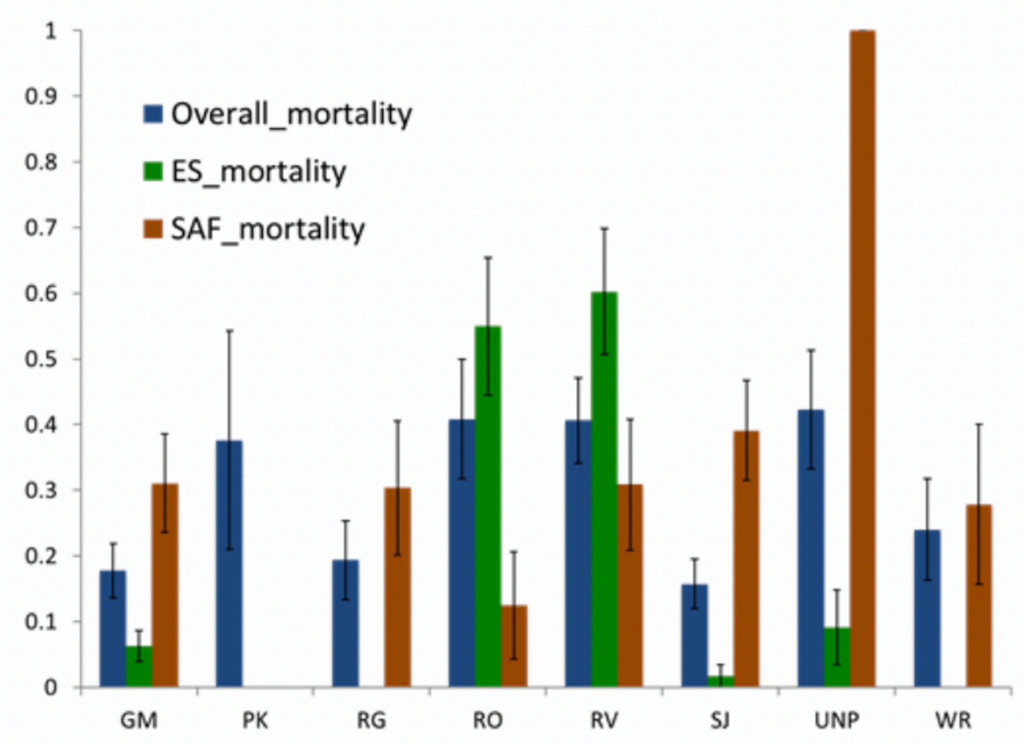

Figure 1. Spruce-fir mortality on each National Forest. Differences in overall mortality from the study species are due to other species presences, such as lodgepole pine.

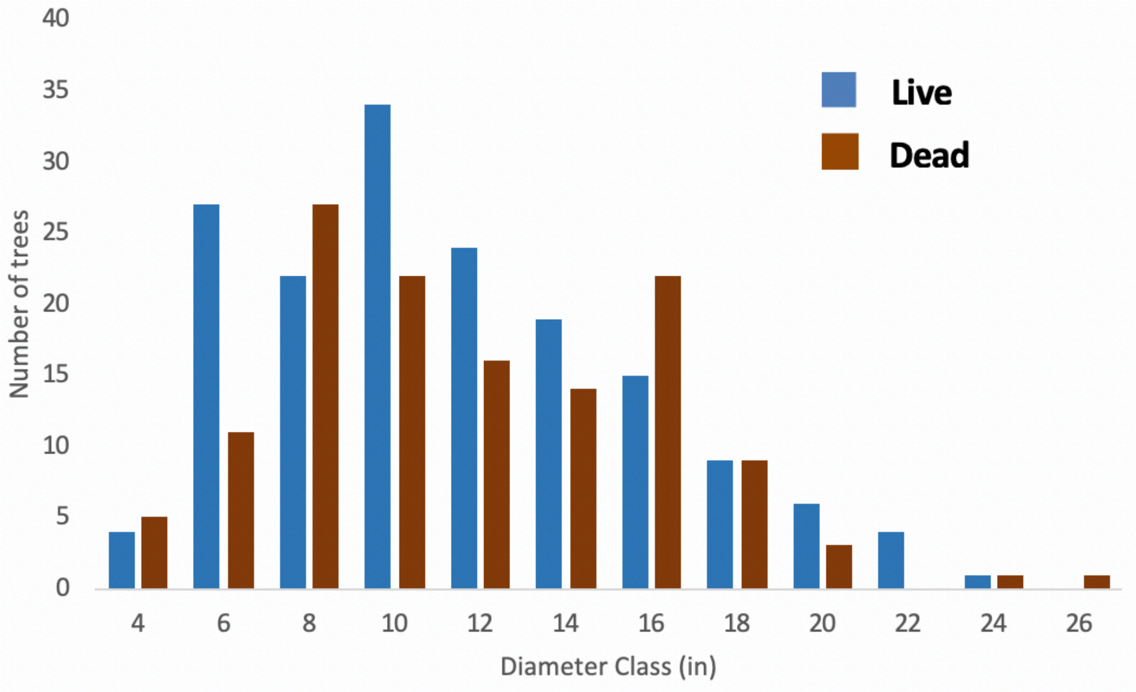

Figure 2. Live/Dead status of subalpine fir by diameter class.

Factors significantly associated with subalpine fir mortality included precipitation and minimum temperature (Figures 3 & 4). As precipitation decreased, there was an increase in mortality. Similarly, as minimum winter temperatures increased, subalpine fir mortality increased. *Armillaria* presence was also significantly correlated to maximum summer temperatures. As maximum summer temperature increased, the presence of *Armillaria* subsequently increased. Interestingly, climatic factors did not have any significant correlation on the presence of *Dryocoetes*.

Elevation was significantly correlated with subalpine fir mortality, such that as elevation decreased mortality increased ($P = 0.0124$) (Figure 5). However, all other site characteristics were not significantly associated with SAF mortality. Several site characteristics did influence *Dryocoetes* presence. Tree stem density, basal area, (Figure 6) and the amount of Engelmann spruce seedlings on a plot were all significantly positively correlated with an increased presence of *Dryocoetes* ($P = 0.0413$). Site characteristics that influenced *Armillaria* presence included elevation ($P = 0.0126$) and slope ($P = 0.013$).

DISCUSSION

This study focuses on the overall health of subalpine fir forests within Colorado's National Forests. The objectives were to identify climatic factors, biotic agents, and site characteristics that influence subalpine fir mortality. High elevation subalpine fir forests are acclimated to a cooler, wetter environment than most other forest types within Colorado. As climate trends shift to a warmer, drier environment in these forests, the probability of observing subalpine fir decline will likely increase due to added stress on trees (Reich et al., 2016). Climate plays an integral role in their mortality. Identifying how biotic agents, associated with mortality, are also influenced by changing climates may help understand the components of subalpine fir decline. The two biotic agents specifically associated with subalpine fir are *Dryocoetes confusus* and Armillaria root disease. The high proportion of dead trees infested with *Dryocoetes* indicates that there is a relationship between climate driven stress and the presence of beetles in subalpine fir. During drought characteristics, there is a greater likelihood that beetle populations will produce outbreaks or epidemic populations (Bentz et al., 2010), yet the logistic regression shows that climatic factors do not influence the presence of *Dryocoetes*.

However, stand density plays a significant role in the presence of the beetle, with forests of greater basal area having more *Dryocoetes*. Colorado forests have become overstocked because of fire suppression. More competition in a forest may cause trees to be less vigorous from a lack of water, nutrients, and space. Sites with higher basal area provide an increased ability for biotic agents to thrive. As populations increase within Colorado, subalpine fir mortality will continue to plague spruce-fir forests.

At our study sites, Armillaria root disease is less prevalent on dead trees, which could be due to a decrease in mycelial growth in the presence of drought conditions. *Armillaria* is present in most forest environments and symptoms are more expressed as trees become stressed. There was a significant increase in the presence of *Armillaria* on plots were maximum summers temperature were higher. This likely highlights the importance of stress as a factor of subalpine fir mortality. These slight departures in climate factors, from 30-year averages, have detrimental effects on the overall health of our forests.

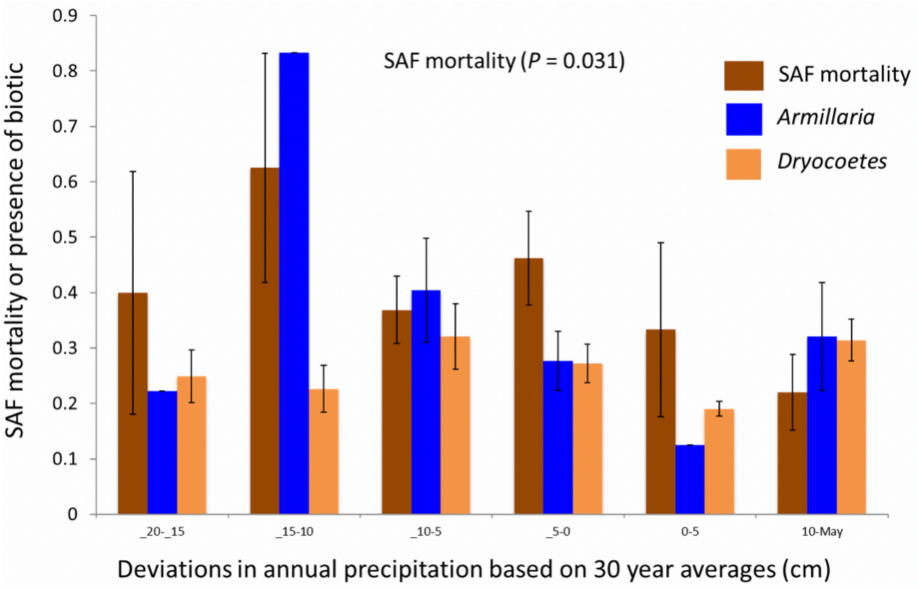

Figure 3. Mortality proportion and proportion of trees with biotic factors associated with departures in annual precipitation.

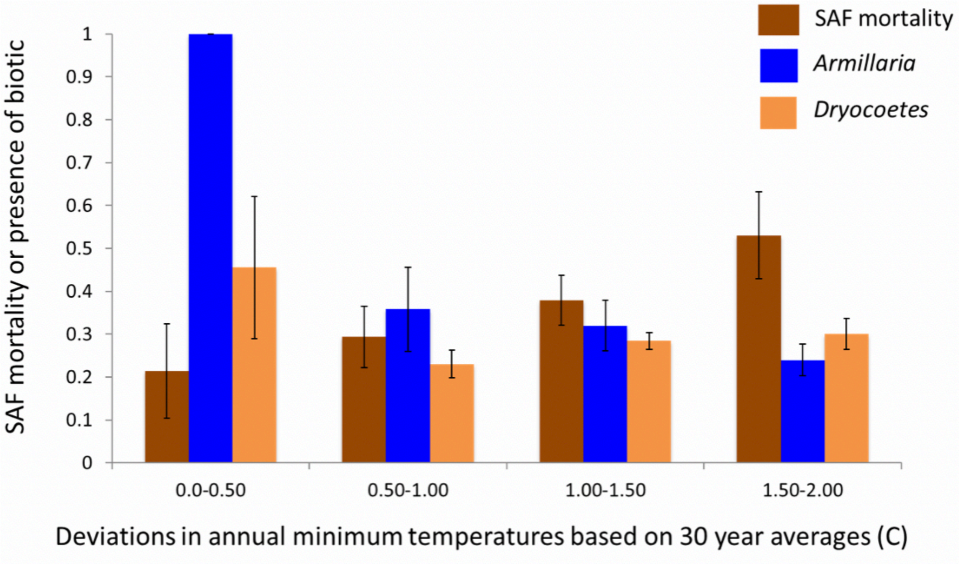

Figure 4. Mortality proportion and proportion of trees with biotic factors associated with departures in winter minimum temperatures.

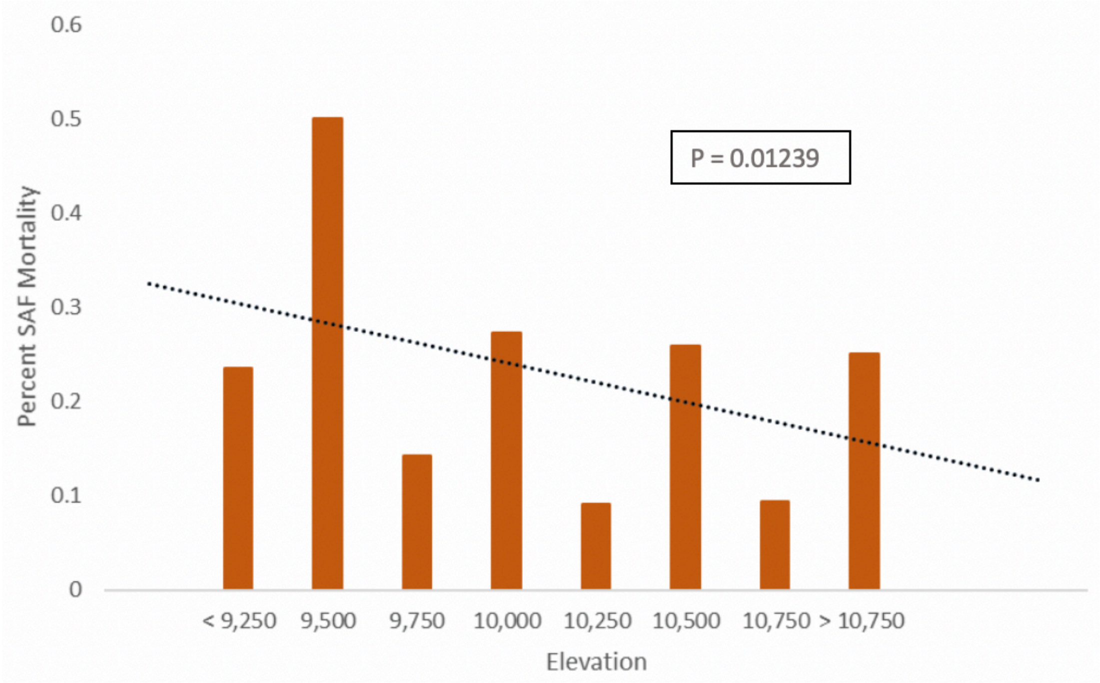

Figure 5. SAF mortality associated with elevation (ft).

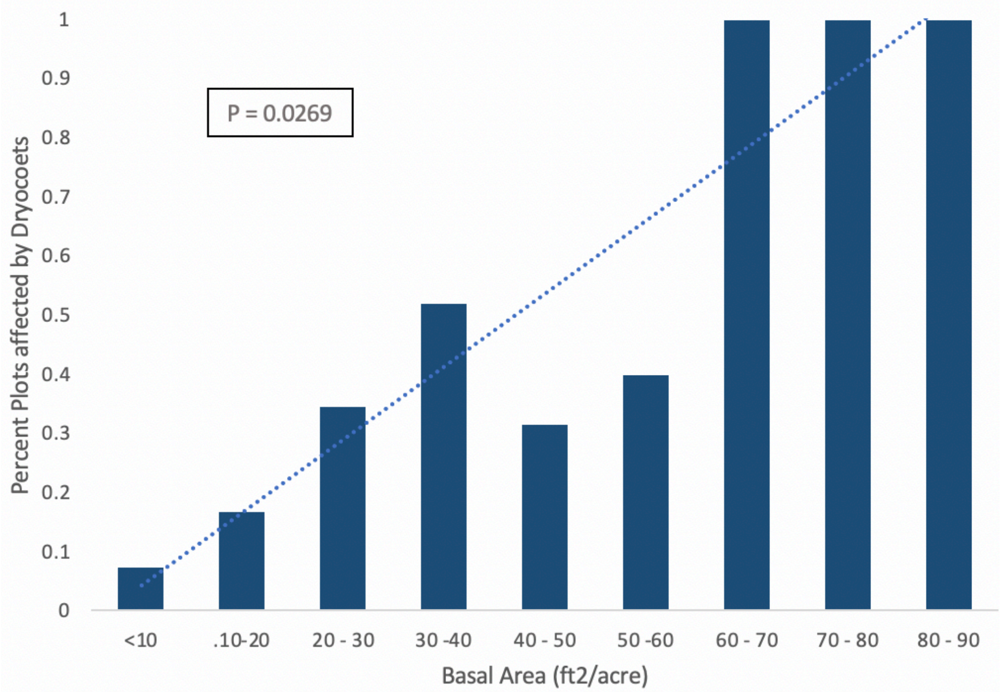

Figure 6. Basal area association to plots affected with *Dryocoetes.*

CONCLUSION

Factors that directly influence mortality or either of the two biotic agents consist of a combination of climatic variables and site characteristics. The majority of mortality has occurred in 8-16 inch diameter trees, showing that a wide range of sizes is affected. Decline diseases are known to influence older trees in a population and have at least three factors that fall into distinct categories that affect the spread of mortality; predisposing, inciting, and contributing factors. Our data suggests that density and climatic factors may be predisposing subalpine fir to increased mortality. *Armillaria* is present in most stands within the state but it is not directly influencing mortality of trees. We hypothesize, however, that this could be an inciting factor, and the contributing factor that is associated more directly to mortality of subalpine fir is *Dryocoetes*.

Though, the total numbers of acres affected by subalpine fir decline has slowly tapered off within the last few years, drought characteristics have heightened in Colorado. This could give rise to increased acreage as stress levels of alpine fir increase. Since our forests have endured recent epidemic populations of mountain pine beetle and spruce beetle, the ability to identify potential threats will assist managers to prepare for future mortality and forest management.

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SPECIAL PAPERS

MODERATOR: DAVE SHAW

CONTEMPORARY TREATMENTS OF *ARCEUTHOBIUM*, SERIES *CAMPYLOPODA*

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ABSTRACT

In Hawksworth and Wiens' 1996 monograph for *Arceuthobium*, they classified 16 taxa in subgenus *Vaginata*, section *Campylopoda*, series *Campylopoda*. Since 1996, there have been four new subspecies described in this series: *A. tsugense* subsp. *contortae* (2003) and subsp. *amabilae* (2007), *A. abietinum* subsp. *wiensii* (2009), and *A. microcarpum* subsp. *aristatae* (2009). Based primarily on molecular evidence, another treatment was proposed by Nickrent in 2012 which recombined nearly all of the species in series *Campylopoda* as subspecies of *A. campylopodum*. Furthermore, in 2012, Kuijt treated all of the species in *Campylopoda* found in California as synonymous with *A. campylopodum* in the revised Jepson manual, thereby recognizing only three species of *Arceuthobium* in the state. Then in 2016, Nickrent followed his 2012 classification of the series in his treatment of the Viscaceae for the Flora of North America. In this treatment, Nickrent recognized only seven species of *Arceuthobium* in the United States and three in Canada with 13 subspecies of *A. campylopodum* in the United States and two in Canada. Here, we compare these latter two treatments for *Campylopoda* with Hawksworth and Wiens' treatment. We also discuss the advantages and disadvantages to forest pathologists/foresters in using the different taxonomic treatments for this taxonomically difficult group of dwarf mistletoes. A comparison of the morphologies and host distributions of *A. campylopodum* with the subspecies of *A. tsugense* is used as an example of the advantage of using the Hawksworth and Wiens' interpretation for *Campylopoda*.

INTRODUCTION

Dwarf mistletoes (*Arceuthobium* spp., Viscaceae) are dioecious, parasitic plants of the Pinaceae in the New World that are common and abundant inhabitants of forests in the western United States, Canada, Mexico and into Central America (Hawksworth and Wiens 1996). One species (*A. pusillum*) is found in the northeastern United States and eastern Canada, but by far the most species are found in the Klamath-Siskiyou Mountain Region (CA and OR) and the Sierra Madre Occidental of Durango, Mexico (Hawksworth and Wiens 1996; Mathiasen and Marshall 1999). Dwarf mistletoes parasitize nearly all of the economically important conifers harvested in the West and severely infected trees have reduced height and diameter growth and increased mortality rates. Although the dwarf mistletoes are recognized as serious forest diseases in many forest ecosystems, they also have complex interactions with a wide variety of other organisms in these forests. Insects pollinate dwarf mistletoes and mistletoe plants, pollen, and nectar serve as food for various fungi, arthropods, birds, and mammals. Animals forage among mistletoe plants and the witches' brooms induced by dwarf mistletoe infections and many birds and mammals use the brooms as nesting, resting, and hiding sites (Hawksworth and Wiens 1996; Mathiasen 1996).

Arceuthobium has long been considered a taxonomically difficult genus because of the morphological and phenological similarities among many of the currently recognized species. This is particularly true for the taxa classified by Hawksworth and Wiens (1972, 1996) in subgenus *Vaginata*, section *Campylopoda*, series *Campylopoda*; this series still representing by far the most taxonomically challenging group in the genus.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]School of Forestry, Northern Arizona University, Flagstaff, Arizona. [2]School of Integrative Plant Science, Plant Pathology and Plant-Microbe Biology Section, Cornell University, Ithaca, New York.

Not only do the dwarf mistletoes have small, scale-like leaves, but their male flowers are similar in form and relatively small (2-5 mm in diameter); their fruits are also similar (bi-colored and 3-9 mm in length). These characteristics have contributed to the difficulties associated with their taxonomic classification and to their identification by many foresters, botanists, and even forest pathologists. However, because many of the dwarf mistletoes recognized by Hawksworth and Wiens (1996) – and ourselves (Mathiasen and Kenaley 2015a, 2016, 2017) – are host specific, knowing the geographic location and correct identification of the host being affected, allows most species of *Arceuthobium* to be easily determined.

BACKGROUND ON THE CLASSIFICATION OF *ARCEUTHOBIUM*

George Engelmann was the first to describe a species of *Arceuthobium* in the United States - *A. americanum* in 1850. Because Engelmann described most of the species of *Arceuthobium* known from the U.S. and Canada until the 1930s, including several taxa in series *Campylopoda*, he has been considered the "father" of *Arceuthobium* classification in the United States (Table 1).

Table 1. George Engelmann's classification of *Arceuthobium* in the United States. Taxa in bold type are in series *Campylopoda.*

Species	Year Described	Synonym
A. abietinum	1872	
A. americanum	1850	
A. campylopodum	1850	
A. cryptopodum	1850	*A. vaginatum* subsp. *cryptopodum*
A. divaricatum	1878	
A. douglasii	1878	
A. douglasii var microcarpum	1878	*A. microcarpum*
A. minutum	1871	*A. pusillum*
A. occidentale	1878	

In the early 1900s, several plant taxonomists recognized that there were additional dwarf mistletoe populations that were morphologically distinct from *A. campylopodum*, and more new species in series *Campylopoda* were described, including *A. tsugense* (1903), *A. laricis* (1906), *A. cyanocarpum* (1909), and *A. blumeri* (1913). See Hawksworth and Wiens (1972, 1996) for more detailed information on the nomenclature of these four species.

The first monographic treatment of *Arceuthobium* for the United States was by Lake Gill (1935) in which he separated *A. campylopodum* and *A. vaginatum* into forms solely based on host relationships. This has been referred to as Gill's "host form concept." Gill also recognized well-defined species such as *A. americanum*, *A. douglasii*, and *A. pusillum*, but he chose to group several dwarf mistletoes (including *A. abietinum*, *A. blumeri*, *A. cyanocarpum*, *A. divaricatum*, *A. laricis*, *A. microcarpum*, and *A. tsugense*) as host forms of *A. campylopodum*. Gill's host form system classified all dwarf mistletoe parasitizing a true fir (*Abies* spp.) as *A. campylopodum* forma *abietinum*; it didn't matter if the mistletoe was also severely parasitizing a hemlock (*Tsuga* spp.) in the same locality. Even when the mistletoe on the true fir morphologically resembled the plants on the hemlock, these mistletoes were classified as different host forms of *A. campylopodum*: the mistletoe on the true fir was forma *abietinum* and the mistletoe on the hemlock was forma *tsugensis* under Gill's host form concept. The inadequacies of this system were soon apparent to anyone trying to sort out the host affinities of dwarf mistletoes which usually parasitize a principal host, but frequently cross infect other hosts in the same stand to a lesser degree.

Following Gill (1935), few changes occurred in the nomenclature of *Arceuthobium* until Hawkworth and Wiens (1964) described *A. gillii*. Thereafter, Hawksworth and Wiens (1965) described five new taxa of *Arceuthobium* from northern Mexico: *A. globosum*, *A. rubrum*, *A. strictum*, *A. gillii* subsp. *nigrum*, and *A. vaginatum* subsp. *durangense*. They also "re-discovered" a species that had been almost completely ignored since it had been originally described from Durango by Engelmann in 1880: *A. verticilliflorum*. They also acknowledged the classification of the dwarf mistletoe from central Mexico on sacred fir (*Abies religiosa*) described by Heil (1923) – *A. abietis-religiosae*.

Hawksworth and Wiens (1970) continued their taxonomic studies of *Arceuthobium* in the late 1960s describing five new species: *A. apachecum* (Southwestern U.S.), *A. californicum* (California), *A. guatemalense* (Guatemala), *A. hondurense* (Honduras), and *A. pini* (China). They also recognized *A. abietinum* as a valid species, but classified the populations only infecting white fir (*Abies concolor*) and those only infecting red fir (*Abies magnifica*) as special forms: *A. abietinum* formae specialis (f. sp.) *concoloris* and f. sp. *magnificae*, respectively. They used the special form designation because they maintained there were no major morphological differences between the plants produced on white fir versus those on red fir, yet Dick Parmeter and Bob Scharpf had clearly demonstrated the two special forms would not cross infect the other fir host (Parmeter and Scharpf 1963). This fascinating host specialization by fir dwarf mistletoe appears to hold true in the Sierra Nevada Mountains, but it doesn't hold true in true fir stands of the Klamath-Siskiyou Mountain Region in northwestern California and southwestern Oregon (Mathiasen and Daugherty 2007; Mathiasen and Kenaley 2016).

Hawksworth and Wiens (1972) published their first taxonomic monograph of *Arceuthobium* which became the authoritative publication on the biology and taxonomy of the genus for many years. In this monograph, they recognized 28 species, 5 subspecies, and the two special forms of *A. abietinum*. In the monograph, they placed 12 species in subgenus *Vaginata*, section *Campylopoda*, series *Campylopoda*. All of the species of *Arceuthobium* mentioned above were included in this monograph, including the recognition of the species described by Engelmann in the 1800s (see Table 1), except that Engelmann's *A. minutum* was treated as *A. pusillum* which was described by Peck in 1872. In their monograph, Hawksworth and Wiens used morphology (shoot size and color, flower and fruit characters), phenology (time of meiosis, flowering and seed dispersal), palynology (pollen characters), chemical (anthocyanins and flavonoids), cytology (chromosome characters), and host relationships and reactions (host range and host response to infection) in support of their treatment for *Arceuthobium*.

Hawksworth and Wiens (1976, 1977, 1980, 1989) remained the most active taxonomic investigators of *Arceuthobium* from the early 1970s into the 1980s. They continued their studies of dwarf mistletoes in the Old World, Mexico and Central America, particularly the populations they treated as *A. globosum*, and in 1977, they separated this species into several new taxa: *A. globosum* subsp. *globosum*, *A. globosum* subsp. *grandicaule*, *A. aureum* subsp. *aureum*, and *A. aureum* subsp. *petersonii*. Next, after several trips to Mexico looking for a reported dwarf mistletoe parasitizing pinyons, they discovered it in San Luis Potosi and described it as *A. pendens* in 1980. Nearly 10 years passed before Hawksworth and Wiens discovered another dwarf mistletoe new to science in northern Mexico which they described as *A. yecorense* in 1989. In this paper, they also described the populations of what they had earlier classified as *A. rubrum* in Oaxaca, Mexico as a new species: *A. oaxacanum*. Furthermore, they raised two subspecies, *A. vaginatum* subsp. *durangense* and *A. gillii* subsp. *nigrum* to specific rank as *A. durangense* and *A. nigrum*.

The last taxonomic efforts Hawksworth and Wiens (Hawksworth et al. 1992; Hawksworth and Wiens 1993) completed together were in the early 1990s. In 1992, working in cooperation with Dan Nickrent, they described two new species of *Arceuthobium* from northern California that they had originally aligned in 1972 with *A.*

campylopodum: *A. littorum* and *A. siskiyouense*. They also classified the populations parasitizing western white pine (*Pinus monticola*) in northern California and southern Oregon as *A. monticola*, which they separated from *A. californicum* which parasitizes sugar pine (*P. lambertiana*). They also separated the dwarf mistletoe populations parasitizing mountain hemlock (*Tsuga mertensiana*) from the populations on western hemlock (*T. heterophylla*) as a subspecies of hemlock dwarf mistletoe: *A. tsugense* subsp. *mertensianae*. Furthemore, they designated the populations of hemlock dwarf mistletoe parasitizing shore pine (*P. contorta* var. *contorta*) in British Columbia and northern Washington as a race of western hemlock dwarf mistletoe (*A. tsugense* subsp. *tsugense*). This classification of shore pine dwarf mistletoe then became the only application of the race concept in *Arceuthobium*.

In a revised monograph of *Arceuthobium*, Hawksworth and Wiens (1996) recognized 46 taxa comprised of 42 species, four of which had two subspecies each, and the two special forms of *A. abietinum* were retained (Table 2). Eight species were recognized that occur in the Old World and 34 species were recognized from the New World. The revised monograph provided systematic and descriptive information for each species and subspecies as well as detailed information on the biology, anatomy, physiology, ecological relationships, pathology, and management of dwarf mistletoes. This work remains the most definitive publication on all aspects of *Arceuthobium* history, biology, and systematics, even though it is over 20 years since it was printed.

Table 2. Classification proposed for *Arceuthobium* by Hawksworth and Wiens in 1996. Species grouped by major geographic regions. Taxa in bold type were in series *Campylopoda*.

United States and Canada	Mexico and Central America	Europe and Africa	Asia
A. abietinum	*A. abietis-religiosae*	*A. azoricum*	*A. chinense*
f. sp. *concoloris* [1]	*A. aureum*	*A. juniperi-procerae*	*A. minutissimum*
f. sp. *magnificae*	*A. aureum* subsp. *petersonii*	*A. oxycedri*	*A. pini*
A. americanum [2]	*A. bicarinatum*		*A. sichuanense*
A. apachecum [1]	***A. blumeri*** [3]		*A. tibetense*
A. californicum	*A. durangense*		
A. campylopodum [1]	*A. globosum*		
A. cyanocarpum	*A. globosum* subsp. *grandicaule*		
A. divaricatum	***A. guatemalense***		
A. douglasii [1,2]	*A. hawksworthii*		
A. gillii [1]	*A. hondurense*		
A. laricis [2]	*A. nigrum*		
A. littorum	*A. oaxacanum*		
A. microcarpum	***A. pendens***		
A. monticola	*A. rubrum*		
A. occidentale	*A. strictum*		
A. pusillum [2]	*A. vaginatum*		
A. siskiyouense	*A. verticilliflorum*		
A. tsugense [2]	*A. yecorense*		
***A. tsugense* subsp. mertensianae**			
A. vaginatum subsp. crytopodum [1]			

[1] – also occurs in Mexico; [2] – occurs in Canada; [3] – also occurs in the United States.

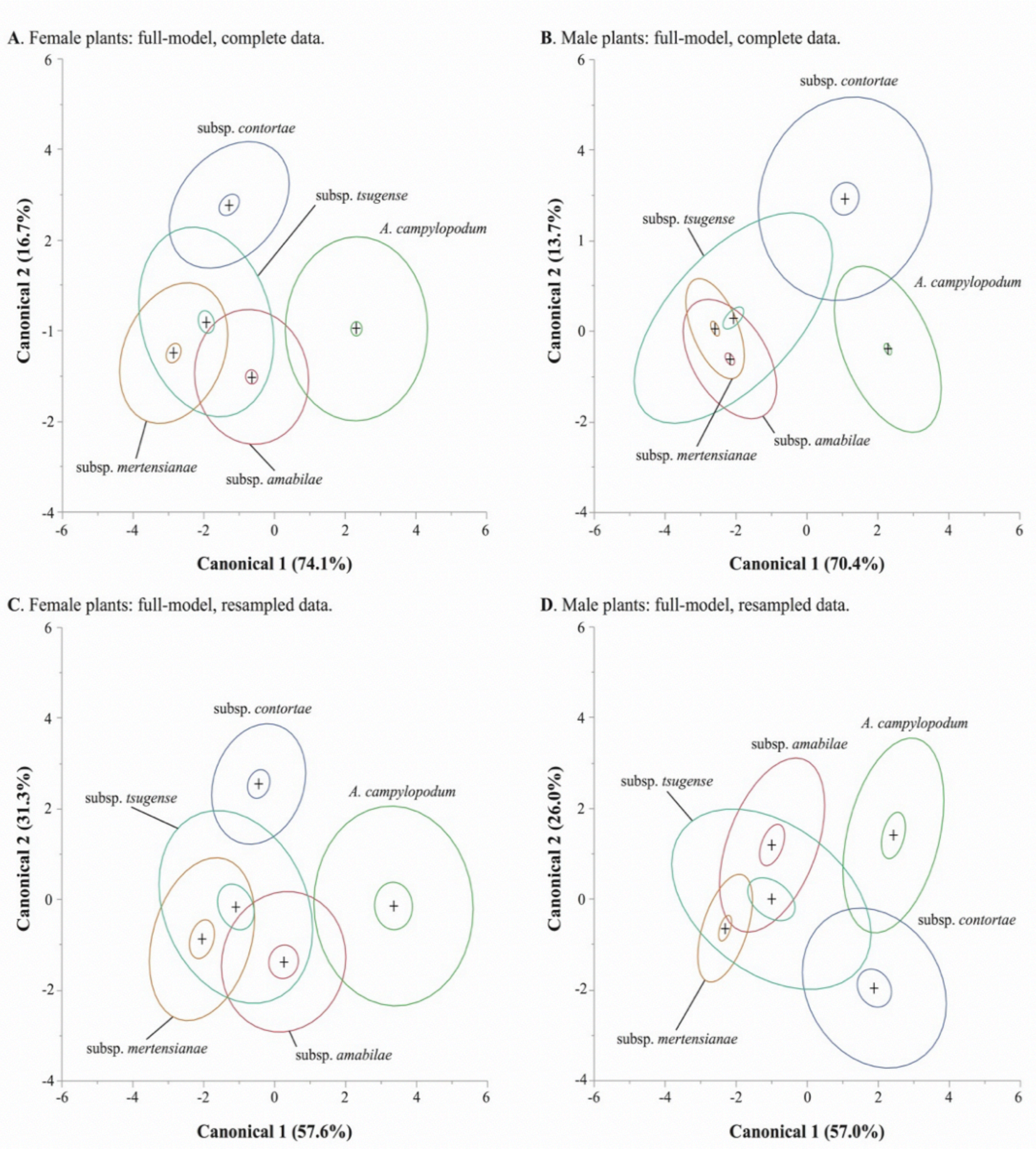


Figure 1. Canonical plots for discriminant function analyses (DFA) of *Arceuthobium campylopodum*, *A. tsugense* subsp. *tsugense*, subsp. *amabilae*, subsp. *contortae*, and subsp. *mertensianae* based on morphological characteristics of female (A, C) and male plants (B, D) shown in Table 5. Multivariate means (cross hairs) were computed using complete data for each species by sex (A, B) or a random subset (50 complete records/species) of female (C) and male plants (D), respectively. The inner ellipses correspond to a 95% confidence limit for the mean, and the outer ellipses represent a normal 50% contour wherein 50% of plants for each taxon reside. Figure from Mathiasen and Kenaley (2017).

CLASSIFICATION OF *ARCEUTHOBIUM* SERIES *CAMPYLOPODA* POST HAWKSWORTH AND WIENS

Essentially, no new species of *Arceuthobium* have been described since Hawksworth and Wiens published their revised 1996 monograph. However, four new subspecies have been described under three species in series *Campylopoda*:

1. *Arceuthobium tsugense* subsp. *contortae* – Wass and Mathiasen (2003).
   Shore pine dwarf mistletoe
2. *A. tsugense* subsp. *amabilae* – Mathiasen and Daugherty (2007)
   Pacific silver fir dwarf mistletoe
3. *A. abietinum* subsp. *wiensii* – Mathiasen and Daugherty (2009)
   Wiens' dwarf mistletoe
4. *A. microcarpum* subsp. *aristatae* – Scott and Mathiasen (2009)
   Bristlecone pine dwarf mistletoe

Only the subspecies described under *A. tsugense* will be discussed below because they provide a good example of why the treatment proposed for series *Campylopoda* by Hawksworth and Wiens (1996) is the most practical classification for this group of dwarf mistletoes.

In 2003, Wass and Mathiasen raised the shore pine race of hemlock dwarf mistletoe to subspecific rank based on morphological, phenological, and host range differences between western hemlock dwarf mistletoe (*A. tsugense* subsp. *tsugense*) and shore pine dwarf mistletoe (*A. tsugense* subsp. *contortae*). This allows an alternative classification of the shore pine dwarf mistletoe that does not use the race designation. Shore pine dwarf mistletoe differs from western hemlock dwarf mistletoe in several ways. Shoots of shore pine dwarf mistletoe are shorter on average, greenish-brown in color, its flowers are larger, and it only occasionally infects western hemlock (Table 3). Furthermore, in stands where both shore pine and western hemlock dwarf mistletoes co-occur on Vancouver Island, shore pine dwarf mistletoe consistently reaches its peak in seed dispersal one week before western hemlock dwarf mistletoe. We recently completed additional analyses of the morphologies of subsp. *tsugense* and subsp. *contortae* using multivariate statistical procedures (MANOVA and discriminant function analyses) which also demonstrated that these subspecies are morphologically separable (Mathiasen and Kenaley 2017). This study indicated that female and male plant morphologies of subsp. *contortae* are significantly different when compared to other subspecies of *A. tsugense*, as well as *A. campylopodum*. Thus, given these morphological differences, it might be more taxonomically consistent to raise subsp. *contortae* to a species (*A. contortae*). However, before we undertake that nomenclatural change, we plan to collect and analyze ribosomal DNA sequence data as well as more variable single-copy genes to assess the phylogenetic relationships of subsp. *contortae* and its allied subspecies of *A. tsugense*.

Based on field work in Oregon, it was discovered there were populations of hemlock dwarf mistletoe that were primarily parasitizing Pacific silver fir (*Abies amabilis*), noble fir (*A. procera*), and mountain hemlock that were being confused with mountain hemlock dwarf mistletoe (*A. tsugense* subsp. *mertensianae*) by Hawksworth and Wiens. After collecting a large amount of additional morphological data across many populations of western hemlock dwarf mistletoe (subsp. *tsugense*) and mountain hemlock dwarf mistletoe (subsp. *mertensianae*), as well as for the mistletoe on Pacific silver fir, it was concluded that the dwarf mistletoe on Pacific silver fir deserved taxonomic recognition as a new subspecies: *A. tsugense* subsp. *amabilae* (Pacific silver fir dwarf mistletoe, Mathiasen and Daugherty 2007). This subspecies has larger shoots than both western and mountain hemlock dwarf mistletoes and it only occasionally infects western hemlock (Table 4). Although it also severely parasitizes mountain hemlock, its plants are nearly twice as large as typical mountain hemlock dwarf mistletoe plants. Pacific silver fir dwarf mistletoe is distributed in Oregon from Mt. Hood to as far south as the Umpqua River watershed. The mistletoe parasitizing noble fir on Mary's Peak near Corvallis, OR is classified as a western outlier of Pacific silver fir dwarf mistletoe. The Pacific silver fir dwarf mistletoe severely parasitizes both Pacific silver fir and noble fir, particularly in the vicinity of the H. J. Andrews Experimental Forest. It should be noted here that Frank Hawksworth visited the H. J. Andrews Experimental Forest in 1990 and, in an unpublished report, commented that the dwarf mistletoe populations at the higher elevations on Pacific silver fir, noble fir, and mountain hemlock were different than the dwarf mistletoe populations at lower elevations on western hemlock; the high elevation populations are now treated as subsp. *amabilae* and the low elevation populations are subsp. *tsugense* (Mathiasen and Daugherty 2007).

Table 3. Comparison of western hemlock dwarf mistletoe (*A. tsguense* subsp. *tsugense*) and shore pine dwarf mistletoe (*A. tsugense* subsp. *contortae*) from Wass and Mathiasen (2003).

Characters	Subsp. *tsugense*	Subsp. *contortae*
Mean Plant Height (cm)		
Male	7.8	5.6
Female	8.0	6.6
Plant Color		
Male	yellow-green	green-brown
Female	yellow-green/purple	green-brown
Mean Flower Diameter (mm)	4.3	3.6
Host Susceptibility		
Shore Pine	Rare	Principal
Western	Principal	Occasional
Peak Seed Dispersal	One week later than subsp. *contortae*	One week earlier than subsp. *tsugense*

Table 4. Comparison of the principal differences between Pacific silver fir dwarf mistletoe (*A. tsugense* subsp. *amabilae*), western hemlock dwarf mistletoe (*A. tsugense* subsp. *tsugense*), and mountain hemlock dwarf mistletoe (*A. tsugense* subsp. *mertensianae*) from Mathiasen and Daugherty (2007).

Characters	Subsp. *amabilae*	Subsp. *tsugense*	Subsp. *mertensianae*
Mean Plant Height (cm)			
Male	9.4	7.8	5.7
Female	10.6	8.0	6.1
Mean Basal Diameter (mm)			
Male	3.1	2.6	1.9
Female	3.4	2.7	2.2
Mean Flower Diameter (mm)			
	3.5	3.6	2.7
Host Susceptibility			
Pacific Silver Fir	Principal	Occasional	Immune
Western Hemlock	Occasional	Principal	Occasional
Mountain Hemlock	Principal	Occasional	Principal
Noble Fir	Principal	Occasional	Unknown
Western White Pine	Rare	Rare	Occasional

Not only are the subspecies discussed above morphologically and physiologically distinct from each other, they are also distinct from *A. campylopodum*. Both univariate and multivariate statistical analyses of the morphologies of the subspecies of *A. tsugense* compared to *A. campylopodum* demonstrated that the subspecies were morphologically different (Mathiasen and Kenaley 2017). *Arceuthobium tsugense* subsp. *tsugense*, subsp. *amabilae*, and subsp. *mertensianae* were the most similar subspecies, but subsp. *contortae* was clearly very different from those subspecies as well as from *A. campylopodum* (Table 6, Figure 1). Again, this supports raising subsp. *contortae* to specific rank.

ADDITIONAL PROPOSED CHANGES FOR *ARCEUTHOBIUM*

A major change in the classification of *Arceuthobium* was proposed by Dan Nickrent (Nickrent et al. 2004). Nickrent and his colleagues completed their phylogenetic analyses of *Arceuthobium* based on ribosomal and plastid DNA sequence data of the internal transcribed spacer (ITS) region (New and Old World taxa) and *trnT-L-F* (New World taxa only), respectively. The separate and combined analyses of these gene regions supported the recognition of only 26 species and did not address explicitly the phylogenetic relationships among subspecies or special forms. Moreover, minus *Arceuthobium blumeri*, ITS and *trnT-L-F* sequences among *Campylopoda* species recognized by Hawksworth and Wiens (1996) were identical or nearly homogenous differing by only a few nucleotides and, hence, Nickrent and colleagues suggested that 11 previously recognized species were conspecific with *A. campylopodum*. Because their classification only recognized monophyletic species that were differentiated solely by molecular data, it recognized just 26 species of *Arceuthobium*, no subspecies and no special forms of *A. abietinum* (Table 5). Several species recognized by Hawksworth and Wiens were grouped together because the DNA sequences in the molecular regions Nickrent et al. (2004) examined were very similar. Because this classification is based only on molecular data and does not account for morphological or physiological (phenology, chemistry, and host affinities) differences among dwarf mistletoe populations, its practical application by forest pathologists is difficult, if not impossible. This is primarily because the classification groups the species recognized by Hawksworth and Wiens that are among the most economically important taxa all under one species: *A. campylopodum* (Table 5). This includes *A. abietinum* on true firs, *A. californicum* on sugar pine, *A. laricis* on western larch, and *A. tsugense* on hemlocks. However, Nickrent decided not to adopt this proposed classification for *Arceuthobium* in his treatment for the Flora of North America (see below). We are not aware that this classification has been followed to any large extent by investigators working on *Arceuthobium*.

Another major and very conservative interpretation for the classification of species in series *Campylopoda* was presented in the second revision of the Jepson manual: vascular plants of California by Job Kuijt (Kuijt 2012). Kuijt classified all Californian *Arceuthobium* recognized by Hawksworth and Wiens in *Campylopoda* under *A. campylopodum*; thus, reducing the number of species found in the state from 12 to only three: *A. americanum*, *A. campylopdum*, and *A. douglasii*. This very different interpretation “lumped” nearly all of the species found in California described by George Engelmann in the late 1800s (Table 1) and by other plant taxonomists in the early 1900s under one species: *A. campylopodum* (Table 7). We recommend that Kuijt’s treatment for dwarf mistletoes in California not be followed as it does not represent the high diversity of dwarf mistletoes in California and does not reflect the host specialization that these parasitic plants exhibit on the Pinaceae found there. Because Kuijt’s treatment for *Arceuthobium* represented a major change in the classification of this economically and ecologically important genus in California, we published a critique of Kuijt’s treatment and presented an alternative treatment for the genus which essentially followed the Hawksworth and Wiens classification, but with the addition of one subspecies described since 1996 (Mathiasen and Kenaley 2016).

Table 5. Morphological comparison of male and female plants for *Arceuthobium campylopodum*, *A. tsugense* subsp. *amabilae*, *A. tsugense* subsp. *contortae*, *A. tsugense* subsp. *mertensianae*, and *A. tsugense* subsp. *tsugense*. Data are listed as mean (95% confidence interval, α= 0.05) [N= measurements]. Lower case letters in brackets designate measurement sizes already listed in the same column. Means followed by different capital letters in the same row were significantly different according to a Tukey's honestly significant difference (HSD) test (α= 0.05). Likewise, by row, bolded cells indicate a significant difference in mean measurement compared to *A. campylopodum* (control) using a Dunnett's test. Plant heights are in cm whereas all other measurements are in mm. a—Plant height (PH), basal diameter (BD), length and width of third internode (LTI, WTI), staminate spike length and width (SSL, SSW), flower diameter (FD), petal length and width (PL, PW), anther diameter (AD), anther distance to tip (ADT), fruit length and width (FL, FW), and seed length and width (SL, SW). Measurements of FD for subsp. *contortae* did not distinguish between 3- and 4-merous flowers so comparisons were made with the other taxa by combining all FD measurements. Table from Mathiasen and Kenaley (2017).

Character	***Arceuthobium campylopodum***	***amabilae***	***contortae***	***mertensianae***	***tsugense***
PH					
Female	10.4 A (±0.2) [600a]	10.6 A (±0.2) [380a]	**6.6 B (±0.2) [110a]**	**6.1 B (±0.3) [160a]**	**8.0 C (±0.2) [265a]**
Male	9.7 A (±0.2) [a]	9.4 A (±0.3) [280b]	**5.6 B (±0.3) [a]**	**5.7 B (±0.3) [130b]**	**7.8 C (±0.5) [270b]**
BD					
Female	3.4 A (±0.1) [a]	3.4 A (±0.1) [388]	3.3 A (±0.1) [a]	**2.2 B (±0.1) [a]**	**2.7 B (±0.1) [a]**
Male	3.2 A (±0.0) [a]	**3.1 B (±0.1) [b]**	**2.8 C (±0.1) [a]**	**1.9 D (±0.1) [b]**	**2.6 E (±0.1) [b]**
LTI					
Female	13.0 A (±0.2) [a]	**15.0 B (±0.4) [a]**	**10.7 C (±0.4) [a]**	**9.8 C (±0.5) [a]**	**12.3 D (±0.4) [a]**
Male	11.9 A (±0.3) [a]	**12.6 B (±0.4) [b]**	**9.2 C (±0.4) [a]**	**8.0 D (±0.6) [b]**	11.8 A (±0.4) [b]
WTI					
Female	2.5 A (±0.0) [a]	**2.0 B (±0.0) [a]**	**1.7 C (±0.0) [a]**	**1.4 D (±0.0) [a]**	**1.6 C (±0.1) [a]**
Male	2.5 A (±0.0) [a]	**1.9 B (±0.0) [b]**	**1.8 B (±0.0) [a]**	**1.3 C (±0.0) [b]**	**1.6 D (±0.0) [b]**
SSL	12.7 A (±0.3)[760b]	**9.5 B (±0.4) [a]**	12.6 A (±0.6) [a]	**6.9 C (±0.2) [300c]**	**10.8 D (±0.4) [260c]**
SSW	3.0 A (±0.0) [b]	**1.3 B (±0.0) [a]**	**3.4 C (±0.1) [a]**	**1.2 D (±0.0) [c]**	**1.6 E (±0.1) [c]**
FD					
3-merous	3.1 A (±0.1) [400]	3.2 A (±0.1) [210]	—	**2.4 B (±0.0) [150d]**	3.1 A (±0.1) [115d]
4-merous	4.2 A (±0.0) [360]	**3.7 B (±0.1) [200]**	—	**3.1 C (±0.0) [d]**	**3.8 B (±0.1) [d]**
3&4-merous	3.6 A (±0.0) [b]	**3.4 B (±0.1) [410]**	**4.3 C (±0.1) [a]**	**2.7 D (±0.0) [c]**	**3.5 B (±0.1) [230]**
PL	1.6 A (±0.0) [b]	**1.4 B (±0.0) [a]**	**1.7 A (±0.1) [a]**	**1.1 C (±0.0) [c]**	**1.5 D (±0.0) [c]**
PW	1.4 A (±0.0) [b]	**1.2 B (±0.0) [a]**	1.4 A (±0.0) [a]	**1.0 C (±0.0) [c]**	**1.2 B (±0.0) [c]**
AD	0.6 A (±0.0) [b]	**0.7 B (±0.0) [a]**	**0.7 B (±0.0) [a]**	**0.5 C (±0.0) [c]**	**0.7 B (±0.0) [c]**
ADT	0.6 A (±0.0) [910]	**0.5 B (±0.0) [a]**	**0.9 C (±0.0) [a]**	**0.4 D (±0.0) [c]**	**0.5 E (±0.0) [c]**
FL	5.4 A (±0.0) [480c]	**4.7 B (±0.1) [260b]**	**4.6 BD (±0.1) [a]**	**3.8 C (±0.1) [d]**	**4.4 D (±0.0) [210f]**
FW	3.7 A (±0.0) [c]	**3.0 B (±0.0) [b]**	**3.1 B (±0.1) [a]**	**2.6 C (±0.1) [d]**	**2.9 D (±0.0) [e]**
SL	3.5 A (±0.0) [c]	**3.0 B (±0.0) [b]**	**2.5 C (±0.1)[100b]**	**2.8 D (±0.0) [d]**	**2.6 E (±0.0) [200f]**
SW	1.5 A (±0.0) [c]	**1.2 B (±0.0) [b]**	**1.4 C (±0.0) [b]**	**1.1 D (±0.0) [d]**	**1.1 B (±0.0) [f]**

Table 6. Classification of *Arceuthobium* proposed by Nickrent et al. (2004) based on maximum parsimony analyses using ribosomal and/or plastid DNA sequence data.

United States and Canada	**Mexico and Central America**	**Europe and Africa**	**Asia**
A. americanum	*A. abietis-religiosae*	*A. azoricum*	*A. chinense*
A. campylopodum	*A. bicarinatum*	*A. juniperi-procerae*	*A. minutissimum*
A. divaricatum	*A. blumeri*	*A. oxycedri*	*A. pini*
A. douglasii	*A. globosum*		*A. sichuanense*
A. gillii	*A. guatemalense*		*A. tibetense*
A. pusillum	*A. hondurense*		
	A. pendens		
	A. rubrum		
	A. strictum		
	A. vaginatum		
	A. verticilliflorum		
	A. yecorense		

Table 7. Comparison of contemporary treatments proposed for series *Campylopoda*.

Hawksworth and Wiens (1996)	**Nickrent (2012, 2016)[1]**	**Kuijt (2012)**
A. abietinum	*A. campylopodum*	*A. campylopodum*
f. sp. *concoloris*	subsp. *abietinum*	
f. sp. *magnificae*	subsp. *apachecum*	
A. apachecum	subsp. *blumeri*	
A. blumeri	subsp. *californicum*	
A. californicum	subsp. *campylopodum*	
A. campylopodum	subsp. *cyanocarpum*	
A. cyanocarpum	subsp. *laricis*	
A. laricis	subsp. *littorum*	
A. microcarpum	subsp. *microcarpum*	
A. monticola	subsp. *monticola*	
A. occidentale	subsp. *occidentale*	
A. siskiyouense	subsp. *siskiyouense*	
A. tsugense	subsp. *tsugense*	
subsp. *tsugense*	*A. divaricatum*	
subsp. *mertensianae*		
A. divaricatum		
A. guatemalense		
A. pendens		

[1] *Arceuthobium guatemalense* and *A. pendens* moved to section *Penda* (Nickrent et al. 2004).

The next major modification of Hawksworth and Wiens' classification for series *Campylopoda* was proposed by Dan Nickrent (Nickrent 2012). He recombined nearly all of the species recognized in series *Campylopoda* by Hawksworth and Wiens (1996) as subspecies of *A. campylopodum* (Table 7). Only *A. divaricatum* was retained as a separate species and *A. pendens* and *A. guatemalense* were transferred to a different section (section *Penda*) (Nickrent et al. 2004). Even though Nickrent's molecular data demonstrated that *A. blumeri* (a parasite of southwestern white pine) was genetically distinct from *A. campylopodum*, he also grouped it as a subspecies of the latter species. While this treatment was not nearly as "radical" as Kuijt's (2012) treatment in the Jepson manual, Nickrent's recent classification also has several inherent problems which are discussed below. Nickrent based this treatment on his limited molecular data for ITS and *trnT-L-F* DNA sequences and argued that since most of the species in series *Campylopoda* had similar morphological characteristics and overlapping host ranges they should be considered as ecotypes. He also argued that the sizes of plants and their flowering times could be linked to elevational gradients which he interpreted as further evidence of ecotypic variation among the species. He then concluded that since many plant ecotypes have been classified as subspecies, the species of dwarf mistletoes in series *Campylopoda* should also be classified at this taxonomic rank. In summary, Nickrent (2012) based his decision to recombine most of the species in series *Campylopoda* as subspecies of *A. campylopodum* using the following reasons:

1. The size ranges of the morphological characters used by Hawksworth and Wiens to segregate species overlap.

2. Dwarf mistletoes are not host specific because they often parasitize more than one principal host and their host ranges may overlap; several species frequently parasitize the same hosts but to a lesser extent than their principal hosts.

3. Several species are sympatric (i.e. occur in the same area), yet their interfertility remains unknown. Often their flowering periods overlap, but there is no positive evidence they are not interfertile.

4. The molecular data available thus far (ITS and *trnT-L-F*) indicates most of the species are closely related and have few genetic differences using those markers.

5. Plant size and phenology may be correlated with elevational gradients; taxa with smaller plants and earlier flowering periods occur at higher elevations.

6. Conclusion: the majority of the species recognized by Hawksworth and Wiens in series *Camplopoda* represent ecotypes adapted to different environments (their hosts) and because other treatments of ecotypes have used subspecies designations, it would be appropriate to recombine the species in series *Campylopoda* as subspecies of *A. campylopodum* (except *A. divaricatum*).

CLASSIFICATION OF *ARCEUTHOBIUM* IN THE FLORA OF NORTH AMERICA

Every forest pathologist, botanist, and forester who works with *Arceuthobium* in any capacity needs to be aware that Dan Nickrent has now published his treatment for the mistletoe family Viscaceae in Volume 12 of the Flora of North America (FNA) (Nickrent 2016). Essentially, Nickrent followed his 2012 reclassification of almost all of the species in series *Campylopoda* as subspecies of *A. campylopodum* (Table 7). This treatment has many inherent problems because it doesn't recognize the special forms of *A. abietinum* or the subspecies of *A. tsugense* recognized by Hawksworth and Wiens and ourselves. In addition, it provides very little host range information for the taxa he included under *A. campylopodum*.

The application of Nickrent's treatment in the FNA will be challenging for several reasons:

1. Nickrent (2016), as well as his earlier treatment of series *Campylopoda* (Nickrent 2012), misrepresented the observed and quantified host affinities of subsp. *tsugense* (Hawksworth and Wiens 1996; Mathiasen and Daugherty 2005, Mathiasen and Kenaley 2017). Nickrent included Pacific silver fir, subalpine fir, noble fir, shore pine, western hemlock, and mountain hemlock all as principal hosts of his *A. campylopodum* subsp. *tsugense*, but this has been demonstrated to be incorrect (Mathiasen and Daugherty 2005, 2007). Pacific silver fir, noble fir, and mountain hemlock have been shown to be only occasional hosts of *A. tsugense* subsp. *tsugense*, and therefore, are much less susceptible than the principal host designation assigned by Nickrent (Mathiasen and Daugherty 2007). Furthermore, Nickrent's grouping of secondary, occasional, and rare hosts for his *A. campylopodum* subsp. *tsugense* was an impractical summation in that it provided users of his treatment with no specific information on the relative susceptibility of each host. Susceptibility information is of critical importance to foresters and forest pathologists who are interested in mitigating the growth impacts dwarf mistletoes have on their hosts, or if appropriate, conserving them for wildlife habitat or because of their rarity in specific regions. For example, most of the hosts Nickrent listed as secondary-to-rare hosts were actually rare hosts of *A. tsugense* subsp. *tsugense*. Nickrent listed Douglas-fir (*Pseudotsuga menziesii*) as a host of hemlock dwarf mistletoe, but it is actually immune to both subsp. *contortae* and subsp. *mertensianae*. Douglas-fir has only been reported as a rare host of *A. tsugense* subsp. *tsugense* (Hunt and Smith 1978) and, currently, there is no information relative to the susceptibility of Douglas-fir to subsp. *amabilae*.

2. Nickrent (2016) recommended the subspecies of *A. tsugense*, that we and other investigators recognize as valid taxa, be treated as host races (or forms) with no taxonomic status. If these dwarf mistletoe populations have not been given taxonomic status, it is possible they will not be recognized by foresters, botanists, wildlife biologists, or conservationists interested in their management or preservation. Therefore, we recommend that resource managers working with these parasitic plants not adopt Nickrent's (2016) classification of *A. tsugense* as a subspecies of *A. campylopodum*. It is much more practical and useful to recognize the classification of the dwarf mistletoe populations parasitizing western hemlock as a principal host as *A. tsugense* subsp. *tsugense* and, therefore, the populations on mountain hemlock, Pacific silver fir, noble fir, and shore pine as subspecies of *A. tsugense*. The latter working classification is strongly supported by studies we recently published detailing the morphological differences among these subspecies using robust statistical procedures (Mathiasen and Kenaley 2015b, 2017). This classification was also supported by the clear differences in the host affinities of each of the subspecies if *A. tsugense* reported by several investigators (Tables 8 and 9).

3. Because Nickrent (2016) grouped all of the taxa we recognize as subspecies of *A. tsugense* under *A. campylopodum*, using his keys and descriptions for these dwarf mistletoe populations would be essentially untenable. Applying the information in his treatment would seldom lead to the correct classification or field determination of the populations of *A. tsugense* from central Oregon through Washington where subsp. *tsugense* and subsp. *amabilae* predominate. Likewise, *A. tsugense* subsp. *mertensianae* is the most common dwarf mistletoe on mountain hemlock in southern Oregon and northern California and its circumscription under *A. campylopodum* subsp. *tsugense* would significantly complicate the determination of this genetically distinct taxon in this region. Furthermore, many of the values for key morphological characters such as plant heights, third internode dimensions, flower diameters and fruit dimensions used by Nickrent (2016) were based on data in Hawksworth and Wiens (1996) and do not represent the most current data for these characters reported in our studies (Mathiasen and Kenaley 2015b, 2017).

Table 8. Infection of Pacific silver fir (PSF), noble fir (NF), mountain hemlock (MH), western hemlock (WH), shore pine (SP), and western white pine (WWP) by *Arceuthobium tsugense* subsp. *tsugense*, subsp. *amabilae*, subsp. *mertensianae*, and subsp. *contortae*. Combined data for trees > 1 cm in diameter at breast height from Mathiasen & Hawksworth (1988), Wass & Mathiasen (2003), Mathiasen & Daugherty (2005, 2008), Mathiasen (2011), and Mathiasen & Daugherty (unpublished). An asterisk denotes that no data were available. [1]—Western white pine has been reported to be rarely infected by *Arceuthobium tsugense* subsp. *amabilae*, subsp. *tsugense*, and subsp. *contortae* (Gill 1935; Kuijt 1956; Hawksworth et al. 1992; Hawksworth & Wiens 1996; Wass & Mathiasen 2003; Mathiasen & Daugherty 2007).

Arceuthobium tsugense subsp.

	amabilae			***contortae***		
Host	N	Percent infection	Mean DMR	N	Percent infection	Mean DMR
PSF	2130	95	3.5	*	*	*
NF	1478	92	2.8	*	*	*
MH	2040	93	3.9	*	*	*
WH	268	18	0.4	802	21	0.3
SP	*	*	*	1576	97	4.3
WWP[1]	*	*	*	*	*	*

	mertensianae			***tsugense***		
	N	Percent infection	Mean DMR	N	Percent infection	Mean DMR
PSF	127	0	0	2397	35	0.8
NF	145	0	0	247	14	0.3
MH	2123	94	3.5	165	27	0.7
WH	*	*	*	2495	96	3.1
SP	*	*	*	77	1	0.1
WWP[1]	424	30	0.5	438	0	0

Table 9. Susceptibility of hosts to *Arceuthobium tsugense* subsp. *amabilae*, subsp. *contortae*, subsp. *mertensianae*, and subsp. *tsugense* based on natural infection data in Table 8. Principal host (>90% infection), occasional host (5- 50% infection), rare (<5%, but > 0% infection), and immune (0% infection).

Host Susceptibility

Host	*amabilae*	*contortae*	*mertensianae*	*tsugense*
Pacific silver fir	Principal	Unknown	Immune	Occasional
Nobel Fir	Principal	Unknown	Occasional	Occasional
Mountain hemlock	Principal	Unknown	Principal	Occasional
Western hemlock	Occasional	Occasional	Occasional	Principal
Shore pine	Unknown	Principal	Unknown	Rare
Western white pine	Rare	Rare	Occasional	Rare

Table 10. Recommended classification for taxa in *Arceuthobium*, series *Campylopoda*. New subspecies described since Hawksworth and Wiens (1996) in bold type.

A. abietinum
  formae sp. *concoloris*
  formae sp. *magnificae*
  subsp. *wiensii*
A. apachecum
A. blumeri
A. californicum
A. campylopodum
A. cyanocarpum
A. divaricatum
A. laricis
A. littorum
A. microcarpum
  subsp. *aristatae*
A. monticola
A. occidentale
A. siskiyouense
A. tsugense
  subsp. *tsugense*
  subsp. *contortae*
  subsp. *amabilae*
  subsp. *mertensianae*

.

4. Another major problem with the treatment for series *Campylopoda* in the FNA is that Nickrent's classification of *Arceuthobium abietinum* as a subspecies of *A. campylopodum* precludes the recognition of the special forms that specifically parasitize either white fir or red fir in the Sierra Nevada Mountains. These dwarf mistletoe populations have been demonstrated to be host specific; f. sp. *concoloris* infects white fir and not red fir and f. sp. *magnificae* only infects red fir (Parmeter and Scharpf 1963; Hawksworth and Wiens 1972, 1996). Recognizing these dwarf mistletoe as distinct parasites of their respective hosts is critical to their management (Mathiasen and Kenaley 2016). In addition, the Nickrent (2016) treatment does not recognize *A. abietinum* subsp. *wiensii* (Wiens' dwarf mistletoe) which severely parasitizes Brewer spruce and red fir, and to a much lesser extent white fir, in northwestern California and southwestern Oregon. This cryptic and rare subspecies of fir dwarf mistletoe has been considered for listing as a sensitive plant by the California Botanical Society, but it has not yet been assigned a sensitive plant designation. We believe it deserves to be listed because it is so rare that wildfires could eventually eliminate all of the viable populations of Wiens' dwarf mistletoe. For example, the 2002 Biscuit Fire in southwestern Oregon nearly eliminated Wien's dwarf mistletoe in the vicinity of Flat Top Mountain. However, if the FNA treatment is applied to fir dwarf mistletoe as *A. campylopodum* subsp. *abietinum*, Wiens' dwarf mistletoe will be unrecognized and therefore, cannot be considered for listing as a sensitive, threatened, or endangered plant.

Because Nickrent's treatment of *Arceuthobium* has been published in the FNA, which is a major flora for the United States and Canada, it may gain acceptance by some scientists who are not as knowledgeable as foresters and forest pathologists regarding the Hawksworth and Wiens' classification. Therefore, you will probably start seeing references made to *A. campylopodum* subsp. *abietinum* and *A. campylopodum* subsp. *tsugense* which may be actually referring to different dwarf mistletoe populations from those recognized as *A. abietinum* and *A. tsugense* in Hawksworth and Wiens (1996).

FINAL COMMENTS REGARDING THE CLASSIFICATION OF *ARCEUTHOBIUM*

Typically, forest pathologists don't enjoy nomenclatural changes whether it is for fungi associated with important tree diseases or the dwarf mistletoes. Most forest pathologists and many foresters in general, are knowledgeable of the Hawksworth and Wiens classification for *Arceuthobium* and this is what they use whenever identifying, studying, or managing these parasitic flowering plants. Hawksworth and Wiens were the "modern architects" of the genus and their detailed work on this group of economically important pathogens is by far the most comprehensive and accurate information we have available regarding their classification. All of the current Forest Insect and Disease Leaflets for dwarf mistletoes follow their classification.

Those of us continuing taxonomic work on *Arceuthobium* have learned that usually Hawksworth and Wiens "had it right;" but occasionally they missed some minor details about the morphology or host preferences of specific populations that, for a variety of reasons, they did not have enough time to study in more detail. Our efforts have attempted to identify some of those dwarf mistletoe populations, spend more time working on them than Hawksworth and Wiens could, and use many of the same techniques they used to "fine tune" the basic classification system they developed through over 40 years of intensive field and laboratory studies. None of the new subspecies we have described over the last 10 years change the Hawksworth and Wiens classification to any large extent. They are only different interpretations of how to classify some specific dwarf mistletoe populations using additional morphological, phenological, and host range information that has become available since 1996. In addition, we have now applied more robust multivariate statistical analyses using the old and new morphological data we have available for most of the species in series *Campylopoda* (Mathiasen and Kenaley 2015a, 2015b, 2016, 2017; Reif et al. 2015; Kenaley et al. 2016; Mathiasen et al. 2016). We are now expanding our studies to test the monophyly of longstanding taxa in *Arceuthobium* and reconstruct a genus-wide phylogeny that could be used to develop a revised classification system for the group. We are presently utilizing next-generation sequencing technology in combination with a 'genome skimming' approach to generate deep sequencing data for the plastome (cpDNA), mitogenome (mtDNA), and the full ribosomal cistron (nrDNA) of taxa in series *Campylopoda* as well as other New and Old world *Arceuthobium* (Straub et al. 2012). To date, we have sequenced nearly all *Campylopoda* taxa as well as additional specimens of *Arceuthobium* from China and Mexico and, have been begun processing read data. Over the next year, we will look to finish the sequencing portion of the project and begin assembling cpDNA, mtDNA, and nrDNA sequences for downstream phylogenomic analyses. These analyses should yield many novel insights into the evolutionary histories and phylogenetic relationships among taxa in the series as well as provide valuable single nucleotide polymorphic (SNP) makers for population-based studies. But for now, we recommend that the classification for series *Campylopoda* presented in Table 10 be used for this taxonomically difficult group of dwarf mistletoes.

The four new subspecies we and our co-workers have described in series *Campylopoda* (Table 10) have been validly published with Latin diagnoses in peer-reviewed botanical journals and so they are available for use by anyone working with the specific dwarf mistletoe populations they represent. As far as we are concerned, there are no tenable reasons or valid arguments why anyone should not continue to use the basic Hawksworth and Wiens 1996 classification for *Arceuthobium*. It is an outstanding achievement and deals with nearly all of the subtleties of most dwarf mistletoe populations in the United States and Canada. Some forest pathologists who deal with specific populations, such as those in northern CA and southern OR, may feel that more "lumping" for that region may be warranted. However, the treatment by Kuijt (2012) classifying all of the dwarf mistletoes of series *Campylopoda* in California as *A. campylopodum* is not supported by work in the mid-1800s to early-1900s, that of Hawksworth and Wiens, or by our recent studies. Furthermore, based on the morphological, phenological, and host range data in Hawksworth and Wiens' 1996 monograph and our recent studies, the recombination of species in series *Campylopoda* as subspecies under *A. campylopodum* by Nickrent (2012, 2016) is not supported and is not a practical treatment for use by resource managers.

There are several distinct advantages for continuing the use of the classification for series *Campylopoda* put forth by Hawksworth and Wiens (1972, 1996) and modified as presented in Table 10.

1. This treatment uses morphology, phenology, plant chemistry, host susceptibility, and geographic distributions for taxonomic interpretations.

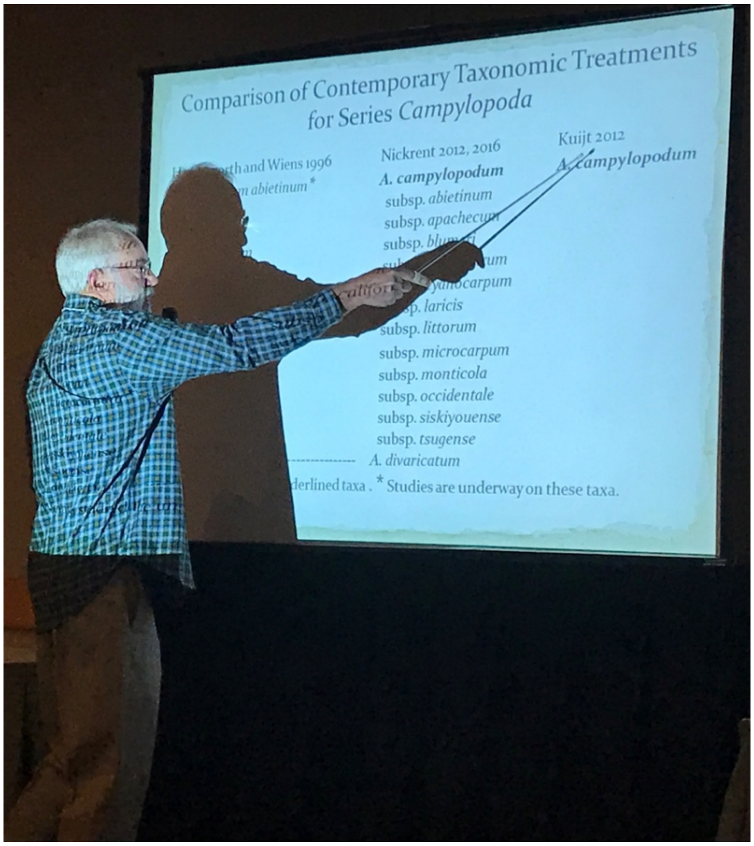
2. It recognizes cryptic and rare populations of *Arceuthobium* as species or subspecies which facilitates the ability to conserve rare lineages, e.g. *A. abietinum* subsp. *wiensii*.

3. Because it recognizes and classifies differences in host susceptibility among taxa, it is a practical classification for managing *Arceuthobium* populations to increase or decrease their abundance.

4. It provides a consistent and well-known classification that has been followed by most investigators studying *Arceuthobium* since Hawksworth and Wiens (1972); published over 40 years ago.

5. Because the treatment uses host specificity and geographic distributions for the classification of taxa, it provides a relatively easy and practical system for the identification of species and subspecies in series *Campylopoda*.

With regards to shore pine dwarf mistletoe (*Arceuthobium tsugense* subsp. *contortae*) in British Columbia, we will continue to argue for and recommend that it is a more desirable alternative to treat it as a subspecies of *A. tsugense* than as a race. Once we manage to obtain additional molecular data using more variable markers, we may have sufficient evidence to describe the shore pine dwarf mistletoe at the specific rank. But even without that data, our analyses of the morphological data we do have has indicated that subsp. *contortae* is morphologically quite distinct from subsp. *tsugense* and deserves taxonomic recognition beyond the classification of race as in Hawksworth and Wiens (1996) or as a form as proposed by Nickrent (2016). We plan to continue our efforts to 'fine tune' the Hawksworth and Wiens classification system and this may lead to more descriptions of new subspecies. But we will continue to follow the Hawksworth and Wiens basic classification for *Arceuthobium* and recommend that the treatment proposed in the FNA by Nickrent (2016), **NOT** be adopted for the classification of taxa in series *Campylopoda*. Moreover, botanists as well as forest pathologists and resource managers must be aware of the changes to the classification of taxa in series *Campylopoda* proposed by Nickrent (2012, 2016) as the application of his treatment in future studies could significantly complicate communication regarding these dwarf mistletoes. To avoid translational difficulties between Nickrent (2012, 2016) and Hawksworth and Wiens (1996), it is imperative that future *Arceuthobium* studies utilizing Nickrent's classification explicitly state at a minimum the host tree species and geographic area where the work occurred. With this information in hand, the likely Hawksworth and Wiens taxon, or taxa, can be readily determined.



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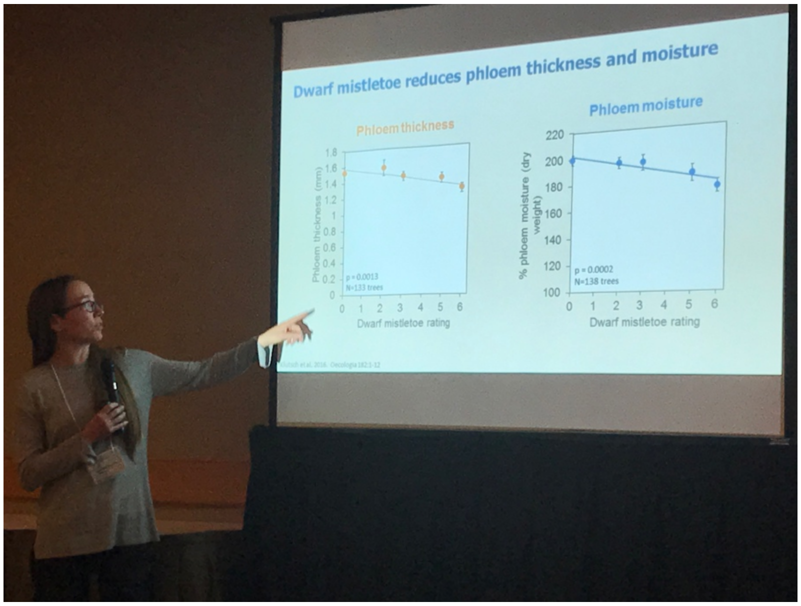
USING JACK PINE-*ARCEUTHOBIUM AMERICANUM* INTERACTIONS TO INVESTIGATE THE SUCCESS OF MOUNTAIN PINE BEETLE IN THE BOREAL FOREST

Jennifer Klutsch[1], *Ahmed Najar*[1], *Jonathan Cale*[1], *Patrick Sherwood*[2,3],
Enrico Bonello[2], and *Nadir Erbilgin*[1]

SUMMARY

Mountain pine beetle (*Dendroctonus ponderosae*) has recently expanded its range into jack pine (*Pinus banksiana*) forests where it will not only interact with this new host tree species, but also with a myriad of other organisms that also share jack pine, such as lodgepole pine dwarf mistletoe (*Arceuthobium americanum*). Understanding the major factors and mechanisms that mediate plant-herbivore-pathogen interactions, such as plant defenses, will be important for determining the impact of mountain pine beetle. We examined the impact of multiple classes of induced host defense compounds (monoterpenes and phenolics) and phloem physical characteristics due to the infection by this widespread native dwarf mistletoe on the success of mountain pine beetle and its associated fungi (*Grosmannia clavigera*). There was a significant decrease in both phloem thickness and moisture with increasing dwarf mistletoe infection severity. Similarly, 10-yr resin duct production and radial increment growth also significantly decreased with increasing infection level. Dwarf mistletoe infection also had a systemic effect on monoterpene concentrations; we found increasing concentrations of monoterpenes at moderate severities and decreasing concentrations at high severities. Dwarf mistletoe-induced changes in monoterpenes seem to result in the systemic induced resistance in trees with moderate dwarf mistletoe severity because they were most resistant to *G. clavigera* (i.e., short lesion lengths). In contrast, phenolic compounds increased in amount with greater dwarf mistletoe infection severity but decreased after inoculation with *G. clavigera*. This inverse response to infection between monoterpenes and phenolics suggests that phenolics are detoxified by the fungus or there are tradeoffs between these two major defense classes. Furthermore, dwarf mistletoe-induced changes in defensive and physical characteristics reduced the competitive advantage of the subcortical insect community on mountain pine beetle performance. While dwarf mistletoe-infected jack pine are poor hosts to mountain pine beetle, they are more susceptible due to lower chemical and anatomical defenses and reduced competition from woodboring beetles. Therefore, infected stands of jack pine may be used as part of a mountain pine beetle detection strategy.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Department of Renewable Resources, University of Alberta, Edmonton, Alberta. [2]Department of Plant Pathology, The Ohio State University, Columbus, Ohio. [3]Current address: The James Hutton Institute, Craigiebuckler Aberdeen, Scotland, United Kingdom.



Dwarf mistletoe reduces phloem thickness and moisture

Klutsch et al. 2016. Oecologia 182:1-12

AGROBACTERIUM-MEDIATED INSERTIONAL MUTAGENESIS OF THE STEM CANKER PATHOGEN, *SPHAERULINA MUSIVA*

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ABSTRACT

Sphaerulina musiva (Peck) Quaedvlieg, Verkley & Crous, is an introduced fungal pathogen in northwestern North America that causes a detrimental leaf spot and stem canker disease of *Populus* species. *Populus trichocarpa* Torr. & A. Gray, a dominant riparian species in this region and the model woody plant species is susceptible to *S. musiva*. In an attempt to further understand the host-parasite interaction between *Populus trichocarpa* and *Sphaerulina musiva*, a modified *Agrobacterium*-mediated transformation mutagenesis protocol was developed. This method randomly inserts a transfer DNA (tDNA) fragment containing a hygromycin-resistance cassette into the chosen organism during co-cultivation with *Agrobacterium*. The random insertion will result in isolates with new phenotypes potentially including some with a lack of virulence. A novel *in-vitro* inoculation protocol will help identify the isolates having reduced virulence on susceptible *Populus trichocarpa* plants grown in tissue culture. Once isolates with a change in virulence have been identified, primers specific to the tDNA insertion and Sanger sequencing will be used to identify genomic DNA that flanks putative loci corresponding to candidate genes.

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MOLECULAR ASSAY FOR FIELD DETECTION OF *CRONARTIUM RIBICOLA*

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SUMMARY

All North American white pine species are susceptible to white pine blister rust disease caused by the invasive rust pathogen, *Cronartium ribicola*. However, positive identification of blister rust cankers can be difficult due to shared symptoms with other damaging agents and lack of pathogenic signs year round. The most definitive sign of the pathogen on white pine are aecia, but they are only present during a short window in spring, making it difficult for managers to identify the disease throughout the year. Spermogonia (pycnia) are sometimes visible at the canker margin from spring to fall, but they are more difficult to identify and can be easily confused with resin. Currently, identification of ambiguous cankers involves extracting and sequencing DNA from the site which can be costly and requires laboratory equipment and expertise. Thus there is need for a relatively quick and simple-to-use field assay for detection of *C. ribicola* on both leaf and wood tissues without specialized equipment.

Loop-mediated isothermal amplification (LAMP) is a DNA amplification technique developed in 2000 that requires no thermal cycling due to its complex primer design. The simplicity of use for this assay allows for its application in a field setting with minimal equipment; all that is required is a means to warm the sample tube(s) to 63°C (145°F) for 1 hour. Currently, specialized primers for use in the LAMP reaction have been developed specific to *C. ribicola* and are undergoing screening for effectiveness at identification of the pathogen against other *Cronartium* spp. This assay will continue to be improved upon accounting for sensitivity of detection within white pine wood tissue as well as leaf tissues of white pine and *Ribes* spp. Additionally, cost of the assay and storage requirements will be considered to ensure the assay is practical and applicable for use by surveyors in the field. It is projected that a simple 1 or 2 tube system will be available to foresters and land managers by summer 2018 for identification of this invasive pathogen in the field.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Colorado State University, Department of Bioagricultural Sciences and Pest Management, Fort Collins, Colorado. [2]Forest Health Protection, USDA Forest Service, Golden, Colorado.

INVESTIGATION AND CHARACTERIZATION OF *CRONARTIUM X FLEXILIS*, A HYBRID PINE STEM RUST

Kiah R. Allen[1], *Nicholas Feau*[1], and *Richard C. Hamelin*[1]

SUMMARY

White pine blister rust, caused by *Cronartium ribicola* J. C. Fisch, was introduced from Europe and Asia in the 19th century and is responsible for one of the most devastating forest disease outbreaks. This pathogen attacks the stems and branches of five-needle pines and alternates on currants and gooseberries (*Ribes* spp.). Comandra blister rust, caused by *C. comandra* Peck, is a native rust that attacks two-needle pines and alternates on bastard toadflax (*Comandra* spp.). The recent discovery of *Cronartium* x *flexili,* a hybrid between these two rusts, was unexpected because they do not share hosts. However, the impact of their hybridization is yet unknown. Our research objective is to determine the level of hybridization and introgression of the hybrid rust and assess its level of fitness. Aeciospores have been collected from *Pinus monticola* Douglas ex. D. Don*, P. albicaulis* Engelm*, P. flexilis* E. James and *P. contorta* Douglas from sites where the presence of the hybrid rust was previously reported (i.e. Smithers, BC and Waterton, AB). The samples will be divided in two subsets to perform: 1) SNP genotyping using genotyping-by-sequencing to analyze hybridization level, direction and pattern; and 2) inoculations on the hosts of the respective parent rusts to assess rust viability and host range. Assessing the potential impact of hybridization between a native and non-native tree rust will help to address disease outbreaks in terms of conservation and to inform forest stewards of better disease management strategies.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Department of Forest and Conservation Sciences, University of British Columbia, Vancouver, British Columbia.

AN EXAMINATION OF THE FACTORS INFLUENCING THE GENETIC STRUCTURE OF THE GLOBAL *PHAEOCRYPTOPUS GAEUMANNII* POPULATION

Patrick Bennett[1] and *Jeff Stone*[1]

Swiss needle cast (SNC), the Douglas-fir foliage disease caused by the fungus *Phaeocryptopus gaeumannii*, continues to intensify in western North America and now affects approximately 900,000 acres of coastal forest in Oregon and Washington. This has prompted research efforts to understand the potential drivers of its emergence in this region. Winton et al. (2006) described the existence of two reproductively isolated lineages of the fungus in costal northwestern Oregon, with one lineage (Lineage 2) found only in the coastal SNC epidemic zone. Some evidence suggested that this rare lineage may have contributed to the emergence of SNC in the Oregon Coast Range. The disease has also continued to intensify where Douglas-fir is planted as an exotic in forest plantations in Europe, New Zealand, and most recently in South America. The taxonomic placement of *P. gaeumannii* also requires revision, as molecular evidence indicates the species does not belong to the same taxonomic group as the type species of the genus *Phaeocryptopus*. Multiple sources have suggested that it should be reassigned to the Mycosphaerellaceae (Schoch et al. 2009, Winton et al. 2007a). The nomenclature associated with this taxonomic placement remains unresolved, and is further complicated by the fact that the two lineages may constitute separate phylogenetic species. These discoveries and unresolved issues formed the basis of our current research program. Our specific research objectives are as follows:

Population genetics: Employ SSR markers from Winton et al. (2007b) to examine factors influencing the genetic structure of native and invasive *P. gaeumannii* population.

- We have amassed a data set of approximately 3,600 multilocus SSR genotypes from U.SA., New Zealand, Australia, and Europe with plans to examine the influence of climate, anthropogenic introductions, reproductive mode(s), and demographic processes on population structure.

Phylogeography: Map the geographic distributions of the two *P. gaeumannii* lineages.

- Determine whether Lineage 2 occurs outside of western Oregon.
- Evaluate the most likely routes of introduction/migration for invasive populations.

Epidemiology: Investigate the relationship between the distributions of the *P. gaeumannii* lineages and disease severity.

- Is there evidence to suggest that they differ in aggressiveness?
- Examine the relationship between Lineage 2 and SNC severity at hierarchical spatial scales from trees to landscapes.

Phylogenetics: Determine whether the *P. gaeumannii* lineages constitute phylogenetic species.

- Should they be described as sister species in a new genus in the Mycosphaerellaceae?
- Construct multi-gene phylogenies with *P. gaeumannii* isolates from each lineage and closely-related fungi.

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This research will provide valuable information about the basic biology and epidemiology of *P. gaeumannii* and Swiss needle cast. This could serve as an excellent model system for studying the influence of climate change on pathogen emergence in native forest ecosystems, and provide a better understanding of the factors influencing the genetic structure of pathogen populations. Changes to the taxonomic classification and associated nomenclature will more accurately reflect the evolutionary relationships between *P. gaeumannii* and other fungi. Ultimately, this knowledge will inform management strategies that could mitigate the impacts of SNC.

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CONTRIBUTED POSTERS

RESISTANCE MECHANISMS TO *DIDYMASCELLA THUJINA* IN *THUJA* SPP.: A HISTOLOGICAL, CHEMICAL AND GENE EXPRESSION APPROACH

Juan A. Aldana[1], *John H. Russell*[2], and *Barbara J. Hawkins*[1]

ABSTRACT

Thuja plicata (western redcedar, WRC) is an important timber species in British Columbia (BC). WRC foliage is susceptible to *Didymascella thujina* (cedar leaf blight, CLB), which can cause growth reduction in young plantations. Resistance to CLB in *Thuja* spp. was first studied in 1956 in Denmark in *Thuja standishii*, WRC and hybrids between both species. It was proposed that an *R* gene from *T. standishii* was responsible for CLB-resistance, and that such gene was passed to the resulting resistant hybrids (Søegaard, 1956). Despite that, the molecular mechanisms of resistance to CLB in the *Thuja* species involved are still poorly understood. Here, the results of one study exploring the differences in leaf anatomy, chemical composition and gene expression among *Thuja* spp. plants with different CLB resistance are presented.

One *T. standishii* clone, one *T. standishii* × *plicata* clone, and two self-pollinated (five generations) WRC seedling lines were investigated. The plant material was characterized by measuring 13 leaf histological variables. A time-course experiment was carried out as well, comparing real and mock CLB infections under controlled conditions using CLB-sporulating cuttings collected in a WRC progeny trial. Foliar samples were collected within 8 days and used for chemical composition (mineral nutrients, terpenes and acid detergent fibre, 60 variables in total) and *RNA*-Seq (100bp paired-end Illumina® HiSeq 2000, 48 samples in total) analyses. Disease resistence of each line was evaluated measuring the disease severity. A reference assembly and the differential expression (DE) matrix were produced for the gene expression part.

CLB was significantly less severe in *T. standishii* and the hybrid than WRC ($p = 0.0020$), and both species had significantly thicker cuticles ($p = 0.0025$) in comparison to WRC lines. Aluminum (Al) was the only chemical variable with significant differences between real and mock inoculations over time ($p = 0.0003$). Stability selection analysis (Meinshausen & Bühlmann, 2010) on the DE transcriptomic data using Al as response variable revealed up-regulation of sequences involved in calcium signalling, the phospholipid pathway and defense, as well as down-regulation of transcripts related to regulation of gene expression. The transcriptomic analysis also suggested changes in the expression levels of transcripts related to heat shock and sulfate transport. Grade of Membership analysis (Dey *et al*., 2017) on the DE data revealed one topic with higher ω values in *T. standishii*, two in *T. standishii* × *plicata* and one in both WRC lines. Bark storage proteins (BSPs) were present exclusively in the representative topic of *T. standishii* and in one of *T. standishii* × *plicata*.

Al is well known for its toxicity in plants (Poschenrieder *et al*., 2008), and has been documented to disrupt the calcium homeostasis (Rengel, 1992), trigger defense-like responses (Hamel *et al*., 1998), and up-regulate the phospholipid pathway (Poot-Poot & Hernandez-Sotomayor, 2011). Although Al has been reported to be toxic to soil-borne fungi (Fichtner, 2003), it has never been shown to increase in leaves as a part of a defense response against foliar pathogens. BSPs, also known as vegetative storage proteins, are jasmonic-acid responsive elements (Stein *et al*., 2008) shown to respond to pathogen attack (Mulema & Denby, 2012). To date, there

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are no reports on BSPs from *T. standishii*, WRC or *T. standishii* × *plicata* hybrids. These results suggest that aluminum and BSPs may play key roles in CLB defense. Further studies to dissect the specific roles of aluminum and BSPs in the defense against CLB in *Thuja* spp. are required.

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EVIDENCE FOR CLIMATE AS A DRIVER OF GENETIC DIVERGENCE IN NATIVE POPULATIONS OF THE DOUGLAS-FIR SWISS NEEDLE CAST FUNGUS *PHAEOCRYPTOPUS GAEUMANNII*

Patrick Bennett[1] and *Jeff Stone*[1]

INTRODUCTION

Swiss needle cast (SNC) is a Douglas-fir foliage disease caused by the fungus *Phaeocryptopus gaeumannii* Rohde (Petrak). The spore-bearing structures of this fungus (pseudothecia) occlude the stomata in Douglas-fir needles resulting in an inhibition of gas exchange and photosynthesis, premature foliage loss, and reduced growth (Hansen et al., 2000; Manter et al., 2000). The volume growth reductions inflicted by SNC can exceed 50% in severely diseased stands (Maguire et al., 2011). Since the 1990s, the disease has continued to intensify in coastal low-elevation forests in the Pacific Northwest due to a combination of factors, including forest management practices that have resulted in extensive young Douglas-fir plantations in the coastal Sitka spruce vegetation zone (Hansen et al., 2000; Shaw et al., 2011), and a climate that is conducive to *P.gaeumannii* infection (Hansen et al., 2000; Lee et al., 2013, 2016; Manter et al., 2005; Rosso and Hansen, 2003; Stone et al., 2007, 2008; Watt et al., 2010, 2011).

The possibility that a more aggressive pathogen strain or race may have contributed to the emergence and intensification of SNC was the focus of early studies of the population genetics of *P. gaeumannii.* That research revealed that the Oregon *P. gaeumannii* population is subdivided into two reproductively-isolated lineages (designated Lineage 1 and Lineage 2) that may constitute phylogenetic species (Winton et al., 2006). Lineage 1 was found to be widespread in northwestern North America (i.e. the native range of Douglas-fir) as well as where Douglas-fir was planted as an exotic in the eastern U.S.A., Europe, and New Zealand. Lineage 2, however, was only found in the SNC "epidemic zone" in the northwestern Oregon Coast Range (Winton et al., 2006). Initial epidemiological studies seemed to implicate Lineage 2 in the recent intensification of SNC in western Oregon. It was found in the highest abundance where SNC was most severe in the western Coast Range, and was absent at sites further inland where SNC was less severe. Forest stands in which both Lineages were present and where the proportion of Lineage 2 was greater than Lineage 1 had greater foliage loss and more severe foliage discoloration (Winton et al., 2006). Compared to Lineage 1, the recovery of Lineage 2 isolates was twice as likely in severely diseased stands, and only half as likely in stands rated as healthy (Winton et al., 2006).

The current study aimed to assess the spatial genetic variation in *P. gaeumannii* across a disease gradient in the western Oregon and Washington Coast Ranges in relation to climatic variables. The goal was to identify factors that might influence SNC disease severity and pathogen population structure along this gradient. The specific objectives of this study are to 1) map the spatial distributions of the two *P. gaeumannii* lineages in relation to SNC disease severity in the western Oregon and Washington Coast Ranges, and 2) apply a multivariate statistical ordination to examine relationships between the genetic structure of *P. gaeumannii* populations, SNC disease severity, climate, and geography in this region.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work C Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon.

METHODS

This study analyzed multilocus SSR genotypes (MLGs) for nine polymorphic microsatellite markers (Winton et al., 2007) in a sample of 549 *P. gaeumannii* isolates collected from 14 sites in the Oregon State University Swiss Needle Cast Cooperative plot network in northwestern Oregon and southwestern Washington in 2014 (Bennett and Stone, 2016; Ritóková et al., 2016), as well as 304 isolates collected from nine sites in western Washington in 2015 (Table 1, Figure 1). Foliage sampling, fungal isolations, culturing, DNA extraction, PCR amplification, and microsatellite genotyping were performed using the methods described in (Bennett and Stone, 2016). Multilocus genotypes were analyzed to determine the relative abundances of both *P. gaeumannii* lineages recovered from each of the 23 sites in western OR and WA. Maps depicting the distributions of the two lineages in this region were superimposed on SNC aerial survey maps from surveys conducted by the Oregon Department of Forestry (ODF), the USDA Forest Service, and the Washington Department of Natural Resources (Ramsey et al., 2015; Ritóková et al., 2016) (Figure 1).

Foliage retention was estimated using the methods described in (Ritóková et al., 2016) for each of the trees from which our isolates were collected, and the average foliage retention index (AFR) was calculated by averaging the values for three canopy sections from each tree.

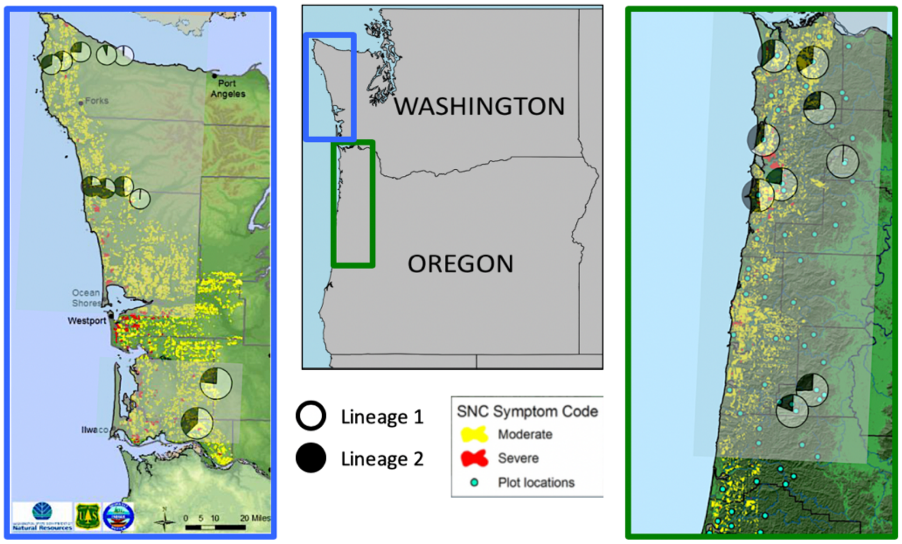

Figure 1. Aerial survey maps showing SNC disease with overlay showing the relative proportions of the two crypic *P. gaeumannii* lineages recovered from each site. Left: Washington SNC aerial survey 2015 map (Ramsey et al. 2015). Southern sites sampled in 2014, Olympic Peninsula sites sampled in 2015. Right: Oregon aerial survey map, sites sampled from SNCC plot network in 2014 (Ritóková et al. 2016).

A non-metric multi-dimensional scaling (NMS) ordination was used as a non-linear approach to depict the genetic differentiation between sampling sites based on allele frequencies. Two separate NMS analyses were performed, one that included all sites sampled in 2014 and 2015, and one that only included the sites sampled in 2014 for which SNC severity data were available. For the analysis that included all 23 sample sites, a 23 x 212 matrix of sample sites x allele frequencies was used as the main matrix. For the analysis that included only the 2014 sample sites, a 14 x 188 matrix of sample sites x allele frequencies was used. Both NMS analyses were based on Euclidean distance measures, and were conducted in PC-ORD 7 (McCune and Mefford 2016).

The environmental matrices consisted of climatic and geographic variables associated with each site, and were used for the joint-plot overlay to visualize statistical correlations with P. gaeumannii allele frequencies. These matrices included geographic coordinates (latitude and longitude in decimal degrees), elevation, and nine climate variables that have been used in predictive models of SNC severity and P. gaeumannii abundance (Manter et al., 2005; Stone et al., 2007, 2008; Watt et al., 2010). Time-series values for the climatic variables were obtained for each of the sample sites from the PRISM data explorer (http://www.prism.oregonstate.edu) (Table 2). The secondary matrix for the NMS with sites sampled in 2014 included a column corresponding to the average foliage retention index (AFR). The matrices also included a column of values corresponding to the relative proportion of Lineage 2 isolates recovered from each of the sample sites. The joint-plot overlay is displayed as a series of radiating vectors, with the direction of the vector corresponding to the statistical correlation with a given NMS axis, and the length of the vector corresponding to the strength of the relationship (r, Pearson correlation coefficient).

Table 1. Summary of sample sizes, numbers of multilocus genotypes (MLG), and diversity statistics for the 2014 and 2015 sample collection years.

Year	Sites	Trees	Isolates	MLG	Gene Diversity (H_{exp})[a]	Genotypic Diversity (H)[b]
2014 (NW OR, SW WA)	14	70	549	332	0.802	5.54
2015 (NW WA)	9	45	304	227	0.798	5.21
Total	23	115	853	559	0.809	6.06

Diversity statistics calculated for rarefied sample size of 8 isolates.
[a] Nei's 1978 Gene Diversity.
[b] Shannon-Weiner Diversity Index (H).

Table 2. Climatic, geographic, and disease variables corresponding to the abbreviations used in NMS joint plot overlay in Figure 3.

Variable (units)	Abbreviation
Latitude (decimal degrees)	Lat
Longitude (decimal degrees)	Long
Elevation (feet)	Elev (ft)
January 2014 minimum temperature (˚C)	Jan Tmin
Winter 2014 mean average temperature (November 2013-March 2014) (˚C)	Tmean Winter
August 2014 maximum temperature (˚C)	Aug Tmax
Summer 2014 maximum temperature (May-September 2014) (˚C)	Summ. Avg. T
Summer 2014 mean temperature (May-September 2014) (˚C)	Summ. Tmean
May-July 2014 mean average dewpoint temperature (˚C)	MADT
May-July 2014 maximum vapor-pressure deficit (kPa)	Max VPD
Relative proportion of Lineage 2 isolates in sample site (Number of Lineage 2 Isolates/Total Number of Isolates)	PL2
Disease severity- Average foliage retention	AFR

RESULTS

An overlay of the maps showing the relative proportions of *P. gaeumannii* Lineages 1 and 2 at each of the sample sites on the SNC aerial disease survey maps from Oregon and Washington revealed a strong association between Lineage 2 and SNC symptom severity. Generally, sites nearest the coast had the highest proportions of Lineage 2 and the most severe SNC symptoms (Figure 1). The multilocus SSR genotype data also revealed that Lineage 2 in Washington has a similar coastal distribution to the sites in northwestern Oregon, and also exhibits a similar relationship with SNC disease severity. Sites further inland, where Lineage 2 is absent, have little or no SNC symptoms (Figure 1). The southwestern-most site in the Olympic peninsula sampling, near Queets, had the highest relative proportion of Lineage 2 of any site in our sampling distribution (PL2 = 0.774).

In both of the NMS ordinations, two axes accounted for most of the variation in allele frequencies (cumulative variance explained = 0.875 (Figure 2A), and 0.917 (Figure 2B)). The alleles of one SSR locus (PgDi1) contributed to the distribution of sample sites along Axis 1. For example, in the NMS that included all sites sampled in 2014 and 2015, the PgDi1 allele 96, which is exclusive to Lineage 1, had a very strong negative relationship with NMS Axis 1 (r = -0.959), while PgDi1 alleles 100 and 102, which are exclusive to Lineage 2, had strong positive correlations with NMS Axis 1 (r = 0.719, r = 0.602 for PgDi1 100 and 102, respectively) (Figure 2) (Winton et al., 2007). This resulted in an arrangement of sample sites along NMS Axis 1 according to the relative proportions of the two lineages present in the sample site. This also resulted in the separation of coastal and inland sample sites along this axis according to the lineage distributions. Longitude was strongly correlated with this arrangement, as sites nearer to the coast generally had greater proportions of Lineage 2 (and thus higher frequencies of SSR alleles associated with this lineage), while Lineage 2 was generally recovered at low frequencies from the sample sites further inland.

In the NMS that included all sites, the proportion of Lineage 2 had the strongest relationship with NMS Axis 1 (PL2, $r = 0.878$), and longitude had the second strongest relationship with this axis (Long, $r = -0.477$) (Figure 2A, Table 3). May-July 2014 dew point temperature had positive relationships with both NMS axes (MADT, NMS Axis 1: $r = 0.426$, NMS Axis 2: $r = 0.378$), and covaried with mean winter temperature on both axes (Tmean Winter: $r_{Axis\ 1} = 0.386$, $r_{Axis\ 2} = 0.313$) (Figure 2A, Table 3). January 2014 minimum temperature had the strongest relationship with NMS Axis 2 (Jan Tmin, $r = 0.447$). August maximum temperature (Aug. Tmax, $r = -0.549$), Summer mean temperature (Summ. Tmean, $r = -0.383$), Summer average maximum temperature (Summ. Avg. Tmax, $r = -0.409$), and May-July maximum vapor pressure deficit (Max VPD, $r = -0.402$) were all negatively correlated with NMS Axis 2 (Figure 2A, Table 3).

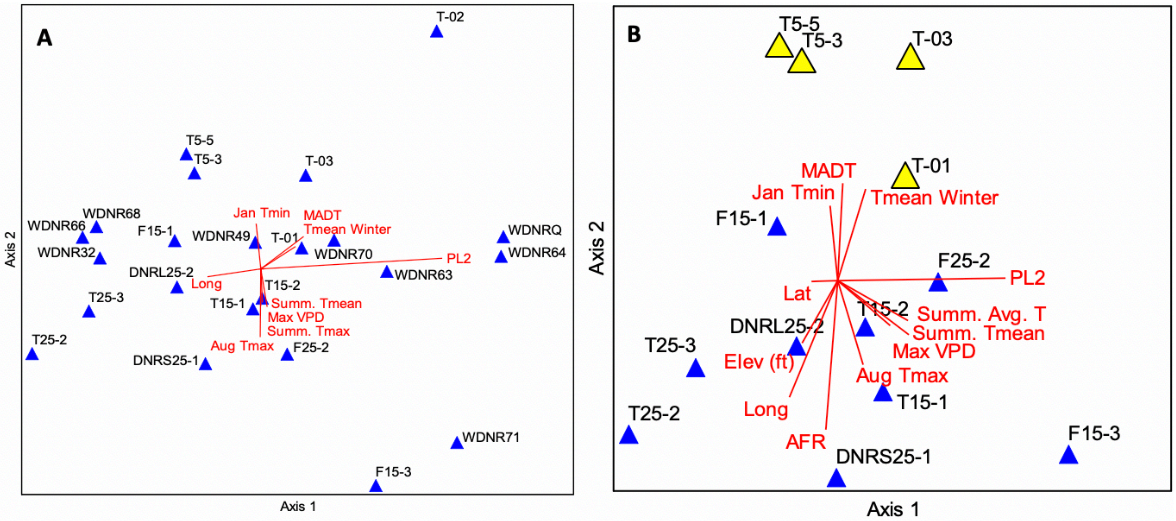

Figure 2. Joint plots from non-metric multidimensional scaling (NMS) ordination of sampling sites in multilocus SSR allele frequency space. The plots are overlaid with vectors representing environmental and geographic variables, and the relative proportion of Lineage 2 (PL2) recovered from the site (Table 2). Only variables with correlation coefficient (r) greater than 0.200 are shown. A) Sites sampled in northwestern Oregon and southwestern Washington in 2014 and northwestern Washington in 2015. Cumulative variance explained = 0.875, final stress = 11.135. B) Sites sampled in 2014 only, with a vector representing an average foliage retention index (AFR) estimated from 5 trees at each site. Cumulative variance explained = 0.917, final stress = 9.036. The yellow triangles in (B) represent sites in the original SNC epidemic zone near Tillamook, Oregon.

Table 3. Pearson coefficients (r) for correlations between the NMS axes and each of the variables used in the joint plot overlay in Figure 2, Table 2.

	2014 + 2015 (Figure 2A)		**2014 only (Figure 2B)**	
Variable	**Axis 1**	**Axis 2**	**Axis 1**	**Axis 2**
Lat	0.121	0.106	-0.347	-0.048
Long	-0.477	-0.188	-0.470	-0.736
Elev (ft)	NA	NA	-0.404	**-0.539**
Jan Tmin	-0.139	0.447	-0.191	**0.589**
Tmean Winter	0.386	0.313	0.356	**0.651**
Aug Tmax	-0.036	**-0.549**	0.343	**-0.625**
Summ. Avg. Tmax	0.166	-0.409	**0.566**	-0.430
Summ. Tmean	0.090	-0.383	**0.569**	**-0.501**
MADT	0.426	0.378	0.150	**0.672**
Max VPD	0.025	-0.402	0.490	-0.458
PL2	**0.878**	0.219	**0.873**	0.101
AFR	NA	NA	-0.229	**-0.831**

For the NMS that included only the 2014 sample sites, the proportion of Lineage 2 also had the strongest relationship with NMS Axis 1 (PL2, $r = 0.873$), and a similar relationship with Longitude also was observed (Long, $r = -0.470$). Summer maximum temperature and mean summer temperature were correlated with both axes (Summ. Avg. Tmax, $r_{Axis\ 1} = 0.566$, $r_{Axis\ 2} = -0.430$; Summ. Tmean, $r_{Axis\ 1} = 0.569$, $r_{Axis\ 2} = -0.501$). Elevation also had negative correlations with both axis (Elev (ft.), $r_{Axis\ 1} = -0.404$, $r_{Axis\ 2} = -0.539$). The average foliage retention index had a very strong negative correlation with Axis 2 (AFR, $r = -0.831$). Variables corresponding to winter temperature and mean dew point temperature had strong positive correlations with Axis 2, while variables associated with summer temperature and vapor pressure deficit had strong negative correlations with this axis (Figure 2B, Table 3).

DISCUSSION

The geographic distribution of *P. gaeumannii* Lineage 2 in the western Coast Ranges in Oregon and Washington appears to be correlated with SNC severity, as assessed via aerial survey. In general, SNC symptoms are most severe where both lineages coexist within 20 miles of the coast. Further inland, Lineage 2 is exceedingly rare and SNC symptoms are less severe or absent (Figure 1). Two sites at the southern end of our sampling distribution did not fit this trend, as the relative proportion of Lineage 2 at these sites were 0.20-0.25, but these sites are outside of the SNC epidemic zone and did not exhibit visible symptoms of SNC. Overall, these trends are in agreement with the findings of Winton et al. (2006), which suggested that sample sites with greater abundances of Lineage 2 also had greater SNC severity.

The multivariate non-metric multidimensional scaling (NMS) analysis revealed strong spatial genetic differentiation between inland and coastal sample sites. This approach allowed the strength of the relationships between the environmental variables and the observed allele frequency variation to be visualized. The geographic distribution of allele frequency variation was highly correlated with mean winter temperature, mean summer maximum temperature, maximum vapor pressure deficit, and mean average dew point temperatures in the year prior to sampling. These results corroborate previous models of SNC severity that included these variables, and provide further statistical support for their importance as predictors of disease severity (Lee et al., 2013, 2016; Manter et al., 2005; Stone et al., 2007, 2008; Watt et al., 2010, 2011). Foliage retention was lowest at sites where Lineage 1 and Lineage 2 coexisted near the coast in Tillamook County, Oregon. These sites had the highest winter average temperature and the highest January minimum temperature, as well as the highest spring/summer dew point temperatures. These sites also had low summer temperatures and low vapor pressure deficits. Foliage retention was much higher at the higher elevation inland sites where the winters were cold, summers were hotter and drier, and Lineage 2 was absent.

The results of the NMS ordinations suggest that climate may be a potential driver of genetic diversification in *P. gaeumannii* populations. The *P. gaeumannii* isolates collected from the original SNC epidemic zone exhibited a unique allelic signature suggesting that some adaptation to local climate, or natural selection for advantageous genotypes, has occurred in this region. Whether these genotypes are more aggressive, or the observed distributions of SNC severity is simply the result of greater *P. geaumannii* abundance and needle colonization due to a conducive climate, should be the focus of future studies. This system could provide a model for answering a variety of biological questions relating to the influence of climate in structuring fungal populations, and the role of climate change as a driver of fungal forest pathogen emergence.

ACKNOWLEDGEMENTS

Special thanks the members and organizers of the Swiss Needle Cast Cooperative, the Portland Garden Club, Cascade Mycological Society, Oregon Mycological Society, Washington Department of Natural Resources, and the U.S. Forest Service for their generous support in funding this research. Thanks to Michelle Agne, Gabi Ritokova, and Dave Shaw for providing the foliage samples from the SNCC plot network, and Dan Omdal and Amy Ramsey for allowing us to sample foliage from their sites in western Washington. The authors would also like to thank Lori Winton for her efforts in laying the groundwork that made this research possible.

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BIGLEAF MAPLE IN WESTERN WASHINGTON

Jacob Betzen[1], *Amy Ramsey*[2], *Dan Omdal*[2], and *Patrick C. Tobin*[1]

INTRODUCTION

Bigleaf maple (*Acer macrophyllum*) is a prominent component of the urban and suburban landscape in western Washington, which lies at the heart of the native range of bigleaf maple. As a component of urban and suburban forests, bigleaf maple provides numerous ecosystem services and benefits. It is a common urban shade tree and provides habitat for numerous wildlife species, as well as the Pacific Northwest's iconic epiphyte communities. However, beginning in 2010, bigleaf maple decline (BLMD) has been reported in California, Oregon, and Washington. Symptoms of this decline include deformed, wilted, and shrunken leaves, partial to entire crown dieback, and complete tree mortality (Figure 1). Recent symptoms also include leaves with yellow edges, red to brown tips, and leaf hoppers. BLMD also appears to affect trees of varying ages. In 2014-2015, the WA-DNR surveyed bigleaf maple throughout Western Washington, reporting widespread decline. To date, the majority of samples have tested negative for many of the usual pathogen suspects that are often associated with the bigleaf maple dieback. As of yet the causative agent remains unknown.

OBJECTIVES

- Determine environmental, anthropogenic, and weather conditions that are associated with presence and severity of BLMD in Western Washington.
- Use dendrochronological techniques to add temporal aspect to decline and investigate climate's role in BLMD.
- Document potential causative agents of BLMD from symptomatic trees.

CURRENT RESEARCH EFFORTS

We plan to resampled and expanded upon sites from 2014-2015 (Figure 2) to include randomized sampling locations with bigleaf maple, and trees symptomatic for BLMD. From these sites we will collect stand composition data, soil and foliar samples for use in an elemental analysis, and cores from bigleaf maple and adjacent conifers to quantify the timing of BLMD. Then, we will combine field-collected data with archived data from public databases to add geographical and land use attributes, and weather variables to our study sites. Ultimately, by determining which variables are positively correlated with the presence and severity of BLMD, we hope to elucidate any possible causative agents of BLMD in the Western Washington region.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]University of Washington, School of Environmental and Forest Sciences, Seattle, Washington. [2]Washington State Department of Natural Resources, Olympia, Washington.

Figure 1. (A) Healthy bigleaf maple leaf (left) and symptomatic leaf (right). **(B)** Yellowing of leaves from a tree symptomatic of BLMD (left) relative to healthy foliage (right). **(C)** Crown dieback observed in a tree symptomatic for BLMD (Photo credit: Amy Ramsey).

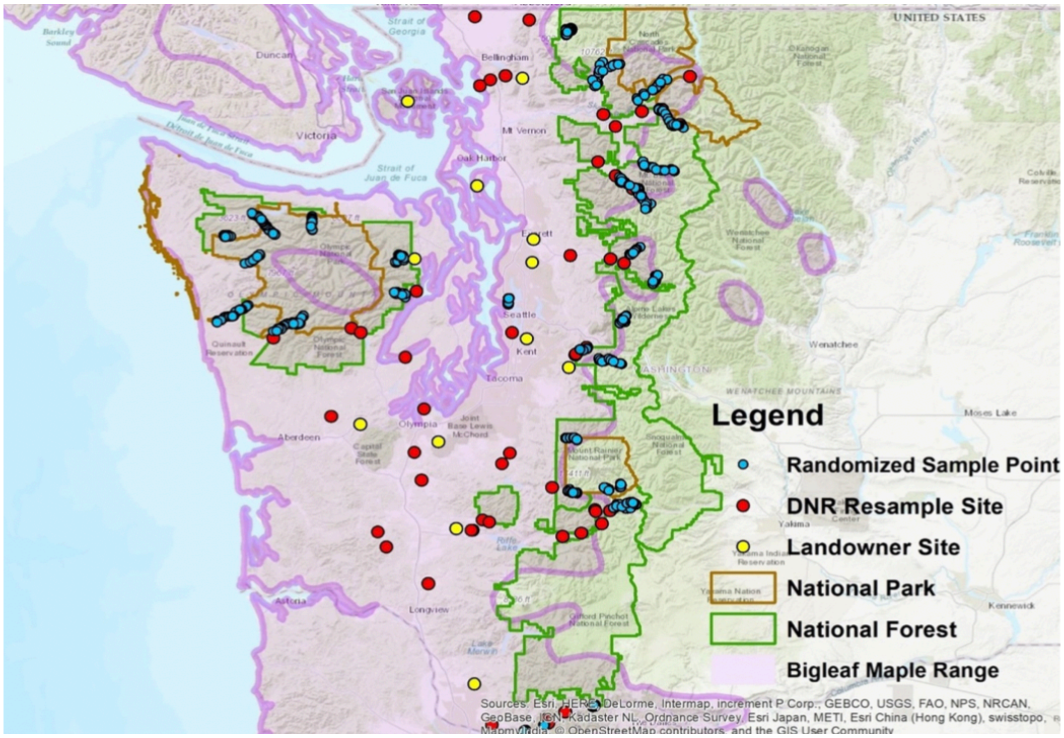


Figure 2. Locations of study sites in 2017 in which we expanded on initial sampled locations (red circles; see Figure 4) by including randomly selected sites and landowner sites. Note that the randomized sampling points (blue circles) are located along a transect to better quantify the spatial extend of BLMD.

ASPEN HEALTH ON NATIONAL FORESTS IN THE NORTHERN ROCKY MOUNTAIN REGION

James T. Blodgett[1]

INTRODUCTION

Quaking aspen (*Populus tremuloides*) is an important and widely distributed species in the Western United States. Aspen forests support a variety of values such as diversity, wildlife, watersheds, and aesthetics. There is concern regarding the health of this ecologically important species.

Long-term monitoring plots and aerial detection surveys suggest extensive sudden decline and deterioration of aspen forests in the Rocky Mountains. Several diseases and insects are associated with aspen mortality.

To determine management recommendations, the distribution and severity of mortality and causal agents involved must be identified. In this study, damage agents and site variables were measured to determine factors contributing to aspen mortality.

The objectives of the study were to: 1) evaluate tree and regeneration health, 2) quantify frequencies of damage agents, and 3) analyze tree mortality and regeneration stocking in relation to site, tree, and damage agents.

METHODS

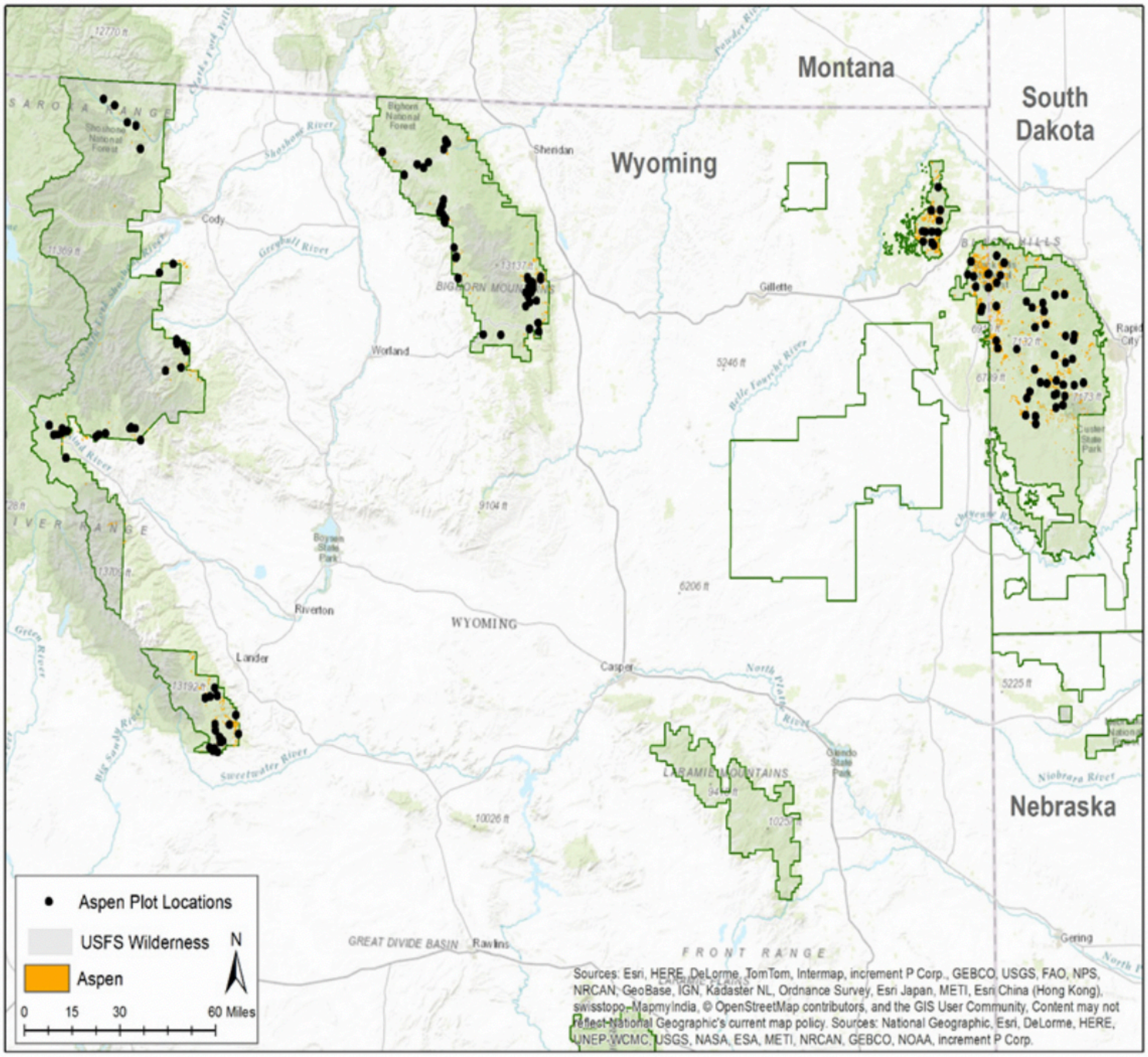
Permanent plots in the Bighorn (44 plots), Black Hills (59 plots), and Shoshone (45 plots) National Forests (NFs) were resampled in 2015 (Figure 1). Plots were established in the Bighorn in 2009, and in the Black Hills and Shoshone NFs in 2008. All plots were previously remeasured in 2012. The study design consisted of three circular plots in an aspen stand (trees 1/50 acre plots; regeneration 1/500 acre plots). All trees = 3 inches DBH were measured and live aspen trees were tagged. Tree mortality rates per plot were calculated based on the number of trees that died since the last sampling divided by the number of years. For 2008/2009, mortality was estimated using recent dead trees. Damage agents were recorded for live and recent dead aspen tree, and were summarized as percentage of stems per plot. Regeneration was classified by species, host condition (living or dead), and damage agents were tallied.

RESULTS AND DISCUSSION

Mean tree mortality has remained low (Figure 2), indicating no significant tree mortality events are occurring. As is common in forests, the average tree diameter of live aspen has increased and the average trees per acre of live aspen has decreased. There were significant correlations in mortality among years, indicating stands with elevated mortality continued to have elevated mortality. Some of the mortality in the Black Hills and Shoshone NFs is due to fire. We found no clear relationships between tree mortality and factors such as elevation, slope, aspect, tree density or age, species composition, or climate (moisture, temperature, etc.). There are numerous insect and disease agents in these forests, but only three are common and show a trend with tree mortality. Thirty-three damage agents were found in trees with up to eight in an individual tree. However, most of these agents were found in <1% of the trees, thus were not contributing to significant mortality at the forest level.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]USDA Forest Service, Rocky Mountain Region, Forest Health Protection, Rapid City, South Dakota.

Although many damage agents were observed, only three agents, Cytospora canker (Figure 3 and 4; *Cytospora* spp.), sooty-bark canker (Figure 3 and 4; *Encoelia pruinosa*), and aspen trunk rot (Figure 4; *Phellinus tremulae*) were weakly correlated with tree mortality in 2015. Although Cytospora canker was the most common and is causing some mortality, the majority of the cankers were small, already healed, or likely to heal. Sooty bark canker was the second most common damage agent, often with large expanding cankers, and was considered to be the most significant factor causing tree mortality. Aspen trunk rot caused stem breakage of larger trees due to extensive internal decay. Other damage agents can cause tree mortality, but their correlations with mortality were not significant or they were infrequent. Consequently, damage agent aggressiveness, tendency with mortality, and frequency should all be considered when determining potential impacts on forest health at the landscape level.



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community, Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Figure 1. Location of stands and aspen cover type.

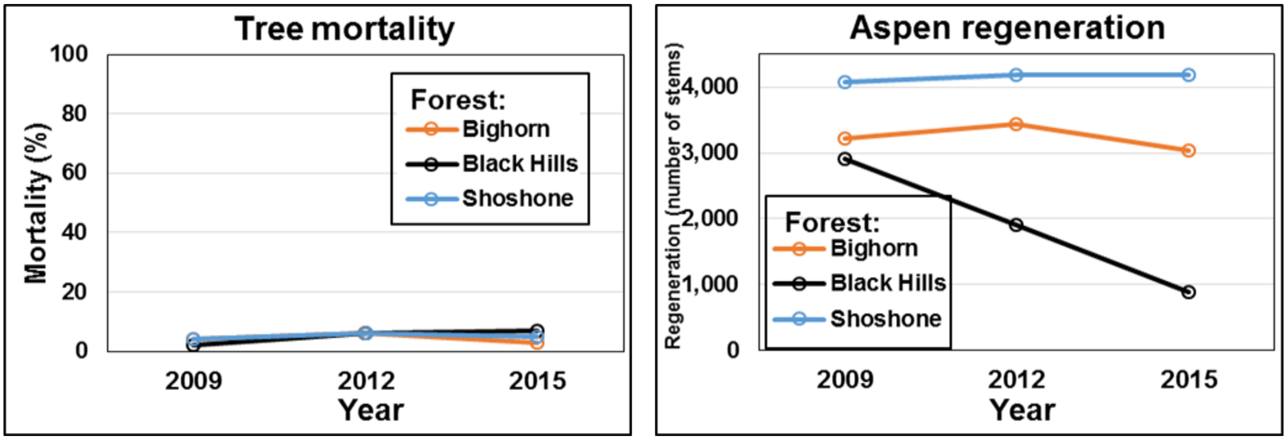


Figure 2. Mortality in trees and number of regeneration stems in aspen stands in the Bighorn, Black Hills, and Shoshone National Forests.

Overall, aspen regeneration was common (Figure 2) and relatively dense (>1,000 stems per acre) across all forests, but there were stands with low regeneration, especially in the Black Hills NF. As with trees, during the first years of this study there were no clear relationship between regeneration numbers and several factors such as elevation, slope, aspect, tree density or age, species composition, or climate (moisture, temperature, etc.). However, when looking at stands with poor regeneration, the most important factors in reducing aspen regeneration were related to individual sites. Factors such as dense overstory, competing regeneration from other species, and in a few cases fire had the greatest impact on reducing aspen regeneration. Only two damage agents were common in regeneration (Figure 5; from most to least common: cankers and animal browsing), but they showed no correlation with decreasing numbers of regeneration. However, cankers and browsing might play a role in reducing aspen regeneration in some stands. Cankers were frequently associated with browse damage. Thus, browsing damage is the likely entry point for the damaging canker pathogens.

MANAGEMENT RECOMMENDATIONS

- Regenerate older aspen stands by clearcutting, prescribed fire, or wildfire to stimulate regeneration and help maintain aspen on sites.

- Sooty-bark canker and aspen trunk rot (not Cytospora canker) tends to attack older trees, so managing aspen in rotations of less than 100 years would reduce losses from those diseases.

- Avoiding wounds should reduce the likelihood of infections from both canker diseases.

- Partial cutting in aspen stands is strongly discouraged since wounding often results in canker infection. Partial cutting also might result in subsequent wounding as a result of increased boring insects.

- Reducing browsing should reduce mortality caused by the canker diseases. Exclosure fencing would reduce animal damage to both trees and regeneration.

- Clonal variation in susceptibility to decay has been demonstrated for aspen trunk rot. Favoring clones with low levels of decay would select for resistance.

- Aspen trunk rot conks are good indicators for detecting and estimating decay. Decay typically extends 8-12 ft in each direction from conks, and cull increases with number of conks.

Figure 3. Sooty bark canker in a live (left) and dead (center) aspen trees. Cytospora canker in a live aspen tree (right).

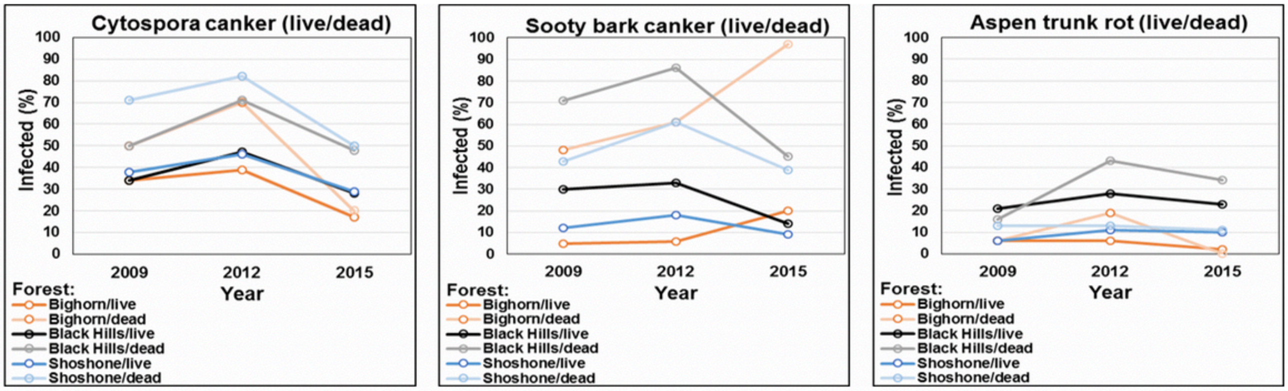


Figure 4. Common damage agents recorded in aspen trees in the Bighorn, Black Hills, and Shoshone National Forests.

Figure 5. Animal browsing with cankers in aspen seedlings (left and center), and a canker in an aspen sapling (right).

IS CLIMATE CHANGE DRIVING YELLOW-CEDAR DECLINE ON HAIDA GWAII?

Vanessa Comeau[1] and *Lori Daniels*[1]

INTRODUCTION

Forest die-back driven by climate change is of great concern around the globe. In the Pacific Northwest, yellow-cedar (*Callitropsis nootkatensis*) decline has captured the attention of forest practitioners because it is ecologically important, culturally significant and economically valuable. The driver of regional decline is thought to be climatic warming, which has led to reduced snowpack and exposed fine roots to freezing damage (Hennon et al. 2012). Decline is most prevalent along the coast of southern Alaska and British Columbia. In recent years, yellow-cedar decline has been observed on the islands of Haida Gwaii, where it was previously absent. However, the proposed mechanisms may not adequately explain the decline on Haida Gwaii due to the temperate climate and the ephemeral snow pack. To further investigate the mechanism for decline, my research used dendrochronology to quantify climate-growth relationships and reconstructed stand dynamics of the declining stands to test the hypothesis that climate is driving yellow-cedar decline on Haida Gwaii.

Questions:

1. In targeted forests exhibiting decline, what proportion of yellow-cedar are live (healthy), declining or dead?

2. Which yellow-cedar are declining and why?

3. Do growth patterns of live, declining and dead yellow-cedar differ over their lifespans?

4. How did inter-annual and multi-decadal climate variation in the 20th century influence radial growth of yellow-cedar?

DATA COLLECTION AND PROCESSING

Areas exhibiting decline on Graham Island, Haida Gwaii were targeted for sampling. A total of 13 sites were sampled. At each site a census of all yellow-cedar trees (DBH ≥10cm) was taken in 100 x 20m transects, to assess population dynamics. Increment cores were also taken from 15 live (asymptomatic) and 15 declining/dead trees. Cores were processed and cross-dated following standard dendro-chronological procedures (Stokes & Smiley 1968). Climate data was collected from ClimateWNA (Wang et al. 2012) and the program DendroClim (Biondi & Waikul 2004) was used for the climate-growth analyses.

RESULTS

Most yellow-cedar are dead or declining

A total of 916 trees were sampled at 13 targeted sites exhibiting yellow-cedar decline. 73.8% of yellow-cedar trees were dead or declining (45.6% dead, 28.2% declining), while only 26.2% of trees were live. At a site level this ranged from 59-86% dead or declining, and 14-41% live and healthy.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Tree-Ring Lab at UBC, Faculty of Forestry, University of British Columbia, Vancouver, British Columbia.

Decline across all sizes, ages and through time

A subset of 210 trees at 7 sites were analyzed as these samples had high cross correlations. DBH ranged from 10 to 77 cm, with live, declining and dead trees present across all size classes (Figure 1a). There was a similar distribution of size for live, declining and dead trees. The ages (tree ring counts) ranged from 29 to 904 years, with live, declining and dead trees present across all age ranges (Figure 1b). The declining and dead trees were not the oldest, which would be consistent with trees reaching their maximum lifespan, nor the youngest, which would be consistent with self-thinning. 93 live and 16 declining trees formed rings in 2015, the year of sampling. 26 living trees (live and declining) stopped forming rings before 2015, as early as 1918 (Figure 1c). For trees which were dead at the time of sampling, 37 died after 1939, with 50% dying from 2000 to 2015 (Figure 1c).

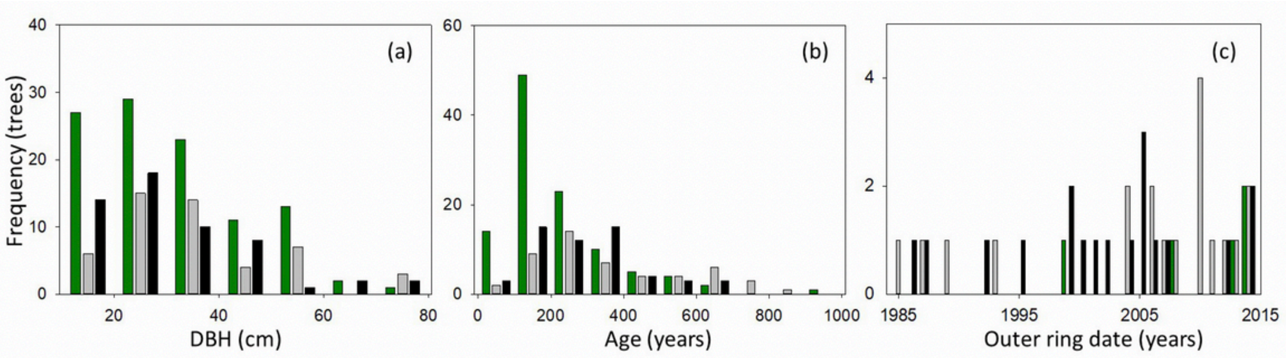


Figure 1. Frequency of DBH class (a), age class (b) and outer ring date (c), for live (green), declining (grey) and dead (black) trees.

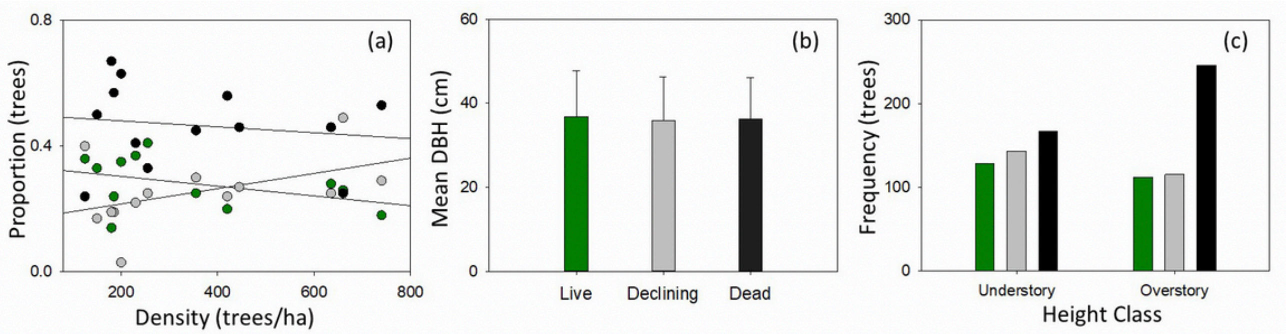


Figure 2. Proportion of trees in each status class across density (a), average DBH for each status class (b), and frequency of trees in the understory/overstory by status class (c). Where green represents live, grey represents declining and black represents dead trees.

Decline not due to competition

We found that the proportion of declining and dead trees did not increase with density. Conversely, the proportion of live trees did not decrease with density (Figure 2a). There was no evidence of density dependent mortality. The mean DBH of live, declining and dead trees were not statistically different (Figure 2b). Declining and dead trees were not the smallest or largest trees. Examining height class, we found that there were more dead overstory trees and fewer live and declining understory trees than expected by chance (Figure 2c). This is opposite to the patterns expected if the decline was due to competition.

Yellow-cedar growth and climate

Patterns of growth for live, declining and dead trees was more similar in the 18th and 19th centuries and diverged in the 20th century (Figure 3). Specifically, there was increasing growth seen in live, healthy trees. This corresponds with increasing temperatures during this period. Growth in declining trees increased minimally and then decreased in the later part of the 20th century. In trees that died, growth increased, but decreased abruptly after 2004.

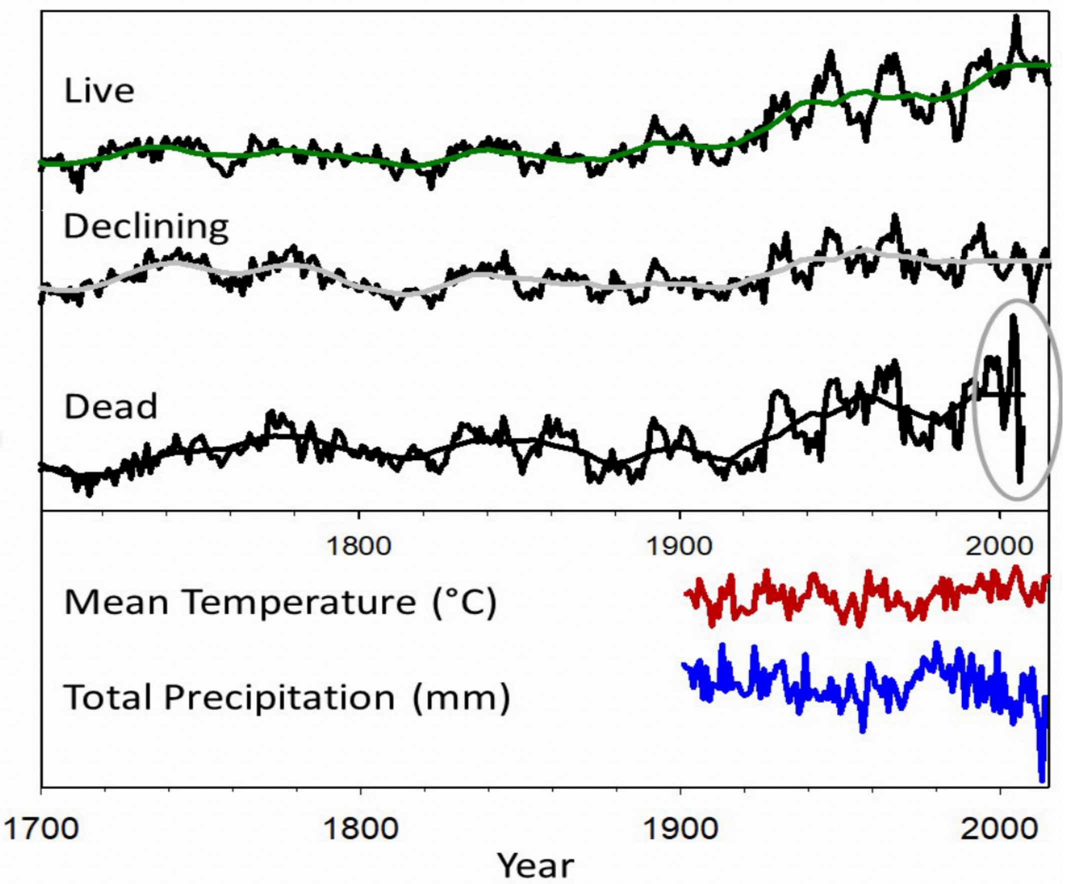


Figure 3. Combined raw ring-width chronologies for all live, declining and dead trees across sites from years 1700 to 2014, and mean yearly temperature and total yearly precipitation for 1902 to 2014.

Climate-growth changes around 1976-77

Warm spring and summer temperatures facilitate yellow-cedar growth during both time periods (1946-1976 and 1977-2014), however correlations were stronger in the early cooler phase (Figure 4). There were weak relations with precipitation during the growing season, indicating that these trees are not moisture limited. During the fall and winter months precipitation interacts with temperature and there is a shift in these relationships between the two time periods (Figure 4). In the 1946-1976 period, a cool dry November and wet (snowy) January facilitate growth. Conversely a warm wet November and dry January limit growth. In the 1977-2014 period, a warm wet (rainy) November/December and cool dry January facilitate growth. Conversely a cool dry November/December and warm wet January limit growth. These winter limiting factors from both time periods are consistent with the low snowpack hypothesis from Alaska, as warm/wet and cool/dry conditions are not conducive to snow. However, an improved understanding of snow distribution and persistence on Haida Gwaii is needed to further explore this.

SUMMARY

Yellow-cedar decline on Haida Gwaii is of great local concern. At targeted sites of decline, there are high proportions of declining and dead trees. Trees of all ages and sizes are affected, with greater impacts on overstory trees, but the decline is not due to competition and self-thinning. Warm growing season temperatures have facilitated increasing growth in the 20th century. Winter limiting factors have changed through time but are consistent with the low snowpack hypothesis from Alaska.

ACKNOWLEDGEMENTS

Thank you for funding from Taan Forest, BC FLNRO and NSERC-Engage, collaboration with the Council of the Haida Nation and R. Chavardès (Tree-Ring Lab at UBC), and research assistants: G. Knochenmus, I. Jarvis, J. Liu, A. Weixelman, J. Coutu, J. Heredia, D. Hornsberger, S. Bronson and D. Fluharty for assistance in the field and lab. VC received scholarships from NSERC-CGS and the UBC Faculty of Forestry.

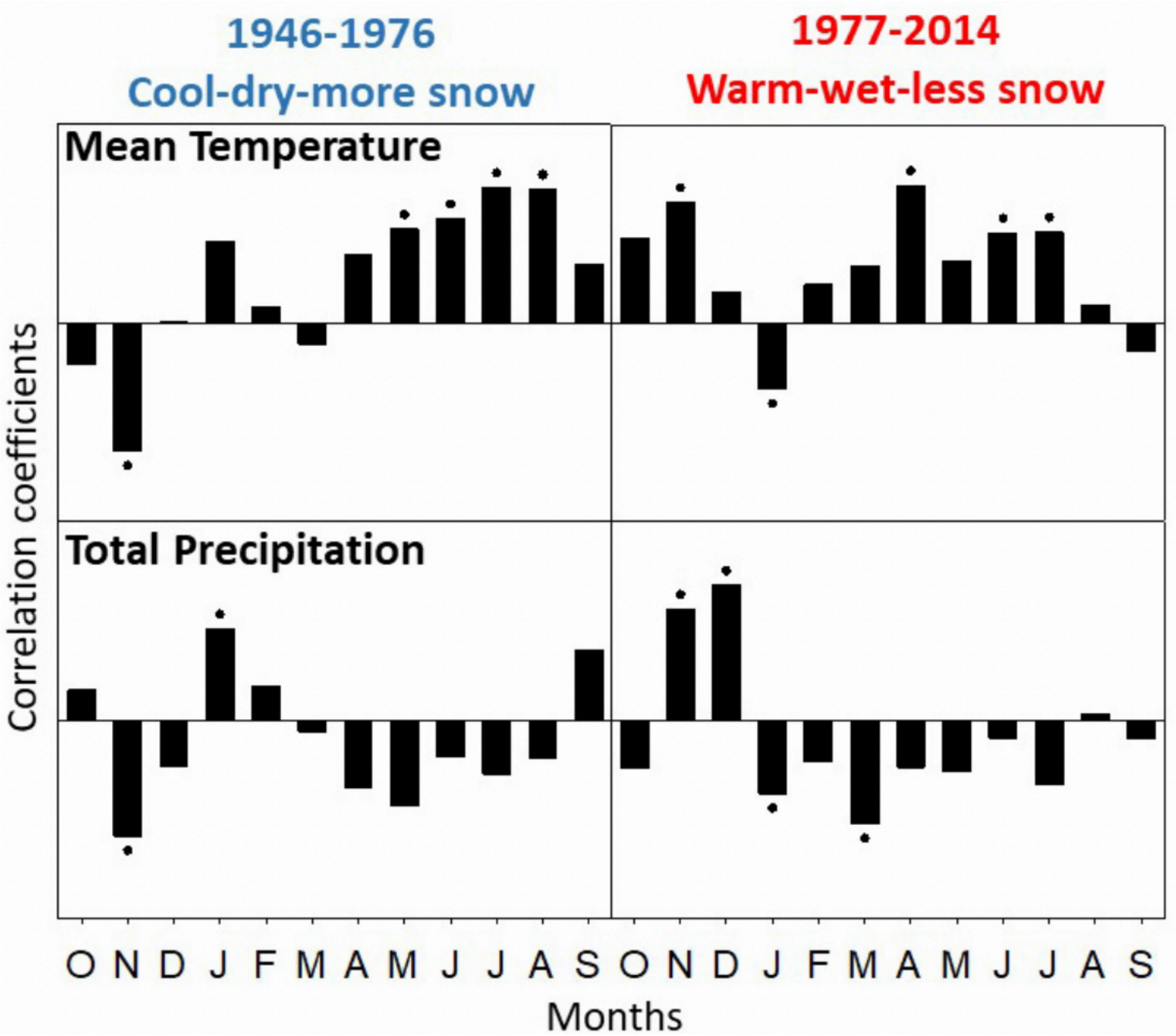


Figure 4. Climate-growth relations over two time periods (columns), comparing mean monthly temperature (top) and total monthly precipitation (bottom) to yearly radial growth, from previous October, through current September. Positive correlations indicate that warm/wet conditions facilitate growth, and cool/dry conditions limit growth. Negative correlations indicate that cool/dry conditions facilitate growth and warm/wet conditions limit growth. Dots indicate a significant relationship.

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DEVELOPMENT OF TOOLS FOR EARLY DETECTION, MONITORING AND MANAGEMENT OF THE KOA WILT PATHOGEN (*FUSARIUM OXYSPORUM* F. SP. *KOAE*) IN HAWAI'I

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INTRODUCTION

Koa (*Acacia koa* Gray) is an endemic, keystone species in Hawai'i's forests. Koa is valuable economically (contributed $30 million to Hawai'i's forestry industry in 2001), ecologically (habitat for many endangered birds and insects), and culturally (koa is the main wood used for making Hawaiian canoes). Mortality of koa trees due to koa wilt (caused by *Fusarium oxysporum* f. sp. *koae*; Foxy-koae) has been increasing, primarily in the low- to mid-elevation forests (Gardner 1980). *Fusarium oxysporum* (Foxy) is an important vascular wilt pathogen of many plant species worldwide (Leslie 2006). Foxy is highly variable and can be pathogenic or saprophytic without discernable, morphological differences. The origin of Foxy-koae strains that are virulent to koa in Hawaii is currently unknown.

Research conducted by Stewart et al. (2006, 2012), showed that highly virulent strains of Foxy could be identified by DNA sequences. The resulting DNA marker enhances the ability to identify the pathogen in nursery systems (Stewart et al 2006, Stewart et al 2012), and methods and markers to detect and identify pathogenic *Fusarium spp*. have been tested in tree nursery systems (Leon 2015). Molecular characterization of Foxy-koae will contribute a better understanding of its biology and ecology for use in further restoration and management efforts.

Development of DNA-based probes that differentiate pathogenic from non-pathogenic Foxy isolates will allow for quick, reliable detection of pathogenic strains of Foxy-koae. A methodology to rapidly detect and quantify pathogenic Foxy in nursery substrates, wood tissue, seedlings, and forest soils using real-time PCR will allow in the implementation of this management technique. Furthermore, an extensive record of newly collected isolates from forest sites will help determine conditions conducive to disease development. This information will allow the development of a recommended protocol to enable foresters and nursery managers to implement timely and appropriate disease management practices.

METHODS

Pathogenicity information of existing Foxy-koae isolates are being used to determine if genetic differentiation exists between pathogenic and non-pathogenic strains. If a clear distinction is found, new isolates will be separated into these two groups. Molecular real-time PCR probes will be developed to identify and quantify pathogenic Foxy-koae isolates. New isolates collected from root and soil samples from symptomatic koa trees

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(exhibiting chlorotic leaves, crown dieback, and dark staining of infected roots – Figure 1) and asymptomatic koa trees will be screened with the molecular probes to verify the presence of pathogenic or non-pathogenic strains of Foxy-koae. To confirm the pathogenicity groups, 20 isolates from each group will be selected for pathogenicity trials, using granulated Foxy-koae inoculum under greenhouse conditions. Protocols and guidelines for koa breeding and restoration programs will be developed based on the estimated population levels of pathogenic Foxy-koae isolates.

To determine virulence variation and genetic diversity, at least 100 new *Fusarium* isolates will be collected from Hawai'i. Isolates will be collected across the main Hawaiian Islands and from various locations within each island to determine variability among and within islands. Initial characterization will be accomplished with phylogenetic analysis of multiple gene regions and Restriction-Site-Associated-DNA sequencing (RADseq). Environmental conditions (such as GPS coordinates, site conditions, slope, climate data, etc) will be collected at each site for examinations of environmental relationships with koa wilt.

Figure 1. 8-year-old Acacia koa tree showing wilt symptoms (crown dieback, yellowing leaves) caused by *Fusarium oxysporum* f sp. *Koae*.

RESULTS

The Hawai'i Agriculture Research Center (HARC) has conducted surveys around the main Hawaiian Islands and found koa wilt across the islands (Figure 2). Over 200 isolates of Foxy-koae have been recovered from symptomatic trees in many of the native forests and restoration sites that were surveyed on the islands of Oahu, Maui, Kauai and Hawai'i. Some of these isolates have been screened for pathogenicity.

Twenty-one screened Foxy-koae isolates were genetically analyzed at the USDA Forest Service Forest Pathology laboratory in Moscow, Idaho in 2015 (see Figure 3). The translation elongation factor-1a (*tef1*) locus and mitochondrial small subunit (mtSSU) (Stewart et al. 2006) have been used to identify single nucleotide polymorphisms (SNPs). Two SNPs from the *tef1* and three SNPs from the mtSSU have been identified at these regions.

DISCUSSION

SNPs analyses have revealed a distinct clade of Foxy-koae isolates, which further confirms that these pathogenic isolates are genetically more similar to each other than other *Fusarium oxysporum* isolates. Further characterization of the genome is needed to develop a molecular marker to distinguish pathogenic from non-pathogenic strains because only a few SNPs have been identified in the tef1 and mtSSU regions. Other regions of the genome will be analyzed to identify genomic areas that are clearly differentiated for marker development. After the development of a diagnostic marker, newly collected Foxy isolates will be screened for pathogenicity. Isolates found to be virulent (causes koa wilt symptoms – Figures 4 and 5) will be used in disease resistance screening programs. New isolates will be collected in spring or summer of 2018 for use with a molecular marker that is being developed.

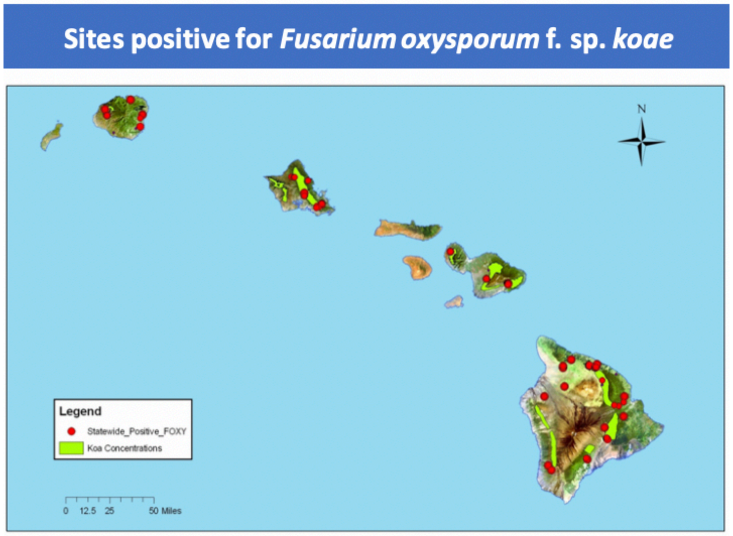

Figure 2. HARC survey of Hawaiian Islands for *Fusarium oxysporum* f sp. *koae* from 2004-2007.

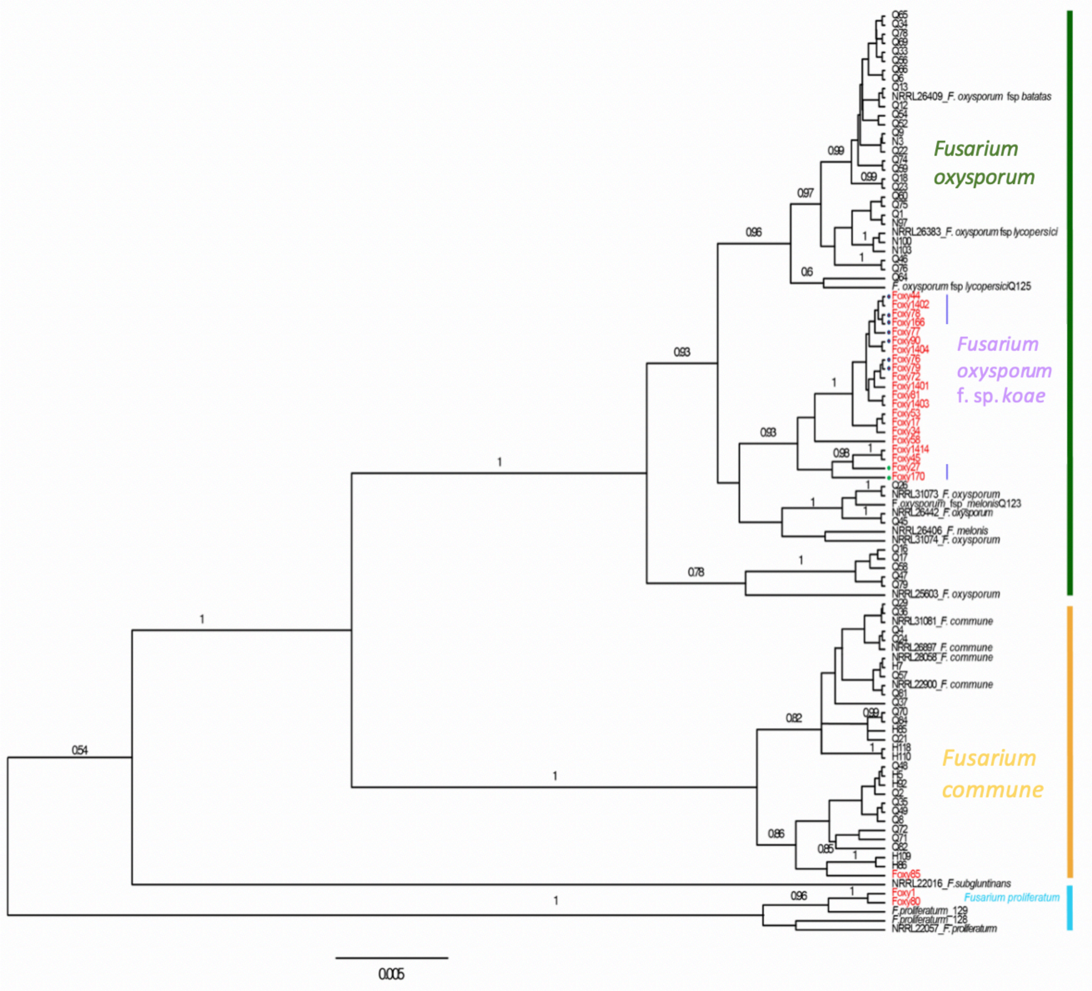

Figure 3. Consensus phylogeny of Fusarium sequences using coalescence-based Bayesian Analysis estimated in Evolutionary Analysis by Sampling Trees (BEAST). In red – 24 *Fusarium spp*. isolates from *Acacia koa* trees from Hawai'i sequenced at *tef-1a*.

Figure 4. Wilted *Acacia koa* seedling caused by *Fusarium oxysporum* f sp. *koae.*

Figure 5. Healthy *Acacia koa* seedling.

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ASSESSING POTENTIAL *ARMILLARIA* SPP. DISTRIBUTIONS IN WESTERN OREGON, WESTERN WASHINGTON, AND ALASKA: INCLUDING PRELIMINARY CONTEMPORARY AND FUTURE BIOCLIMATIC MODELS FOR *ARMILLARIA SOLIDIPES*

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INTRODUCTION

Armillaria species are key components of forest ecosystems throughout most regions of western North America. Their ecological roles range from beneficial saprobes to damaging root pathogens, and their impacts vary with environment and host. Under climate change, the impact of pathogenic species within these regions is predicted to increase (Kliejunas et al 2009), which could result in increased tree mortality, growth loss, and hazard trees that threaten public safety. In 2016, a collaborative project was initiated to survey of *Armillaria* spp. distributions in western Oregon, western Washington, and Alaska. Methods and preliminary results of the 2016 and 2017 (ongoing) field surveys/collections are described herein. *Armillaria* isolates derived from collaborative surveys are identified using DNA-based methods (e.g., translation elongation factor-1α gene sequence; *tef1*). DNA-based identification and 19 location-specific climatic variables are used to develop models to predict areas suitable for the occurrence of Armillaria spp. Preliminary predictions of geographic distributions of suitable habitat for *Armillaria* under current and predicted future climates are presented, based on Maximum entropy distribution models (MaxEnt). MaxEnt models are especially useful because of their ability to produce statistically robust models using limited occurrence-only data (see Phillips et al. 2006). This information will contribute to habitat-specific management strategies for reducing impacts and increasing the benefits of these ecologically important fungal species.

OBJECTIVES

The objectives of this project are to (i) survey, collect, isolate, culture, and identify *A. solidipes* and other *Armillaria* species in under-represented areas of western Oregon, western Washington, and Alaska, and (ii) integrate survey data from these under- represented areas with previous surveys of *A. solidipes* (ID, MT, WA, OR, UT, CO, WY, AZ, NM, and other states/ provinces). The combined survey data will be used to evaluate and refine existing bioclimatic models for predicting the contemporary realized climatic niche for *A. solidipes* and projecting its future geographic distribution under climate change in western North America. Any new *Armillaria* species/host combinations within OR, WA, and AK will also be documented.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]USDA Forest Service, RMRS, Moscow, Idaho. [2]Department of Forestry, Environment and Systems, Kookmin University, Seoul, South Korea. [3]Washington DNR, Olympia, Washington. [4]UDSA Forest Service, FHP Region 10, Juneau, Alaska. [5]UDSA Forest Service, FHP Region 6, Wenatchee, Washington. [6]UDSA Forest Service, FHP Region 6, Central Point, Oregon. [7]UDSA Forest Service, FHP Region 6, Sandy, Oregon. [8]Department of Bioagricultural Sciences and Pest Management, Colorado State University, Ft. Collins, Colorado. [9]USDA Forest Service-Central Oregon Service Center, Bend, Oregon.

METHODS

Point locations for 378 *Armillaria solidipes* isolates were collected from previous studies of Washington, Oregon, Idaho, Montana, Utah, Wyoming, Arizona, Colorado, New Mexico, British Columbia, and Chihuahua (McDonald et al. 1987, Shaw 1989, Omdal et al. 1995, McDonald et al. 1998, Kim 1999, Kim et al. 2000, Ferguson et al. 2003, Worrall et al. 2004, Hanna 2005, Hanna et al. 2007, Hanna et al. 2008a, Hanna et al. 2008b, Blodgett and Lundquist 2011, McDonald et al. 2011, Klopfenstein et al. 2012, Hanna et al. 2014, Hoffman et al. 2014, Blodgett et al. 2015, and unpublished data). Isolates of *A. solidipes* and other *Armillaria* species from ongoing surveys were identified by DNA sequencing (e.g., *tef1* gene) as described in Kim et al. (2006), Ross-Davis et al. (2012), and/or Elías-Román et al. (2013). Identification of some isolates were validated by somatic incompatibly and/or morphology.

Figure 1. *Armillaria* surveys. Armillaria root disease center (top left); Excavating a root collar to survey for *Armillaria* (top right); Armillaria fruiting bodies or basidioma (bottom left); *Armillaria* rhizomorphs (bottom center); and *Armillaria* mycelial fan (bottom right).

MaxEnt distribution models used 19 bioclimatic variables (e.g., annual mean temperature, maximum temperature of warmest month, annual precipitation, precipitation of wettest month, precipitation of coldest quarter, etc.) in two sets of interpolation grids (ca. 1-km^2 resolution) from worldclim.org (Hijmans 2005). One set containing environmental data for contemporary climate (based on data from 1950-2000) and a set of climate projection grids for the year 2070 (average for 2061-2080) based on data from the Intergovernmental Panel on Climate Change/Coupled Model Intercomparison Project Phase 5 (IPCC/CMIP5). For the 2070 predictions, we chose to use the representative concentration pathway 8.5 (RCP8.5), which represents a "business-as-usual" continued rise in CO_2 greenhouse gas scenario and the global circulation model (GCM) HadGEM2-ES (Collins et al. 2008, Riahi et al. 2011). Techniques are further described in Klopfenstein et al. (2009).

RESULTS

Surveys are ongoing, with >30 *Armillaria* isolates collected and established in culture to date (Figure 1). Preliminary climate-based, species distribution models using MaxEnt were created [Figures 2A (*A. solidipes* potential distribution under contemporary climate), and 2B (*A. solidipes* predicted potential distribution for project year 2070 climate)] based on the 378 confirmed locations where *A. solidipes* has already been identified.

DISCUSSION

This project is developing methods to monitor and predict potential threats of Armillaria root disease under contemporary and future climate scenarios across the western USA, including Alaska. Predictions of the present and future distribution of *Armillaria* pathogens will guide forest managers for appropriate practices to manage Armillaria root disease, based on contemporary and future climate scenarios. Information from this project will be incorporated into prediction models for the western USA. In addition, this approach can also be adapted for other native and invasive forest pathogens.

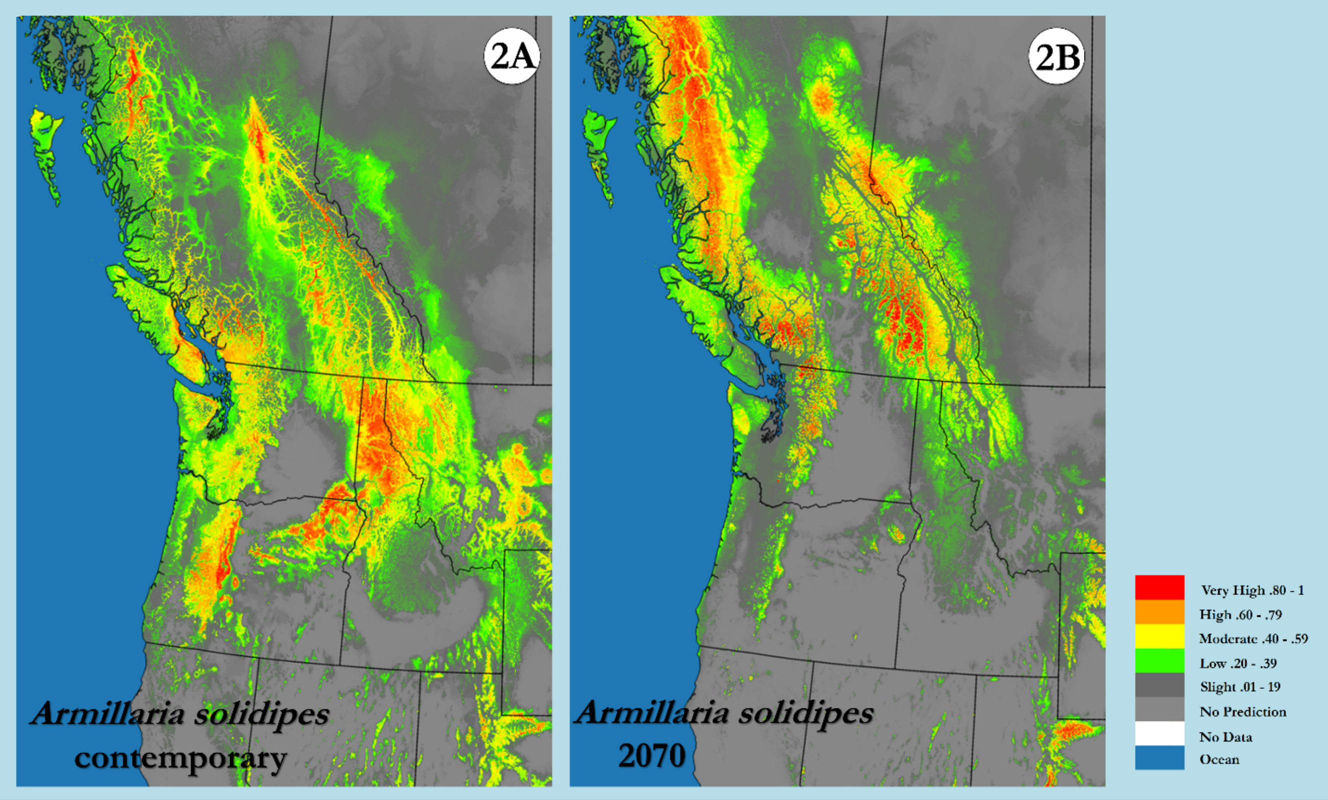

Figure 2. Maximum Entropy bioclimatic model of predicted suitable climate space (potential distribution) for 2A: *Armillaria solidipes* based on contemporary climate; 2B: *Armillaria solidipes* based on the RCP 8.5 "business as usual" climate-change scenario for the year 2070.

Our preliminary models (Figures 2A and 2B) predict that suitable climate for *A. solidipes* will decrease in Oregon and Washington by the year 2070 RCP8.5 "business as usual" scenario; however, these models are based on the pathogen and should be considered in the context of host trees for a better understanding of climate-change impacts. In addition, the adaptation potential of *Armillaria* spp. remains unknown. Predicted changes in climate may also predispose woody hosts that become maladapted (physiologically stressed by changing climate) to Armillaria root disease. It has been hypothesized that woody hosts that are stressed due to changing climate will have a higher likelihood of susceptibility to pathogens (e.g., Kliejunas et al. 2009, Sturrock et al. 2011, and others). For example, ongoing climate change is projected to increase the elevational distribution of *A. solidipes* which could potentially exacerbate Armillaria root disease in high-elevation areas of the southern Cascadia region, where species such as *Pinus albicaulis* (whitebark pine) are predicted to lose much of their suitable climate space due to climate change (Warwell et al. 2007). It seems plausible that disease caused by *A. solidipes* may increase until maladapted hosts and *A. solidipes* vanish from local landscapes.

To date, *A. solidipes* has not been recorded in California (Baumgartner and Rizzo 2001). Additional surveys/collections are needed from southern Oregon and northern California to determine the southern extent of *A. solidipes* distribution and the distribution of other *Armillaria* spp. along the west coast. Based on the predicted 2070 suitable habitat for *A. solidipes*, collections from these areas appear vital for determining which *Armillaria* species have potential to invade in the Cascadian region under future-climate scenarios. Currently, *A. solidipes* has not been found in Alaska. Bioclimatic model predictions indicate suitable climate space for *A. solidipes* is predicted to greatly increase throughout the southern coast of British Columbia and into southeast Alaska. Hence, caution is warranted for any northward movement of woody materials infected with *Armillaria* because of the increased potential (under future climate change) for *A. solidipes* to survive in northern areas that are currently considered climatically unsuitable for its survival.

The predictive capacity of bioclimatic models for *A. solidipes* and other *Armillaria* sp. can be further improved by 1) Removing bias with bias grids and/or collection of additional isolates from under-represented areas, 2) Adding additional predictive variables (i.e. soil types, solar radiation, topography, predictions of other *Armillaria* species, etc.), and 3) Obtaining population-level data to allow independent predictions based on diverse populations within a species.

ACKNOWLEDGEMENTS

This project is supported by USDA Forest Service, State and Private Forestry, Forest Health Protection - Special Technology Development Program; Western Wildlands Environmental Threat Assessment Center (WWETAC); and Rocky Mountain Research Station - Forest Woodland Ecosystems Program. The authors also thank Amy K. B. LaBarge, Seattle Public Utilities and Aaron Smith, NIBIO, Norsk institutt for bioøkonomi (formerly Forest Service FHP, Bend, Oregon) for their help with *Armillaria* collections.

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VIRULENCE PHENOTYPING OF *SPHAERULINA MUSIVA* ISOLATES INDICATES CLONE-BY-ISOLATE INTERACTION

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

INTRODUCTION

The ascomycete *Sphaerulina musiva* causes Septoria leaf spot and stem canker on *Populus spp*., and is considered to be the most serious pathogen affecting poplar cultivation in North America. The fungus is native to eastern and central North America, where it occurs sympatrically with its native host *Populus deltoides*. As a co-evolved host, *P. deltoides* suffers only from Septoria leaf spot. Black cottonwood (*Populus trichocarpa*), which is a naïve host native to the Pacific Northwest, is severely affected both by Septoria leaf spot and stem canker (Feau *et al*., 2010). Septoria stem canker infections on black cottonwood have been reported since 1920's within the native range of *S. musiva* (Waterman, 1954), where black cottonwood and its hybrids are widely cultivated. First confirmed reports of S. musiva in northwest North America within black cottonwood's native range are from British Columbia in 2006 (Callan *et al.*, 2007). As susceptibility to *S. musiva* is dominant in black cottonwood (Newcombe & Ostry, 2001), a large-scale *S. musiva* outbreak in the Pacific Northwest could have ecologically and economically devastating consequences. Knowledge of *S. musiva* virulence factors can promote the development of efficient control strategies against the disease, and improve the accuracy of risk analysis. In this project, we characterized the virulence of 66 *S. musiva* isolates from geographically distinct populations. We detected a strong clone-by-isolate interaction, and significant differences in the ability of the isolates to cause stem cankers. In an ongoing project, we will apply genome-wide association mapping (GWAS) to identify loci associated with *S. musiva* virulence.

MATERIALS AND METHODS

Five *P. trichocarpa* genotypes originating from Washington and British Columbia were inoculated with 66 isolates of *S. musiva*. The isolates were collected from the native distribution of the pathogen, and from the Fraser River Valley where the pathogen has been introduced (Figure 1). We applied a non-wounding spray inoculation method (LeBoldus *et al.*, 2010). Briefly, five-week-old *P. trichocarpa* plants were sprayed with an *S. musiva* spore suspension (1×10^6 spores/ml) and incubated in plastic bags in the dark for 48 hours. Subsequently, the plants were removed from the bags and incubated in a growth chamber with an 18-hour photoperiod. Four plants of each host genotype were inoculated with each pathogen isolate, totaling 264 plants in the experiment. After three weeks, the number of cankers per stem was recorded. Linear mixed models were applied to analyze the data with the lme4 package in R (Bates *et al.*, 2015).

RESULTS AND DISCUSSION

We found a strong clone-by-isolate interaction that explained 22% of the variation (Figure 2), which is consistent with earlier observations (LeBoldus *et al.*, 2008). Also isolate affected the canker counts (16% of explained variation), whereas the geographic origin of the isolates had no significant effect (P>0.05). This suggests that phenotyping more isolates from a single geographic origin could help to capture a more representative spectrum of the phenotypic variation. However, as many geographic origins were only

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represented by a few isolates, these results are not conclusive on whether the virulence of geographically distinct *S. musiva* populations differs. In contrast to earlier results (LeBoldus *et al.*, 2008), host genotype had only a marginal effect on the canker counts (2% of explained variation). This indicates that five host genotypes were sufficient to reveal phenotypic differences in the virulence of *S. musiva* isolates. However, due to the significant clone-by-isolate interaction, larger number of host genotypes might improve the accuracy of the virulence phenotyping.

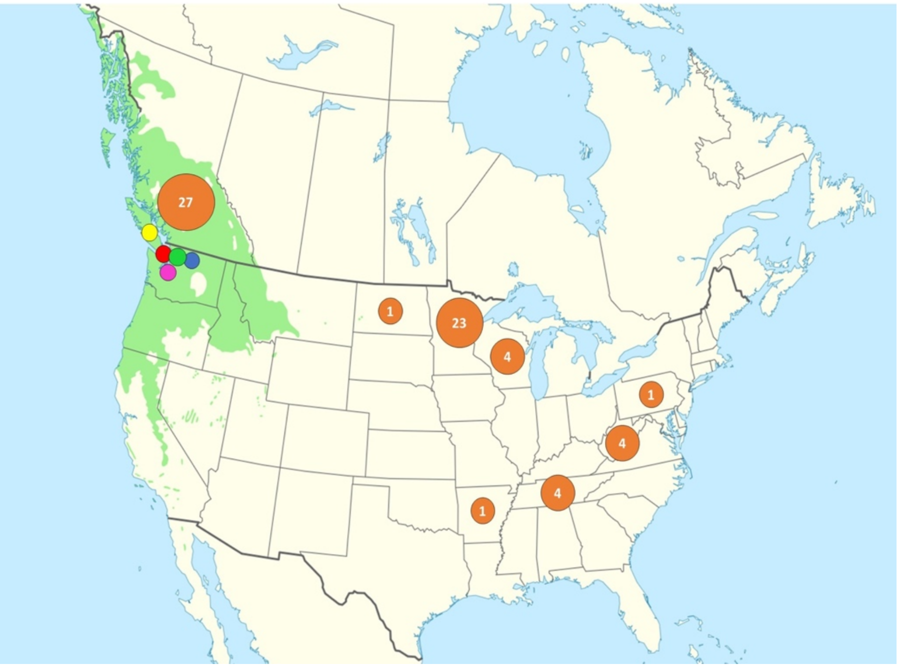

Figure 1. A map showing the geographic origins of the used *P. trichocarpa* genotypes and *S. musiva* isolates. Circles without numbers indicate the geographic origins of the *P. trichocarpa* genotypes (BESC-400 = green; CMBF28-1 = yellow; BESC-234 = pink; GW-9823 = blue; GW-11026, = red). Circles with numbers indicate the geographic origin and the count of *S. musiva* isolates. Distribution range of *P. trichocarpa* is indicated with green shading.

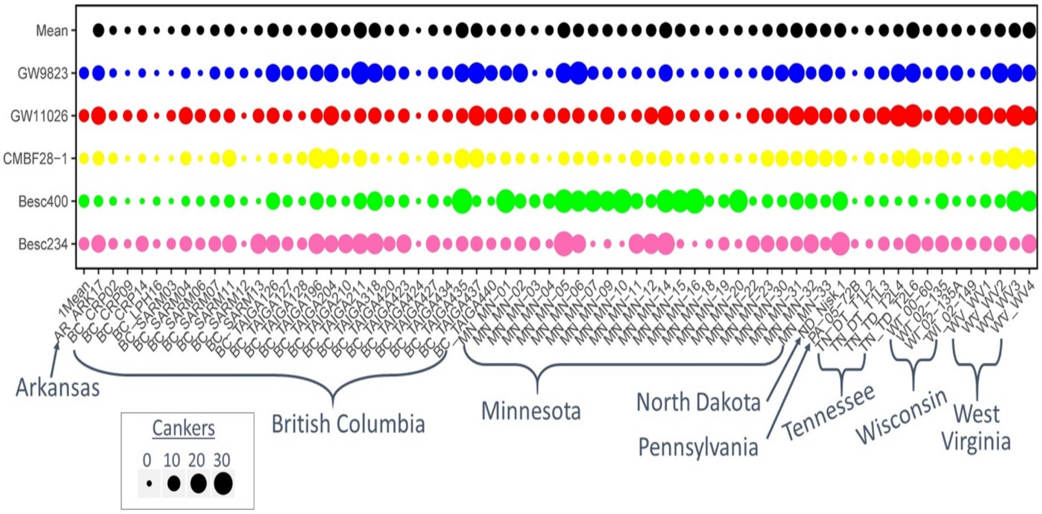

Figure 2. Number of cankers per stem caused by 66 different *S. musiva* isolates on five *P. trichocarpa* genotypes. Means are indicated for genotypes across isolates, and for isolates across genotypes.

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OVERVIEW OF GENOME CANADA RESILIENT FORESTS PROJECT: INTEGRATING GENOMIC, METABOLOMIC, AND PHENOTYPIC DATA FOR GENOMIC SELECTION IN TREE IMPROVEMENT AND THE ROLE OF DEFENSE CHEMISTRY IN PEST RESISTANCE SCREENING

Jennifer Klutsch[1], Chen Xin Kee[1], Barb R. Thomas[1], and *Nadir Erbilgin[1]*

Sustaining healthy forests requires trees with resistance to attacking organisms and resilience to abiotic stress. However, climate change is threatening Canadian forests. Alberta is facing increased moisture deficits at a pace that could be outstripping the natural adaptive capacity of our trees species. Furthermore, traditional tree improvement activities, which involves testing, breeding and production cycles that take upwards of 30 years, may not be able to produce trees quickly enough that are resilient to future climatic conditions. However, emerging technologies such as genomics and metabolomics can be techniques which accelerate our ability to produce well-adapted genetic material.

PROJECT PURPOSE

The purpose of the Resilient Forests (RES-FOR): Climate, Pests & Policy, Genomic Applications project is to integrate phenotyping and genotyping capabilities to enable early identification and incorporation of more desirable and adaptive traits into future forest breeding stock (Figure 1).

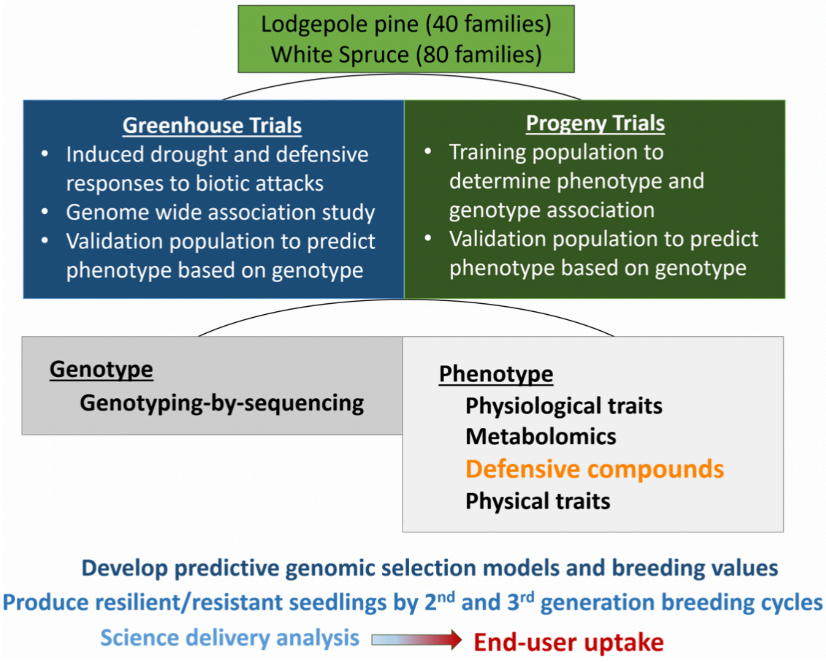

Figure 2. Design of overall RES-FOR program.

OVERVIEW OF DEFENSE PHENOTYPING

A greenhouse experiment with lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*) will measure the impact of drought and herbivore feeding on defenses. The mountain pine beetle (*Dendroctonus ponderosae*)-associated fungus *Grosmannia clavigera* will be inoculated on lodgepole pine from 20 families. And changes in defenses will be measure from white spruce from 40 families that have been fed on by eastern spruce budworm (*Choristoneura fumiferana*). Also, constitutive defenses will be measured from ~35 yr old field grown trees. A targeted analysis of terpene and phenolic compound concentrations will be conducted from phloem of 1600 lodgepole pine in four progeny sites and needles of 1600 white spruce in three progeny trials. Furthermore, resin duct and growth patterns are being assessed in a subsample of both trees. Western gall rust (*Endocronartium harknessii*) is a major pathogen in the lodgepole pine progeny trials. Half of the 1600 lodgepole pine are infected. We will assess the impact of infection on defensive chemistry and anatomy.

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CONCLUSIONS

Along with improving our understanding of the coordination and trade-offs between chemical defenses, information on the defensive phenotyping will feed into the genomic selection models. These genomic selection models developed in this project will speed up the development and turnover of production population seed orchards. This selection strategy will lead to more rapid production of resilient and resistant seedlings that are ready for deployment in three genomic selection enabled breeding cycles, where only two breeding cycles would be possible using conventional tree improvement methods.

METAGENOMIC APPROACHES TO DETERMINE SOIL MICROBIAL COMMUNITIES ASSOCIATED WITH ARMILLARIA ROOT DISEASE

Bradley Lalande[1], *Zaid Abdo*[1], *John W. Hanna*[2], *Deborah S. Page-Dumroese*[2], *Marcus V. Warwell*[2], *Joanne M. Tirocke*[2], *Mee-Sook Kim*[3] *Ned B. Klopfenstein*[2], and *Jane E. Stewart*[1]

INTRODUCTION

Armillaria root disease causes extensive damage to tree roots throughout the world, but efficacious management practices are lacking. However, soil interactions among *Armillaria* species, microbial communities, and trees may determine the impact of pathogenic *Armillaria* on the growth and survival of trees. Two species, *A. solidipes* (highly virulent) and *A. altimontana* (less virulent), frequently co-occur in forests of inland northwestern USA. Soil metagenomics and metatransciptomics may provide key insights into how interactions among soil microbial communities and root pathogens influence disease severity. If we can understand how soil microbial communities influence Armillaria root disease, then we can potentially develop novel management techniques that enhance biocontrol microbes and favor microbial communities that suppress disease caused by virulent *Armillaria* species.

The research objective is to provide a baseline for soil fungal and bacterial communities that are associated with two *Armillaria* species with differing ecological roles, *A. solidipes* (high virulence) and *A. altimontana* (low virulence).

METHODS

Data were collected from the Priest River Experimental Forest in northern Idaho within a western white pine (*Pinus monticola*) provenance (seed source) study (Figure 1). Of the original 2,400 planted in 1971, <600 trees remain after ~75% thinning in 1987 and other mortality. Sampling was completed during late June, 2016. From the remaining trees, 63 trees were selected, based by health status and previous *Armillaria* association that was determined in 1987. Rhizomorphs, bulk density soil cores, diameter at breast height (DBH), and tree health status were collected from each sampled tree. Soil DNA and RNA were extracted, and tag-amplicon sequencing of the rDNA ITS2 (fungal) and 16S (bacterial) was completed. Rhizomorph-derived cultures were established. From these, DNA was extracted and the translation elongation factor-1α (*tef*1) was amplified and sequenced for *Armillaria* species identification. Illumina files were cleaned using Trimmomatic and aligned to Silva and UNITE reference

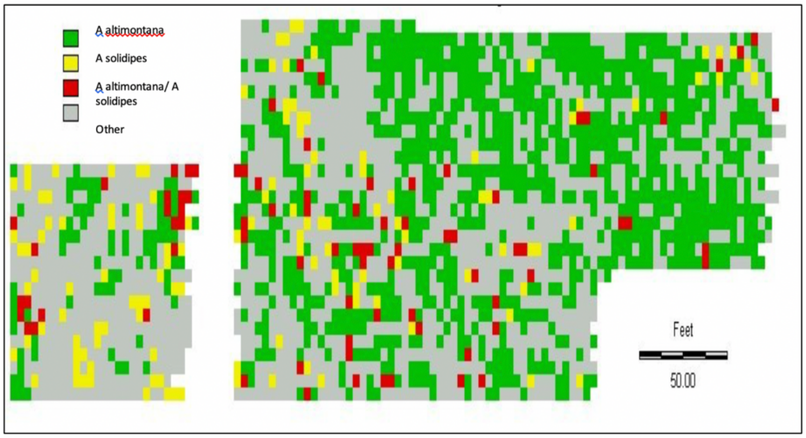

Figure 1. Map of western white pine planting and associated *Armillaria* spp.

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databases for identification. OTU tables were referenced to microbial communities using R (Rstudio Team, 2017). The number of species within fungal and bacterial communities, richness, and the relative abundance, diversity, of samples were analyzed. The analysis was done to determine if soil microbial communities differ in respect to associated *Armillaria* species and tree health status.

RESULTS

Of the total 59 trees sampled, 56 trees were associated with *A. altimontana,* whereas only three trees were associated with *A. solidipes*. *A. altimontana* and healthy trees were associated with more diverse bacterial communities, both in richness and in Shannon's diversity, compared with *A. solidipes* and dead-standing trees. Yet, these differences were only significant for tree health (Figures 2 A & C). Interestingly, *A. solidipes* and dead trees were associated with more diverse fungal communities compared to *A. altimontana* and healthy trees. Yet, there was no significant differences observed for fungal communities (Figures 2 B & D).

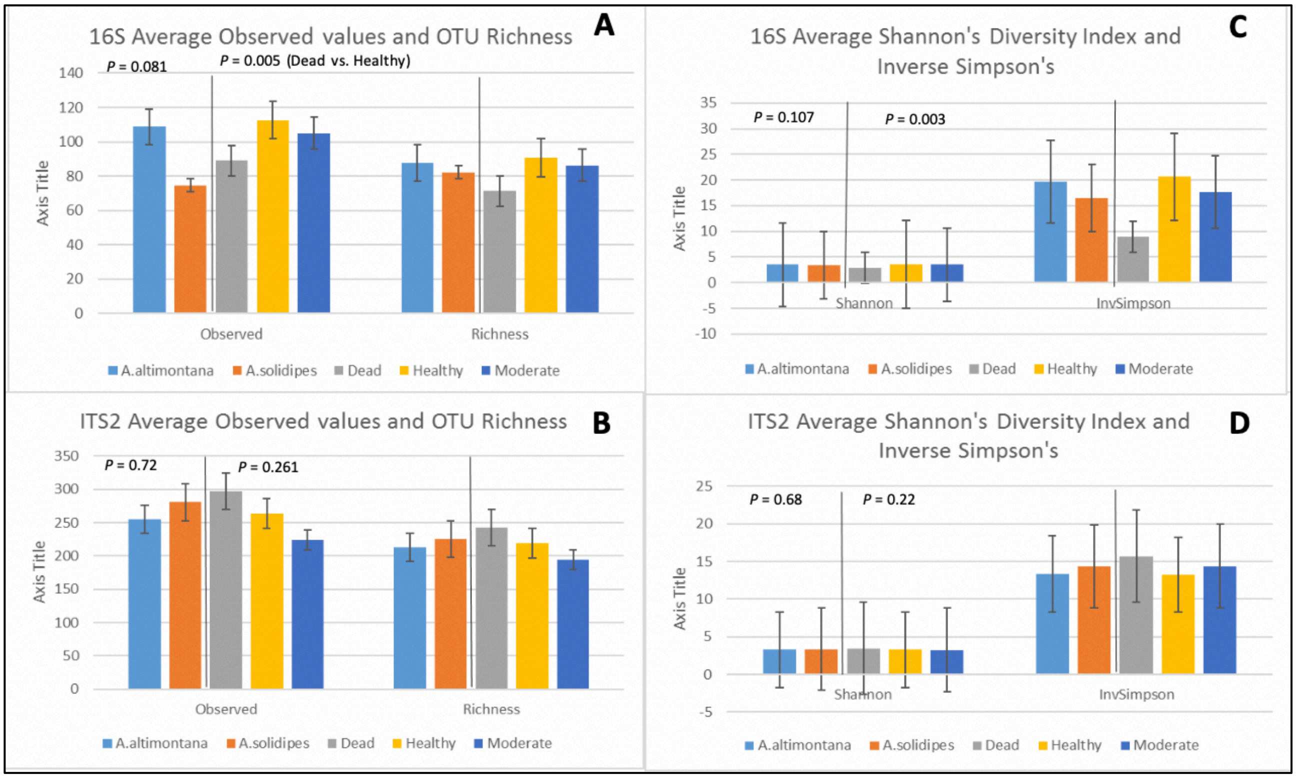

Figure 2. Average observed values and Operational Taxonomic Unit (OTU) richness for bacterial communities (**A**) and fungal communities (**B**) Average Shannon's diversity and inverse Simpson's values for bacterial (**C**) and fungal communities (**D**).

Based on the 712 unique bacterial OTUs identified, more Pseudomonadaceae and Spartobacteria were associated with healthy trees, while more Acidobacteria were associated with dead trees (Figure 3). In respect to *Armillaria* species, more Pseudomonadaceae and Rhizobiales were associated with *A. altimontana*; whereas, more Acidobacteria and Enterobacteriaceae were associated with *A. solidipes* (Figure 3).

Based on the 3,383 unique fungal OTUs identified, more Cortinariceae and Hypocreaceae (e.g., *Trichoderma*) associated with healthy trees, and more Inocybaceae were associated with dead trees (Figure 4). More Trichocomaceae, Cortinariaceae, and Rhizopogonaceae were found in association with *A. altimontana*, while more Mortierellaceae were found in association with *A. solidipes* (Figure 4).

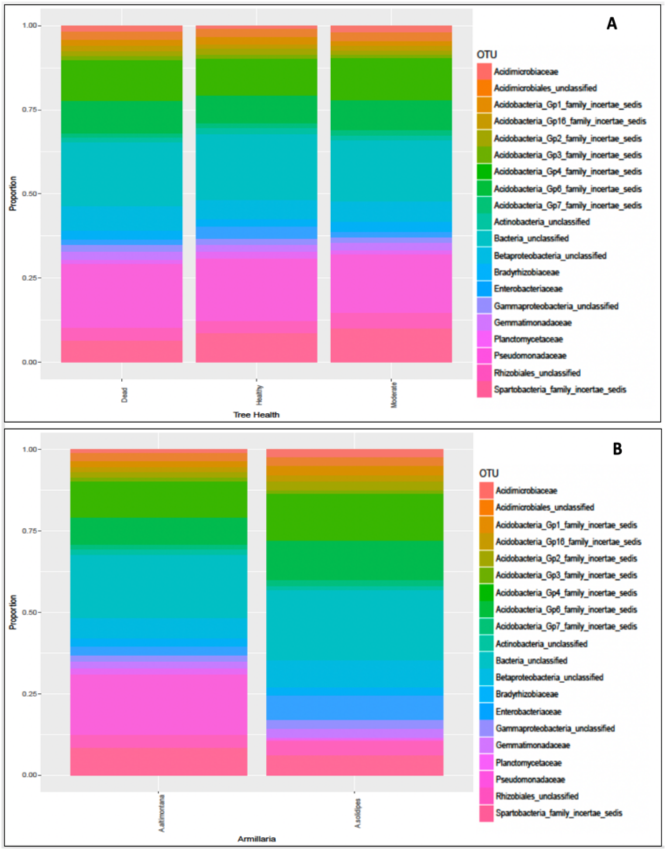

Figure 3. Stacked bar graphs identifying most prevalent bacterial communities; Tree health (A), Armillaria species (B).

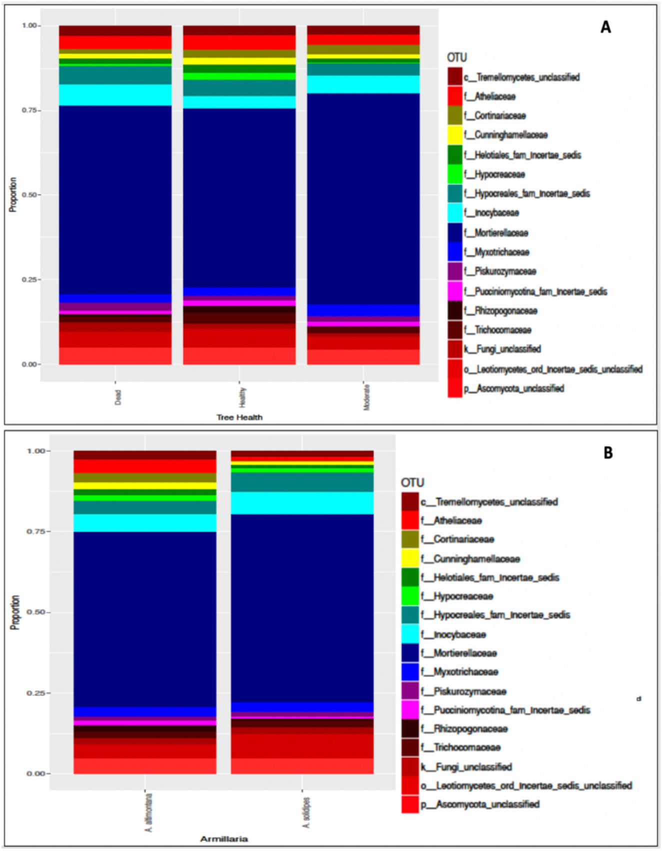

Figure 4. Stacked bar graph identifying most prevalent fungal communities; Tree health (A), Armillaria species (B).

DISCUSSION

Potentially higher bacterial diversity is associated with healthy trees and *A. altimontana*; whereas, higher fungal diversity may be associated with dead-standing trees and *A. solidipes.* When examining OTUs within communities, we found higher levels of Pseudomonadaceae and *Trichoderma* species associated with healthy trees and *A. altimontana.* These organisms are known to be important in biocontrol against pathogens in disease-suppressive soils. Preliminary results suggest novel approaches could be developed for managing Armillaria root disease by fostering soil conditions to favor microbial communities that suppress Armillaria root disease. Results will be correlated to soil physical/chemical properties and efforts are underway to further explore microbial communities associated with *A. solidipes* and *A. altimontana* using artificial inoculations.

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LANDSCAPE-LEVEL PLANNING TO IMPLEMENT BLISTER RUST PRUNING IN YOUNG WESTERN WHITE PINE ON THE WARM SPRINGS RESERVATION, OREGON

Brent Oblinger[1] and *Ryan Singleton*[2]

INTRODUCTION

White pine blister rust (*Cronartium ribicola*) has been damaging western white pine (*Pinus monticola*) and other five-needle pines on the Warm Springs Reservation in Oregon since the 1920's (Bedwell and Childs 1943). Screening western white pine on the Reservation for resistance to blister rust has been on-going through collaboration with the U.S. Forest Service's Dorena Genetic Resource Center. Seed orchards containing families with varying levels of resistance exist on Warm Springs and western white pine seedlings are commonly planted after regeneration harvests or fires. There are 50,000-60,000 western white pine seedlings now planted annually on the Reservation. However, blister rust is still a management concern due to mortality caused by the disease in some plantations (Figure 1).

Figure 1. White pine blister rust bole cankers near the gound on young western white pine on the Warm Springs Reservation.

Along with breeding for genetic resistance to this disease, one of the few other options for controlling blister rust in plantations is by pruning branches in the lower crowns of young western white pines (Schnepf and Schwandt 2006; Schwandt et al. 2013; Zeglen et al. 2009; Zeglen et al. 2010). By removing the lower branches within the first 8 ft of the ground, new infections can be prevented and infected branches can be removed before the fungus reaches the bole and becomes lethal (Schnepf and Schwandt 2006; Schwandt et al. 2013; Zeglen et al. 2010). Blister rust pruning in young western white pine has been carried out on other tribal lands and on other ownerships in the Interior Northwest. The objectives of this project in 2015-2016 were to: a) prioritize stands with young western white pine for blister rust pruning to reduce losses from this disease; b) implement blister rust pruning (single crown lift) in multiple stands that were assigned high priority; and c) determine where to focus additional survey and pruning efforts based on blister rust survey results. Additional details are reported by Singleton and Oblinger (2017) in the *Journal of Forestry*.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1] USDA Forest Service, Pacific Northwest Region, Forest Health Protection, Central Oregon Service Area, Bend, Oregon. [2] The Confederated Tribes of the Warm Springs Reservation, Department of Forestry, Warm Springs, Oregon.

METHODS

Plantations with young western white pine were identified using the Reservation's stand-based inventory data and located in GIS (ArcMap ver. 10.2.2, ESRI, Redlands, CA) to be surveyed for blister rust and the number of prunable white pines present. Inventory data were grown forward to 2015 using the Forest Planning and Projection System ver. 6.97 (Forest Biometrics Research Institute, Portland, OR) to identify stands with some western white pine present. Stands were then prioritized for rust surveys to narrow down the number to a manageable level across the Reservation based on: stand age (10-30 years), the abundance of white pines present (≥100 trees per acre (TPA)), and heights of vegetation present (majority of trees 8-30 ft tall). Visual interpretation of airborne light detection and ranging (lidar) first-return data, acquired in 2011, was used to estimate heights of vegetation and white pines present. If the majority of vegetation heights appeared outside the 8-30 ft range within a stand, that stand was then excluded. Stands identified were surveyed in the field for blister rust and for the number of prunable white pines present. Prunable trees included live white pines with no visible cankers and those with branch cankers where the canker margin was ≥6 in. from the bole. Stands with moderate infection levels (incidence of rust between 15-50%) and ≥70 prunable white pine TPA were assigned high priority for blister rust pruning. Blister rust survey results were compared among three geographic areas (north-to-south, based on major watersheds) to determine whether incidence of rust differed to help prioritize where future planning and treatment efforts should occur in the next several years.

Table 1. Number of stands and total area with young western white pine queried based on stand age from the Reservation's stand-based inventory and tree height estimates from visual interpretation of lidar data.

Stand attributes	No. stands	Total acres (hectacres)
Stands with >0 white pine TPA and stand age 10-30 yr	725	18,249 (7,385)
Stands with ≥100 white pine TPA and stand age 10-30 yr	221	5,165 (2,090)
Stands with ≥100 white pine TPA and stand age 10-30 yr and majority of trees 8-30 ft tall	144	2,967 (1,200)

RESULTS AND DISCUSSION

The number of stands initially prioritized to be surveyed for blister rust was narrowed down from 725 to 144 and totaled 2,967 ac (Table 1). However, 63 of these 144 stands were surveyed for rust and the number of prunable white pines due to available funding. We can now utilize lidar data more when planning a variety of forest restoration treatments, including blister rust pruning to identify even-aged plantations with trees in a certain height range to then be surveyed on the ground. The number of stands identified, to be surveyed for blister rust and the number of prunable white pines present, was reduced by 35% using lidar data. Along with visual interpretation of lidar-derived vegetation canopy heights, stand summary statistics could be calculated using ArcMap to help identify stands of appropriate height.

Prior to this project, limited information was available on incidence and severity of blister rust in young plantations throughout Warm Springs. Overall, about one in six white pines within a plantation had blister rust across the Reservation. Some plantations did not have *Ribes* or other alternate hosts present where blister rust occurred on white pine. Additional work is needed to determine whether the abundance of certain *Ribes* species is significantly related to incidence and severity of blister rust on white pine within a plantation. Incidence of blister rust and the number of prunable white pines present were variable, but a significantly lower (values of $p < 0.01$) incidence of rust was found in the southern portion (Lemiti Meadow) of the Reservation based on non-parametric tests (Figure 2). There were 21 stands of the 63 surveyed that were assigned high priority for blister rust pruning with moderate infection levels and ≥70 prunable white pine TPA present. This totaled 440 ac.

In fall of 2016, blister rust pruning was completed in all 21 stands prioritized for treatment (Figure 3). There were nine stands in the Mt. Wilson, 15 in the Camas Prairie and three in the Lemiti Meadow areas treated. White pines were pruned up to ~50% of their total height if ≤16 ft tall and pruned up to 8-10 ft if trees were >16 ft tall (Schnepf and Schwandt 2006; Zeglen et al. 2009). Implementation of this project was a significant example of a landscape-scale approach that led to restoration treatments being accomplished to maintain western white pine in the presence of blister rust.

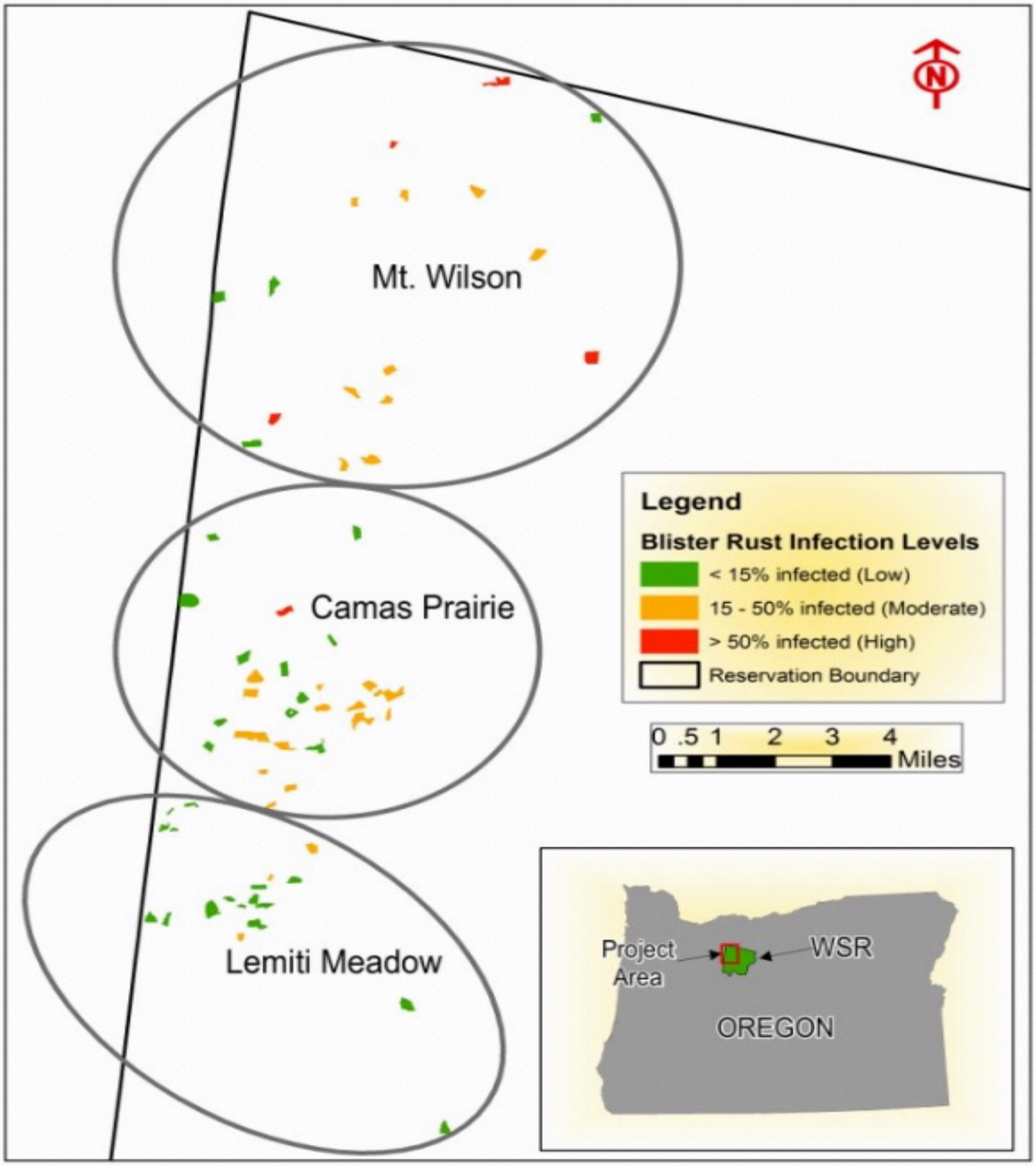

Figure 2. Incidence of white pine blister rust on young western white pine in 63 plantations surveyed across three areas on the Reservation.

Figure 3. Young western white pine recently pruned on the Warm Springs Reservation.

Thinning may or may not occur along with pruning on the Reservation due to limited funds available for pre-commercial thinning and at times, concerns over fuel loading post-treatment. Thinning coupled with pruning in the Oregon East Cascades should be evaluated further versus pruning by itself to combat blister rust and enhance white pine survival (Schwandt et al. 2013). There is also limited funding available for multiple crown lifts, but two pruning treatments could be considered where this is higher rust hazard, opposed to waiting until white pines are taller and doing a single crown lift (Zeglen et al. 2009; Zeglen et al. 2010).

On larger forest ownerships with numerous stands containing young western white pine, a broad, systematic approach is needed to prioritize treatments in order to best-utilize limited funds for pruning and increase the chances of treatments being effective. Our approach was similar to what Schwandt et al. (2013) recommended in northern Idaho and Montana. Blister rust survey results suggest that additional planning efforts in the near-term could be focused in the Mt. Wilson and Camas Prairie areas. Future work also could be completed to map rust hazard zones on the Reservation.

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ADVANCES TOWARD DNA-BASED DETECTION, IDENTIFICATION AND DIFFERENTIATION OF NORTH AMERICAN *HETEROBASIDION* SPECIES

Simon Francis Shamoun[1]*, Craig Hammett*[2]*, Irina Kassatenko*[1]*, Grace Sumampong*[1]*,* and *Xiang Li*[3]

SUMMARY

The basidiomycete species complex *Heterobasidion annosum sensu lato* are regarded as some of the most destructive pathogens of conifers worldwide. Recent work on *H. annosum* has classified the species complex into five species based on their genetic diversity, inter-sterility between mating groups, geographical distribution, and host preference. In North America, there are two species *H. irregulare* and *H. occidentale*, while *H. annosum s.s.*, *H. parviporum*, and *H. abietinum* occur in Eurasia. The Canadian Food Inspection Agency has identified *Heterobasidion* spp. as a forest pest species of significant regulatory concern because of the invasive risk posed by the fungus. To date, we have developed species-specific PCR primers that bind specifically to conserved alleles in glyceraldehyde 3-phosphate dehydrogenase and elongation factor 1α genes for detection, identification and differentiation of *H. irregulare* and *H. occidentale*. The method is sensitive enough to detect either species from infected wood and root substrates. In addition, using these PCR primers, we were able to document for first time the occurrence of *H. irregulare* isolated from basidiocarps collected from ponderosa pine and eastern white pine in Okanagan, Naramata, and Summerland, respectively, from the southern interior British Columbia (BC) forests. These samples are preserved at the DAVFP Pacific Forestry Centre Herbarium, Victoria, BC. Ongoing research work is focusing on designing and validating Loop-Mediated Isothermal Amplification (LAMP) assays for detection and identification of all *Heterobasidion* spp. complex. Furthermore, genomic sequencing of *H. occidentale* is underway to search for candidate virulence genes and marker development for detection and identification of individual species of the *Heterobasidion* complex.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia. [2]University of British Columbia, Department of Forest Science and Conservation, Vancouver, British Columbia. [3]Canadian Food Inspection Agency, Charlottetown, Prince Edward Island.

TOWARDS UNDERSTANDING PATHOGENICITY ACROSS ALL SPECIES IN THE GENUS *GEOSMITHIA*

Rachael Sitz[1,2], *Jorge Ibarra Caballero*[1], *Dan West*[3], and *Jane Stewart*[1]

INTRODUCTION

Recently, an increasing amount of beetle-associated fungi were documented as plant pathogens of agriculturally and ecologically important tree species. Ploetz et al. (2013) coined these diseases 'Black Swan events' due to their unpredictable nature, yet the development of pathogenicity in this group of fungi is largely unstudied. The genus *Geosmithia* is particularly interesting because within the last decade three species, including *G. morbida*, *G. pallida,* and *G. langdonii*, as well as two newly found yet undescribed species, have become important hardwood pathogens on walnut, oak, and elm respectively (Tisserat et al. 2009; Kolařík and Kirkendall 2010, Kolařík et al. 2011, Zerillo et al. 2014; Lynch et al. 2014; Hänzi et al. 2016).

We conducted a screening study using cut branches from two hosts susceptible to at least one species of *Geosmithia* (oak and walnut) to determine if (1) additional species of *Geosmithia* are able to produce cankers on either oak or walnut, and (2) whether or not the type strain of *G. pallida* forms cankers on oak.

METHODS

Cut branches of red oak (*Quercus rubra*) and black walnut (*Juglans nigra*), measuring approximately 2 cm in diameter and 12 cm in length, were harvested from the Colorado State Forest Service Nursery in Fort Collins, CO. Branches were surface sterilized and ends were painted with a paraffin wax. Each branch was inoculated 3 times and represented a replication. There were 5 replications for each of the 13 *Geosmithia* species tested or a control (Table 1). After inoculation with a 5 mm agar punch, wounds were sealed with parafilm, left for one week at 24˚C, and then the bark around the inoculation site was peeled back in order to quantify canker lengths. Data was analyzed using JMP software.

RESULTS

All tested *Geosmithia* species were less pathogenic than *Geosmithia morbida* on walnut although *Geosmithia microcorthyli* consistently caused the next largest canker. Other trends were not present (Figure 1A). On oak, *G. pallida* was larger than *G. langdonii* and *G. cnesini*, but the difference was not biologically significant. Other species were not different from each other (Figure 1B).

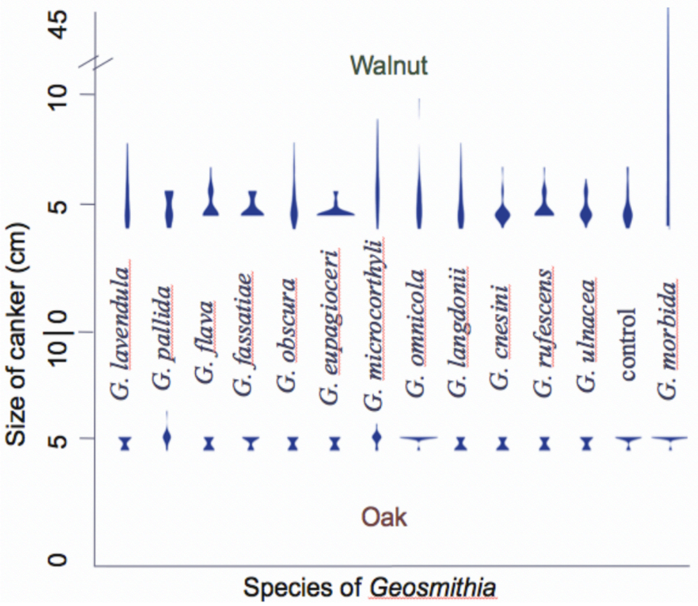

Figure 1. Kernal plot showing average canker sizes produced by each *Geosmithia* species on (A) walnut and (B) oak.

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DISCUSSION AND CONCLUSION

The *G. pallida* strain tested in this experiment was not isolated from foamy bark canker sites and did not produce cankers on oak, a host thought to be susceptible to foamy bark canker. Based on our results, it is likely that the newly pathogenic strains of *G. pallida* are divergent and potentially comprise a different sub-species or even species.

Furthermore, we tested the type strain of *Geosmithia langdonii* in this experiment; it did not produce cankers on walnut or oak, but is a newly described pathogen of elm. In this case host specificity holds true. On the contrary, *Geosmithia microcorthyli* caused cankers on walnut.

There is a range of pathogenicity expressed by species in the genus *Geosmithia*. As many species are emerging as pathogens, they represent an interesting avenue of study. Comparing the gene expression between non-pathogenic and pathogenic species may help tease apart what shift is occurring allowing this group of fungi to become pathogenic. Additionally, characterizing more *Geosmithia* species may help us in tracking host shifts and determining pathogenicity mechanisms.

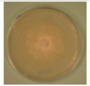
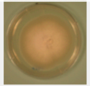
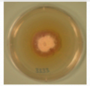
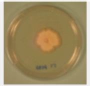
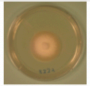
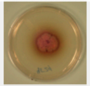
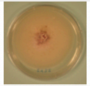
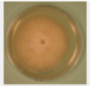
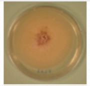
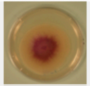
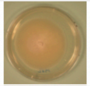
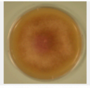
***Geosmithia* Species**	**Strain**	**Host Plant**	**Location**	**Culture**
G. eupagioceri	CCF 3754	*Paulínia renesii*	Costa Rica	
G. cnesini	CCR 4292	*Croton draco*	Costa Rica	
G. omnicola	CCF 4269	*Ulmus minor*	Italy	
G. flava	CCF 3333	*Castanea sativa*	Czech Republic	
G. ulnacea	CNR 23	*Ulmus minor*	Czech Republic	
G. fassatiae	CCF 3334	*Quercus pubescense*	Czech Republic	
G. rufescens	CCR 4524	*Croton draco*	Costa Rica	
G. pallida	CCF 3053	cotton yarn	England, UK	
G. langdonii	CCR 3332	*Quercus robur*	Czech Republic	
G. obscura	CCF 3422	*Quercus robur*	Czech Republic	
G. lavendula	CCF 3051	lab contaminant	Illinois, USA	
G. microcorthyli	CCF 3861	*Cassia grandis*	Costa Rica	
G. morbia	G2071	*Juglans nigra*	Colorado, USA	
1/2 PDA	control	.	.	

Table 1. The *Geosmithia* species and strain used in the experiment, as well as the host plant, collection location, and an image of the isolate grown in pure culture on ½ PDA.

ACKNOWLEDGEMENTS

We thank Miroslav Kolarik who provided *Geosmithia* spp. isolates for this experiment. The USDA Forest Service provided funding for this project, and the Colorado State Forest Service Nursery and Colorado State University main campus allowed us to harvest branches.

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VARIATION IN SUSCEPTIBILITY AMONG SOUTHERN OREGON TANOAK FAMILIES TO *PHYTOPHTHORA RAMORUM*

Kelsey L. Søndreli[1]*, Alan Kanaskie*[2]*, Richard Sniezko*[3]*, Susanna Keriö*[1]*,* and *Jared M. LeBoldus*[1]

SUMMARY

Sudden Oak Death (SOD) is caused by *Phytopthora ramorum,* an invasive oomycete pathogen in coastal California and southern Oregon mixed-hardwood forests. In southwestern Oregon, tanoak (*Notholithocarpus densiflorus*) is the most susceptible species developing lethal stem cankers and sporulating on infected leaves and branches. Two lineages (NA1 and EU1) of *P. ramorum* occur in Oregon. The first step in a successful tanoak-breeding program is to determine if variation in susceptibility to *P. ramorum* exists in the host. The objectives of this study were to: (i) characterize the variability in resistance of *N. densiflorus* among 14 families using lesion length; and (ii) determine whether lineage, isolate, family, or their interactions significantly affect variation in lesion length. There was a difference in lesion length between the EU1 and NA1 lineages detected in 3 out of 14 families. The majority of the variation in lesion length is explained by isolates nested within lineage [isolate(lineage)]. However, the family-isolate(lineage) interaction is also significant suggesting that more than one isolate may be needed in order to evaluate tanoak resistance to *P. ramorum.*

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Oregon State University, Corvallis, Oregon. [2]Oregon Department of Forestry, Salem, Oregon. [3]Dorena Genetic Resource Center, USDA Forest Service, Cottage Grove, Oregon.

CHESTNUT RED STAIN: IDENTIFICATION OF THE FUNGI ASSOCIATED WITH THE COSTLY DISCOLOURATION OF *CASTANEA SATIVA*

Jewel I. Yurkewich[1], *C. Castaño*[1,2], and *C. Colinas*[1,3]

SUMMARY

In Europe, fungal pathogens have reduced the overall productivity of sweet chestnut (*Castanea sativa)* stands and continue to threaten the economic viability of forestry operations. Chestnut Red Stain (CRS) in north-eastern Spain, locally referred to as *Roig*, is capable of decreasing the market value of chestnut timber to the point of rendering chestnut coppices uneconomical. Despite its economic importance, the specific cause of this red discolouration is unknown. With the objective of verifying the presence of fungi within the symptomatic wood, and identifying the fungus or suite of fungi associated with the red stain, wood samples were collected and cultured from 37 stumps found in eight recently harvested stands in the Montseny and Montnegre-Corredor Natural Parks. To separate the fungi associated with CRS from other species inhabiting the chestnut wood, the origin of each fungal culture was mapped in every stump. The fungi were isolated from cultures and identified by sequencing the ITS region. The results provide insight into the fungal community inhabiting chestnut wood and the potential cause of CRS; nine species were identified including two species known to cause decay in chestnut. One of them, *Fistulina hepatica*, appears to be a likely candidate for the causal agent of CRS. This is the first study reporting the fungi associated with CRS and opens the door to new epidemiological studies focused on *F. hepatica*. Full publication available from Journal of Forest Pathology: http://onlinelibrary.wiley.com/doi/10.1111/efp.12335/abstract.

In: Cleaver, C. & P. Palacios (Comps). Proceedings of the 65th Annual Western International Forest Disease Work Conference; 2017 Oct. 2-6; Parksville, British Columbia. [1]Department of Crop and Forest Science, University of Lleida, Lleida, Spain. [2]Forest Bioengineering Solutions S.A., Solsona, Spain. [3]Forest Sciences Centre of Catalonia, Solsona, Spain.

COMMITTEE MEETING REPORTS

RUST COMMITTEE MEETING

Committee Chair: *Paul Zambino* (acting)

Meeting Notes: *Alex Woods* and *Paul Zambino*

The breakfast meeting took place Tuesday morning, October 2, was chaired by Paul Zambino as acting chair, and was well attended. Pending approval by general membership at the general business meeting, Paul Zambino and Jane Stewart agreed to serve as co-chairs of the rust committee. [The committee's nomination of co-chairs was subsequently approved]. Brief reports were offered. Alex Woods provided transcribed notes of the meeting which were edited by the chair and presenters. Reports and discussions are summarized below.

SHORT PRESENTATIONS

Rich Hunt reported on a test of age-related resistance to white pine blister rust in western white pine. The reason for the study was to investigate why offspring of western white pines selected for resistance and exposed to rust as young seedlings typically showed very little improvement in resistance compared to natural populations—just 5% improvement. But, in eastern white pine, Patton found that seedlings from mature trees with apparent resistance were initially very susceptible and became more resistant as they aged.

The Age Related Resistance Trial (ARRT) was developed by Rich and continued by Nick Ukrainetz, the pine breeder in British Columbia. In the ARRT, 2-year old western white pine seedlings of the same six families were planted out annually over several years and protected with plastic cones to prevent exposure to rust basidiospores. The oldest seedlings were emerging through the tops of the protective cones at seedling age six. The cones were then removed from all seedlings (seedling ages 6, 5, 4, and 2 years), exposing them all to rust. Potted black currant cultivar 'Ben Nevis' was placed throughout the trial area. Seedlings were examined annually for rust to 3 years post-inoculation (2016). Seedlings exposed at age 6 had the least rust. When comparing 6-year old seedlings, the wild, control lot, was most rusted at 97.5% while the best family was significantly less rusted at 61.7%. Rich concluded that age increased resistance in some families and that the use of protectors to keep trees safe until seedling age 6 years [four years from planting] was effective. The results raised the question whether screening programs testing western white pine seedlings at an early age may be missing useful resistance.

Paul Zambino mentioned that in eastern Ontario, they developed an alternative method of protecting eastern white pine plantations from rust for a few years after establishment: planting seedlings along with oversized gelatin capsules containing the systemic fungicide triadimefon.

K.A. Leddy reported on a ten-year survey of limber pine health in the Rocky Mountains that she, Jane Stewart, and Kelly Burns have been conducting on over 7500 tagged limber pine trees in Montana, Wyoming, and Colorado. These trees have been assessed 3 times over the 10-13 year period from 2004/07 to 2017 for incidence of white pine blister rust infection and mountain pine beetle attacks. The assessed sites had limber pine dominant in overstory but with no recruitment of new seedlings on over 50% of the plots. The incidence of rust was stable over the 10-13 year period. Some areas had rust incidence at 60-70%, while others had only 10-15% incidence. Mortality from rust was increasing over the monitoring period but was mostly from infections present at the beginning of the monitoring period. Additionally, infections recorded at the beginning of the study have increased in severity. Considered across all sites, health of the trees declined by 25% over the 10-13 year period, and 25% of the trees died. Dramatic limber pine mortality was caused by either mountain pine beetle or white pine blister rust, with a low proportion of trees succumbing to both damage agents. Some sites had no mortality from rust, but where rust was present, as much as 50% of the mortality was from rust. Although the results looked grim, the researchers were not as pessimistic about the future of the species as they have been following previous reports, due to the stabilization of incidence. It is possible susceptible trees behind the disease front have already been infected and severity increases until mortality while a remainder of the limber pine population remains healthy.

Kelly Burns added that although many apparently rust-resistant limber pines were killed by MPB, many others survived.

Paul Zambino gave an update on the performance of F2 generation western white pine from the U.S.D.A. Region 1 screening program monitored at 20 plantations in northern Idaho. The sites were established from 1991 to 2000 in plantations that had no pruning or thinning and ranged in age from just planted to 10 years from planting. Sufficient 1/20 acre plots were installed at each site to capture at least 100 western white pine trees. Measurements were at about 5-year intervals. Measurements in 2011 (about 16 years after plot establishment) included trees' rust infection status (uninfected, lethal, prunable, and safe as defined by canker growth studies; percent stem girdling; numbers of cankers), dbh, and cause of mortality for each tree, if identifiable (white pine blister rust, Armillaria root disease, or other causes). Results of the 2011 remeasurement were previously presented and are available in the 2013 WIFDWC proceedings and in Schwandt and others (2013) paper "Impacts of White Pine Blister Rust in 22 Plantations of Western White Pine in Northern Idaho 1995-2011".

The trial is now down to 14 sites from the original 20, due to heavy bear damage at some sites, and unplanned thinning and pruning through others. The 2016 measurements added additional data categories: height to safe canopy (distance from ground to branches where green needles were > 24" [=60 cm] from the stem), height to crown (height to living branches in two quadrants,as defined in the U.S.D.A. Forest Service's Common Stand Exam [CSE] Protocols), and height of highest infection.

The 2016 measurements indicated there was probably a severe wave year of infection in 2011 or 2012, and many stands were not free of danger from new blister rust infections. In general, sites that had high tree growth rates had few new infections and almost all infections were "safe", due to crown recession. Six stands had average height of safe canopy ≥ 8', with one at >16'. Height to safe canopy was often higher, and often much higher, than height to crown. The worst infection rates were on the poorest growth sites, where most trees still had branches very low to the ground. Trees on these sites had no reduction in infection rates, even 23 years after planting: infection rates on the few trees that had remained uninfected at the four slowest-growing sites averaged 10% per year for the period from 2011-2016. This extremely high rate of infection at these stands was likely due to the wave year.

Three trial sites with moderate to high tree growth also had high mortality from Armillaria root disease in earlier measurement intervals, but Armillaria root disease caused no mortality from 2011 to 2016. The two most productive sites previously affected by Armillaria root disease had almost no blister rust infection in any of the monitoring periods. Only one living tree had basal symptoms of Armillaria root disease in the entire study in 2016.

Some unanswered questions include:

1. Can differences in trees' diameters and percent girdling from 2011 to 2016 be used to estimate girdling rates to predict when to thin or harvest to recover value? [Harry Kope mentioned that his work on western gall rust girdling rates could be useful.]

2. What caused some sites to have high root disease mortality but extremely low rust infection and mortality?

3. Can the U.S.D.A. Forest Service's Forest Vegetation Simulator (FVS) be improved using the study's data? The declining rates of infection and mortality from Armillaria root disease and white pine blister in western white pine in this study are at odds with the current root disease and blister rust extensions of FVS, which assume that western white pine has uniform percentage losses from these diseases for each decade of growth.

Alex Woods asked if Paul looked at climatic differences between the sites to see if that explains the wide range of incidence across sites. Paul mentioned that Research Silviculturist Terrie Jain at the Moscow, ID Forestry Sciences Lab is interested in collaborating with Paul in risk modeling, and plans to include climatic factors among other risk factors (such as air flow from topography, predicted presence of local inoculum based on nearby openings from prior harvests). Part of the approach will be to see if climate envelopes can be developed for areas of high versus low disease, akin to Gerry Rehfeldt's climate models for tree species. Dave Shaw and Nick Ukrainetz suggested Paul use ClimateWNA to look for differences in weather between the sites that may be related to white pine blister rust risk and wave years.

Mike McWilliams asked Paul that if F2 stock is still getting 50% mortality, would he still recommend planting it? Paul answered yes, for a number of reasons: Some sites have very low infection. Wherever naturally seeded trees and F2 trees occur together, infection rate is double the incidence in naturals compared to F2 material. F2 material has improved since the plantings in the study occurred due to poorer preforming resistant trees being rogued from seed orchards. On sites where natural regeneration is occurring under a canopy of F2 stock, regenerants look to have low infection rates that may surpass the resistance of the parents. Also, besides having the greatest potential productivity of all species on western redcedar habitat types, western white pine has beneficial characteristics for fire and soil hydrology: Western white pine has much lower amounts of ground fuels, and in recent fires, fire behavior was better when wildfires went through western white pine plantations than for ponderosa pine. Also, western white pine doesn't hold snow in the canopy the way most of our other conifers do, so there is more and longer soil moisture benefit from winter precipitation in stands dominated by western white pine.

[Alex Woods provided a comment while compiling these notes about how categorizing branch infections as "safe" vs. "lethal" or "prunable" could be applied in other rusts. He suggested that the behavior of comandra rust in lodgepole pine in British Columbia is similar to that of white pine blister rust in western white pine and considered it reasonable that safe canker distances for comandra rust might be similar to those of white pine blister rust.]

ROUND ROBIN

Phil Cannon reported that *Austropuccinia psidii* is an ongoing, important issue in the U.S.D.A. Forest Service's Pacific Region [which includes California and Pacific islands and countries]. This rust has different strains that affect many members of the myrtle family, including eucalyptus and ohia. This year, the rust fungus formerly called *Pucccinia psidii* was put in a new genus *Austropuccinia*, because *Austropuccinia psidii* was found to be very distinct genetically from other members of the genus *Puccinia*. Phil also mentioned that most forest pathologists in California have retired.

Michael Murray stated that limber pine is still recommended for designation in Canada as a species at risk or endangered species.

Richard Hamelin reported that the white pine blister rust genome was submitted to Genome Canada for sequencing. Richard was continuing his work on hybrid rust between *Cronartium ribicola* and *C. comandrae* from the Smithers area and Waterton Lakes National Park, Alberta, Canada. He and mentioned Kiah Allen's Flash-and-Dash presentation on the hybrid rust later that would occur later that morning. [See separate abstract.]

Brent Oblinger mentioned pruning to manage white pine blister rust at Warm Springs Reservation. [This study was presented in the poster session; see separate abstract].

Christy Cleaver described a pictorial guide to aid pruning western white pine to reduce white pine blister rust losses and offered copies to attendees. This guide was developed by Forest Health Protection forest pathologists of the U.S. Forest Service's Northern and Intermountain Regions. The guide presented images of blister rust and look-alikes and proper and improper pruning with captions in English and Spanish. The guide was at the publishers and would be printed soon. Those wanting copies for distribution were suggested to contact Christy or Paul, who can send them out after printing.

FOLIAR AND TWIG DISEASES MEETING

Committee Chair: *Harry Kope*

The lunch meeting took place on Tuesday, October 3rd from 12:00 – 1:30.

SHORT PRESENTATIONS

PowerPoint presentation by **Patrick Bennett** – (PhD Candidate - Oregon State University)

Patrick spoke to the topic "How might climate change influence the SNC epidemic in western Oregon and Washington?"

- Weather conditions including moisture and temperature were discussed;
  - Temperature influenced needle colonization (Pseudothecia formation).
  - Moisture influenced spore dispersal, spore germination and subsequent needle infection.
  - The abundance of pseudothecia was equated with Swiss Needle Cast severity

- Factors that might decrease or increase SNC incidence/severity were discussed;
  - Decrease – higher summer temperatures; colder winter temperatures led to drought-like conditions.
  - Increase – warmer winter temperatures; more spring and early summer moisture led to warm wet conditions in winter and spring.

- Further research to incorporate these above. mentioned weather conditions was discussed;
  - SNC climate modelling to include mean daily winter temperatures and late spring early summer moisture.
  - A colonization index was discussed which equals infection incidence multiplied by pseudothecia density.
  - It was assumed that there would be a linear correlation between stomatal occlusion by pseudothecia and foliage retention, which is an indicator of disease severity.

NURSERY PATHOLOGY COMMITTEE MEETING

Committee Chair: *Anna Leon*

The Nursery Committee follows a roundtable format in which participants share research, new disease issues, and local updates. A range of disease issues were discussed including *Fusarium commune* on multiple hosts, *Botrytis* on nursery stock, and an unexplained mortality issue that has arisen in a western white pine seed orchard. The committee also discussed a request to endorse Guidelines for *Phytophthora* in Restoration Nurseries, a set of guidelines for California released by the Working Group for *Phytophthoras* in Native Habitats. While WIFDWC endorsed these guidelines when the request was originally made, a discussion was begun at this committee meeting on how we want to proceed in similar situations as an organization.

ROUND ROBIN

Jane Stewart – *F. commune* has been reported on 5 non-conifer hosts and her lab will be looking at microsatellites to distinguish between different host isolates. This work will include pathogenicity tests of isolates onto each host as well.

Gary Chastagner – Discussed a project looking at *Botrytis* on nursery stock. All isolates so far are *B. cinerea* and fungicide resistance is very common. WSU is participating in IR-4 funded fungicide trials looking at both traditional and biocontrol fungicides and then examining disease expression during production and during storage. One of the interesting early findings is that Zerotol, a popular fungicide, is phytotoxic on seedlings. *Botrytis* species other than *B. cinerea* tend to be very host specific and different fungicides work well for different species.

WSU has also been tracking *Rhizoctonia* web blight in stored Christmas trees. This species is a moss pathogen from Europe, not the *Rhizoctonia* web blight forest pathogen.

Chal Landgren helped establish seed orchards and progeny trials for noble fir, Douglas-fir, Nordmann fir, and Turkish fir in the US from seeds collected in Europe. Nordmann and Turkish fir have good disease and insect resistance and good needle retention.

Harry Kope – Mortality recently appeared at a western white pine seed orchard. Many white pine, evenly distributed through the orchard, turned red within one month. There appears to be no oomycete activity after a cursory first test. However, the only tests done for oomycetes were through plating and the committee recommended further molecular testing be done. Black stain root disease has been suggested as a cause due to the dark streaking under the bark, however no insects have been found. This problem is happening in both Victoria and the Okanagan orchards, which implicates the root stock that was used to establish the orchard. The orchard was planted in 2007 and trees have only begun to die within the last year. It was mentioned that grafting incompatibility can sometimes take years to show up. It was also suggested that if an insect is believed to be spreading disease, the roots can be caged to see what emerges. Finally, samples were sent to UBC for further testing.

Jim Blodgett – White pine seed from the Black Hills was replanted in its native range and there has been 100% seedling survival so far. They weren't allowed to plant in the wilderness so the seed was planted just outside of it. This seed isn't technically tested for resistance, but it is a secondary trait that some trees appear to be expressing.

Betsy Goodrich – Surveys for pests in seed orchards are ongoing in the Wenatchee region.

Anna Leon – Testing of the fumigant Dominus (allyl isothiocyanate) is continuing in a partnership between WSU, the Washington DNR, and Weyerhaeuser in an IR-4 funded trial to test its efficacy against methyl bromide. Based on the first round of trials, it appears that Dominus controls pathogens as well as methyl bromide in most situations. *Shortly after the WIFDWC meeting, this project was selected to receive additional funding from IR-4 for 2017 and 2018.

Discussion on Guidelines for *Phytophthora* in Restoration Nurseries:

The nursery committee had a lively discussion on the criteria that must be followed when WIFDWC is asked to endorse plans developed by outside parties. The following summarizes the main points of the discussion that were then shared at the business meeting:

- We must make sure that the science supports the guidelines being proposed, especially if the guidelines are being linked to legislation or other activities that limit the nursery businesses.
- These guidelines will disproportionately affect small nurseries, in part because small nurseries were responsible for the release of several *phytophthoras* in recent years.
- Wording must be very clear to limit the spread of known pathogens and not an entire genus.
- Instead of making recommendations ourselves, we can support the recommendations of other well-respected working groups (i.e. The California Forest Pest Committee).
- This issue would probably be best addressed by an ad hoc committee assembled by the president.

CLIMATE CHANGE COMMITTEE MEETING

Committee Chair: *Alex Woods*
Meeting Notes: *Paul Zambino* and *Alex Woods*

SHORT PRESENTATIONS

Phil Cannon: Impact of climate change on a few forest diseases in USDA Forest Service, Pacific Southwest Region (R5 - CA, Hawaii, Guam and other Pacific Islands).

The concept of the disease triangle helps us understand the interplay between host, pathogen and the environment and when the climate changes we can expect changes in the resulting disease.

Phellinus noxius is a very impressive disease in American Samoa and it can grow up to 20'/year along roots. The fungus produces a resupinate fruiting body that can attain considerable size. The fungus is referred to as the "black sock" because of the way it colonizes the bottom portion of the boles of trees and may totally cover the base of the trees. Trees are rapidly colonized and can go from healthy to fallen over in 6 months. John Hanna, USFS, Rocky Mtn. RS, has modelled the potential habitat for this rapidly spreading fungus and there is a lot of area in the tropics where this fungus could colonize, from South and Central America to Madagascar and large portions of SE Asia and Oceania.

In 2014 there were 8 super typhoons in the W Pacific Region. Oceans store as much as 90% of the excess heat caused by anthropogenic forces. If the oceans didn't trap and store this heat the earth's atmosphere would be significantly warmer (Scientific American, Oct 18, 2016). *P. noxius* appears to be spreading more rapidly as a result of the wounding caused by the super typhoons and the damage the storms do to the roots of trees. The fungus is not host specific and has a broad host list. Breadfruit is one of these hosts and the fungus is able to rapidly colonize breadfruit trees allowing for the fungus to be spread by people as breadfruit trees are a traditional gift among the locals.

Austropuccinia psidii is a rust with a voracious appetite for the Myrtaceae including the roseapple (invasive) in Hawaii. The rust also attacks Ohia (*Metrosideros polymorpha*) a keystone species that grows on very thin soils that supports ecosystems and help prevent erosion. The rust is so virulent that after exceptionally heavy rains on Oahu, areas of Ohia forest were observed dying. Ohia also suffers from a wilt (*Ceratocystis fimbriata*) which has 2 forms one of which has a very fast rate of growth in wood. In older stands the damage is worse, in younger stands on younger lava flows the disease is not as severe. It is thought that cyclones create infection courts for ambrosia beetles which then serve as possible vectors for the wilt fungus. The damage is also aggravated by drought.

The combination of storm surges and higher tides is also killing coastal trees due to inundation. In southern CA, drought in the Sierra Mtns has led to the death of over 103 million trees. In the same general area the frequency of atmospheric rivers that direct weather systems straight on to the coast of CA has greatly increased and these have resulted in 3 times the normal rainfall and high winds. 45 atmospheric rivers have made landfall on the West Coast thus far during the 2017 water year (1 Oct- Mar 2017) (but not all crossed through CA).

http://cw3e.ucsd.edu/how-many-atmospheric-rivers-have-hit-the-u-s-west-coast-during-the-remarkably-wet-water-year-2017/

Dave Shaw asked what the connection was between *Phellinus noxious* and climate change. Phil answered that wetter conditions and more intense and frequent storms have led to root wounds that are rapidly colonized.

ROUND ROBIN (ROUSING DISCUSSION)

Alex started by recounting how lively the discussion was at last year's WIFDWC climate change committee meeting in Sitka AK and how it would be great to pick up where we left off last year. At that meeting the trigger point seemed to be the reluctance of many to connect any changes in disease behaviour with climate change. Alex said we all know of the disease triangle and we can see how in some areas conditions are getting warmer and wetter and we have a good idea how those changes affect some pathogens. In other areas it is getting warmer and drier and that leads to increased stress for trees and we know some pathogens preferred stressed trees so it shouldn't be a big stretch to think climate change could be behind changes we are seeing in disease behavior… so why the reluctance? In many cases we have long-term records of weather and climate but we don't have long-term records of disease behaviour. In trying to publish papers on the subject it is common to run into reviewers who want to see traditional statistical tests showing how there has been a clear change in disease but without long-term records of disease over periods of 30+ years you can't do this.

Mike McWilliams said maybe it is more important to refer to 'a preponderance of evidence' rather than 'beyond and reasonable doubt'. Marcus Warwell pointed out that 'climate' is typically the weather conditions over a 30 year period or more and weather is less than that. He said all of Phil Cannon's examples were related to weather and if he were an editor or a reviewer he would say these were perhaps due to specific weather events, but not climate change. Danny Norlander said that many pathogens are responsive to thresholds and threshold events. Have we reached a threshold event where the climatic conditions have changed sufficiently to trigger new disease behaviours? Phil C. added that if we have just 3 years of increased wetness that could be enough for 50 cycles of rust infections. Alex countered, "Is it necessary to say that the changes we are seeing in disease behaviour are due to climate change? Can we just say that the changes are consistent with climate change projections and what we might expect?" Marcus W. said he would be OK with that if he were the editor. Holly Kearns said that if we have similar events we can expect to have similar outcomes to those that have already presented.

Alex said the Dothistroma example in NW BC and our ability to publish that story was due to a lot of good luck. We had records of the disease being present from the FIDs data and that prior outbreaks of the disease were related to certain weather conditions and when the favourable weather conditions were no longer present the disease died back. We were fortunate to have very good studies of the epidemiology of the pathogen from work done by P. Gadgil in New Zealand and G. Peterson in Nebraska. So we knew what weather favoured the disease. Then when we saw this unprecedented event with mature lodgepole pine trees dying from the foliar disease we could trace that change in behaviour back to a very clear change in the weather that is consistent with climate change forecasts. Subsequently a relationship between El Ninos and past outbreaks of the disease has been uncovered but this is still consistent with overall climate change being a major driver of this disease condition because climate change influences the frequency and intensity of El Nino events.

Phil C. said it only takes one event to wipe out 20 years of forest growth and it could be a 3 week event or period and not just a single rainfall. In many cases it is the number of consecutive days of rain rather than the actual rainfall amount that may trigger a response in a pathogen.

Betsy Goodrich said that it isn't that the US Forest Service isn't interested and concerned about climate change but the organization wants to be sure that forest health people are giving their clients good recommendations.

Amy Ramsey and Alex said that it is very helpful when making those recommendations to have peer-reviewed scientific literature in hand to back them up.

Michael Murray said old trees have stories to tell and dendrochronology can help show how climatic changes have affected tree growth and the interactions with pathogens. Alex said Kathy Lewis pointed that out the first time she saw the severely attacked trees in the Dothistroma example in NW BC. She cored the trees and it was clear where the rings had narrowed at the same time as the prior Dothistroma outbreaks noted in the FIDs surveys.

ROBIN CONTINUED (MORE ROUSING DISCUSSION)

Alex W. noted how alders are dying in BC and felt embarrassed about not knowing of Jim Worrall's paper that linked dying alder in AK and CO to *Cytospora umbrina* and to heat stress and drought. In BC the phenomenon might in part help explain moose population declines because the dead alder provide less cover for the animals to hide from hunters. Lori Winton said that she is still studying alder canker in AK and that Jenny Ritchie a PhD student is looking into it further. The fungus involved is also known as *Valsa melanodiscus* but that naming conventions have decided that *Cytospora umbrina* is the name that will be used. Jane Stewart had more details about the actual name change. Lori W. has set up long-term monitoring surveys for alder health for 3 different spp in AK since 2006. She monitors over 3000 miles of flight lines and 192 sites with stations every 10 miles. 40% of the sites have alders and > 8% of the sites have alder canker. Thinleaf alders are hard hit and in general there has been a 3X increase in disturbances in these alder sites. Alex mentioned that in BC there would not be long-term records of alder because it is not a timber species, but having a reference like Worrall's paper and his description of heat stress as an initial cause made good sense in BC.

Brennan Ferguson is increasingly concerned about what to tell forest managers who want to grow forest on 75-100 year rotations and he really doesn't know what climate changes will mean for ponderosa pine and the interface between sagebrush grasslands and forests. Brennan feels it is necessary to try to explain the climatic changes and what his best guess is to how those change will affect tree physiology and not just the forest pathogens. Brennan wants to put all of the references online so that clients can look for themselves in the peer-reviewed literature. He said there are useful examples of Western white pine pole blight and heat stress, birch decline and drought, Alaska yellow cedar decline and loss of snowpack. Each example starts with predisposing weather events followed by a lot of effort going into finding the fungal agents responsible then come back to the weather being the true initial predisposing event. Brennan isn't sure how to best present all of the cases but it is frightening to see all of the various events going on and he isn't sure if the information is being passed down to those who are doing the habitat typing and forecast changes in them. Mike McWilliams said the difference between having trees and not having trees is 14"of annual rainfall. Mike suggests the best idea is to put effort into areas that we think will still have trees in the future.

Ned Klopfenstein said it is important to include invasive species with climate change because climate change is creating new environments that can release invasive species from environmental thresholds that may have held them in check. Changes in pathogens behaviour and disease conditions may be the result of pathogens taking the non-adapted species out of the mix.

Marcus W. asked where will the predictions used in GCMs be in the future? Climate models only show where the climate envelopes currently associated with a species will occur.

Another big knowledge gap is the environmental requirements of many pathogens. The basic information for optimum temperatures and moisture regimes for diseases like Septoria leaf spot simply are not known. This gets back to the threshold issue and if we don't know what the environmental requirements are we won't know when we have crossed an environmental threshold until we are long past crossing it. Jane Stewart said it isn't just the temp. requirements of the pathogens but also for the hosts themselves. Can we rely on optimum temperature values determined in growth chambers? Juan Aldana argued that in the absence of any other information that we have to rely on growth chamber values. Paul Z. gave the example of white pine blister rust teliospores that will die if temps are above 25°C.

Alex W. asked Lorne Bedford (BC provincial manager of harvesting and silviculture practices) what he would like to see in terms of guidance for climate change and forest diseases. Lorne said he would like the pathologists to tell him exactly what to do. Lorne said he can see how we can have a single weather event over a 30 year period that results in wide-scale changes in the forests but a single event is not climate change. In BC we are now planting higher densities and we are using assisted migration to help counter the expected losses.

Alex W. said in general we have to get more comfortable with making recommendations knowing that we may well be making mistakes because there is simply too much uncertainty and we can't expect to get it right all of the time. We need to be informed and make intelligent recommendations and if we see something isn't working, make changes to future recommendations.

Dave Shaw said he is willing to make mistakes but is more comfortable with taking a cautious approach.

Mike McWilliams said we have to give the best recommendations we can and monitor, monitor, monitor.

Alex said Yes! We have to monitor extensively but that we need to make sure our monitoring protocols don't become so expensive that we cannot maintain them in times of limited budgets and that they aren't overly complex so that in times of limited resources they can still be conducted. They also need to be timely because we can't wait to have all of the precise answers, we need answers that can change practices now if those changes are warranted.

Danny N. said at a minimum we have to be able to say that things are changing even without the papers that might specifically spell things out. Educating the public about these changes is key and some people don't even believe that drought kills trees.

Alex W said we have to be alright with saying "I'm an expert in the field of forest pathology and I know about trees and pathogens and how they interact with the environment and given those relationships if the climate changes in this direction I expect to see this. I might be wrong but this is my best guess knowing what I know".

Marcus W. asked if part of the challenge was a tech transfer issue? Danny N. said some clients are just not willing to take risks. Dean Meason (NZ) said, part of the problem is getting others to share your concerns and to have early adapters for change. In NZ they have been able to use the physiological limitations of the hosts trees themselves in light of climate forecasts to advocate for changes in management practices. Pathologists have to get comfortable with not knowing exactly how things will turn out but need to get involved in the conversation.

Lori Winton shared that she has millions of acres of forests to look out for in AK and that the inventory system already has a plot network that can be tied into. The inventory plots provide a long-term data set that she doesn't have to go set up herself.

Dave Shaw said we need to connect aerial detection survey data, remote sensing satellite data, FIA and other data sources and get rates of mortality which would give us a pretty good picture. The rate of mortality in trees is critical and despite problems with FIA data they do get mortality rates correct. There are challenges with the quality of individual path code calls but overall the FIA data can be very useful. Paul Z. has more confidence in some of the codes than in others.

Phil Cannon said pathologists should take more advantage of the climate data analysis and weather monitoring information available from the weather data analysis folks.

Paul Z. and Amy Ramsey said it is very important to know the environmental requirements of the pathogens and to know the temperature limits of survival and optima. Some of these environmental requirements can be determined in the lab but lab conditions don't always line up well with real world environmental conditions.

Overall lots of good discussion about climate change and forest pathogens and the challenges of trying to sort out how best to gain insights into how we think conditions may change over time and how we provide advice in such an uncertain world.

ROOT DISEASE COMMITTEE MEETING

Committee Chair: *Blakey Lockman*

Meeting Notes: *Mike McWilliams, Brennan Ferguson,* and *Blakey Lockman*

The breakfast meeting took place Thursday morning, October 5, was chaired by Blakey Lockman, and was well attended. Brief reports were offered and are summarized below.

Dave Shaw reported on remeasurement of old growth and yield plots for *Phellinus (weirii) sulphurascens* (laminated root rot= LRR). The plots were established in 1926, on 1-acre plots, and two were on the NE Olympic peninsula established in a natural 36-year-old Douglas-fir stand. In the 1950s they realized they had a *P. weirii* problem, these became known as the "McArdle and Meyer" plots, and are being converted to western redcedar by LRR. Plots were remeasured in 2017- Dave and others collected samples of LRR, resulting in ~38 isolates. Cross-platings will be done to see how many clones exist on these two plots. There is a plan to incorporate carbon measurements to see if the same amount of carbon remains sequestered as if it had stayed in standing live Douglas-fir.

Harry Kope reported on what may be blackstain in a western white pine seed orchard near Victoria. The orchard was planted in 2007, and has been suffering mortality since 2012. Death happens fast, with trees fading and dying within a month. They haven't found *Phytophthora* or *Pythium* yet with culturing on selective medium, but have not used water baits. There is *Leptographium* reported on *Pinus strobus*. There may be stain on the small roots, but in general, very little stain has been found and no insects have been found. He is looking for ideas. Some in the audience suggested looking further for *Phytophthora*. He will give us an update at the next meeting.

Jared LeBoldus gave an update on the blackstain affecting Douglas-fir in southwest Oregon. This unusual occurrence is mostly affecting 5- to 7-year-old trees, but is usually typical in 20-year-old stands. Currently, it is affecting about 5% of the trees in these young stands. Soil compaction has historically been a risk factor leading to increased incidence of blackstain, but in these cases many stands are on slopes with no history of ground equipment use. Many of the occurrences are on Weyerhaeuser and Stimson ground near Roseburg. Jared hopes to get a new graduate student who will be working on population genetics of *Poria weirii* and *Leptographium*.

Bart van der Kamp reported on the Hidden Lake plots- *Armillaria* spread plots established in the Okanagan area of B.C. in ICH (Interior Cedar Hemlock B.E.C). Initially there were 30 centers per hectare, usually small 1-2 tree 'centers', and there is still mortality occurring in Douglas-fir. There has been little mortality recently, and many trees have healed over that were half-girdled by *Armillaria*, or had half their root systems rotted. Recently some trees have tipped out supported by one live 'stilt' root, so even though *Armillaria* didn't kill the tree, it compromised the structural integrity. Callus does not regenerate roots, and even in *Phaeolus schweinitzii* there are extra roots formed, but not from callus. Bart did an interpretive dance to show the tip-up because his slide didn't work.

Simon Shamoun discussed elements of regulation for *Heterobasidion*. There is concern that the conidial state could infect green wood products or wood not treated. Simon cited the example of *Heterobasidion* getting to Italy on crates moving military equipment. There are now three *Heterobasidion* species in Europe and two in North America. We need diagnostic tools to distinguish *H. irregulare* and *H. occidentale*, and could use PCR to evaluate different primers that may distinguish the different species. Simon is also investigating the occurrence and biological significance of double-stranded RNA (dsRNA), in *Heterobasidion* species complex. There seems to be a higher incidence of dsRNA in *H. irregulare* populations than in *H. occidentale* populations. Surveys have been done in Haida Gwaii, and *H. occidentale* is found there. Simon's research team has confirmed for the first time (via using PCR species-specific markers) the occurrence of *Heterobasidion irregulare* in B.C. The sample was collected in Okanagan, BC in 1993. The sample originally found by Janice Hodge and confirmed by Brenda Callan as *H. annosum* on ponderosa pine- a PFC herbarium specimen exists. In addition, a second record of *H. irregulare* on planted eastern white pine was found in Summerland, BC- Agriculture and Agri-Food Canada Research Station site. The confirmation of was also confirmed by Simon's research team via using PCR-species specific markers.

Blakey Lockman discussed some aspects of "Rotstop C", the bio-pesticide registered for control of *Heterobasidion*. The product is registered in Canada and in the US for stump treatment, but needs state-by-state registration for use in the US. The product is manufactured using a *Plebiopsis gigantea* isolate from eastern North America. We would like to know if the genetics are the same as west-coast isolates, and what is the level of variation among isolates? One small study comparing isolates used two isolates from the west and found no differences. Blakey suggested developing an STDP with Matteo Garbelotto from Berkeley. Rich Hunt noted that *Phlebiopsis gigantea* was used in California to treat pine stumps and was found to be ineffective, probably because the temperature was too high in the pine stumps. Simon Shamoun remarked that the company could make the product with any isolate we provide to them, but it's unclear if this would require a new registration.

Mike Cruickshank discussed a study to look for genetic resistance to *Ophiostoma*, *Armillaria, Phellinus*, and drought in half sib families of interior Douglas-fir. Resistance or tolerance to one stress does not correlate well with resistance to another. He contrasted resistance and tolerance, the cost of resistance comes after induction. Resistance only was the least frequent strategy, and more commonly a combination of resistance and tolerance was found. He's finishing up and then will do a write-up/paper. He also remarked that stump removal is economic under the right conditions, and we should put the carbon costs in the figures to help determine economic viability. Mike also mentioned the cedar butt rot poster: *Armillaria ostoyae* forms infection courts for butt decay fungi, and this is common in western redcedar.

Rich Hunt and Ned Klopfenstein entertained us with the on-going saga of the correct name for the west-coast tree killing *Armillaria* species. WIFDWC has written letters in support of using the name 'ostoyae', and the International Botanical Congress currently recognizes the name *Armillaria ostoyae* for our west-coast fungus. Hunt says he followed the rules when choosing *ostoyae*. Ned pointed out, the North American '*A. ostoyae'* is "phylogenetically distinct" from Eurasian '*A. ostoyae'*, and it is more closely related to *A. gemina*. A 2016 publication by a Chinese research group (Guo et al.) provisionally assigned North American isolates to *A. solidipes* and Eurasian isolates to *A. ostoyae*. The holotype for '*A. ostoyae'* was collected by Romagnesi (1970) in France. We currently need an 'epitype' (a new type specimen) collection and an associated culture for *A. solidipes*, which was originally collected by Peck (1900) in Colorado. A new epitype of *A. solidipes* would allow characterization based on DNA sequences. No doubt we will hear more *Armillaria* taxonomy from the pathologists and mycologists in the near future.

A recent publication by 30 world-wide co-authors examined the phylogenetic relationships of Northern Hemisphere *Armillaria* (Klopfenstein et al. 2017. Mycologia 109: 75-91). *Armillaria gallica* was found on koa (*Acacia koa*) and ʻōhiʻa lehua (*Metrosideros polymorpha*) on the island of Kauaʻi, Hawaiʻi (Kim et al. 2017; Plant Disease 101: 255). John Hanna and others are continuing the project to identify *Armillaria* spp. in western Oregon, western Washington, and Alaska. Marcus Warwell and others are examining influences of *A. solidipes* and *A. altimontana* on growth and survival of western white pine. Jane Stewart, Bradley Lalande and others are using soil metagenomic approaches to evaluate the association of soil microbial communities with Armillaria root disease.

Jane Stewart, Ned Klopfenstein, Mee-Sook Kim, Phil Cannon and others are currently conducting phylogenetic analyses of *Phellinus noxius*, an invasive pathogen that causes brown root rot disease of diverse woody hosts in the Pacific islands, eastern Asia, and eastern Australia.

Rona Sturrock made the comment that while the generic name of *Phellinidium* vs *Phellinus* was more commonly coming into use for the LRR pathogen, a new generic name- *Coniferiporia*- has recently been proposed and generally accepted. Groans were heard in the room!

Thanks to all who presented, and to the chair, Blakey Lockman.

Notes transcribed by Mike McWilliams and Brennan Ferguson and edited by all.

HAZARD TREE COMMITTEE MEETING

Committee Chair: *Holly Kearns* (acting chair for *Kristen Chadwick*)
Meeting Notes: *Christy Cleaver* and *Holly Kearns*

The lunch meeting took place Thursday from 12:00 p.m. until 1:30 p.m., October 5, was chaired by Holly Kearns, who was acting chair for Kristen Chadwick, and was well attended. Brief reports are summarized below.

BUSINESS

The most recent Western Hazard Tree Workshop took place October 17th – 20th, 2016 in Bend, Oregon. Over 65 people attended from all over the US, including many arborists. Many thanks to the planning committee, Pete Angwin, Nelda Matheny, Alan Kanaskie, Jessie Glaeser, and especially the local arrangement folks, Brent Oblinger and Helen Maffei. We used Oregon State University conference services for registration, bus contracts, hotel contracts, and the banquet. Overall it was a good experience; however, we're likely to keep the arrangements in-house in the future.

The next meeting is scheduled for 2019 and will be held in the fall to avoid conflicting with the spring 2019 WIFDWC. We are looking for a meeting host and putting the planning committee together. Please contact Kristen if you're interested in helping out.

SHORT PRESENTATIONS

***Kretzschmaria deusta* on Western Hardwood Trees – Biology and Diagnosis**

Brenda Callan: Canadian Forest Service, Natural Resources Canada, Pacific Forestry Centre, Victoria British Columbia.

Charcoal-like ascostromata (upper right) and grey velvety immature conidial stromata (lower left) on butt of Acer macrophyllum. Yellow bar is 1cm wide.

Kretzschmaria deusta (Hoffm.) P.M.D. Martin, previously also called *Hypoxylon deustum* and *Ustulina deusta*, is an unusual perithecial ascomycete (pyrenomycete, Xylariaceae) that causes basal cankers, root and butt rot and stem failure of hardwood trees. Found worldwide, *K. deusta* predominately infects *Fagus*, *Aesculus*, *Acer*, *Tilia*, *Carpinus*, *Platanus, Fraxinus, Quercus*, and *Ulmus*. In Europe, together with *Ganoderma* spp., it is the third most common decay fungus associated with structural failure after *Laetiporus* and *Armillaria* spp. (Schwarze et al. 1995). Pacific Northwest herbaria (DAVFP, UBC, WTU, OSU) contain sparse records (less than 10 per herbarium) for BC, WA, and OR, but it is likely under-collected. In southern BC, it is primarily associated with native bigleaf maple, *Acer macrophyllum*, and non-native ornamental maples that are highly popular in urban boulevards, parks, and gardens. It has also occasionally been collected on red alder, *Alnus rubra*, in Victoria BC. Urban tree diagnosticians and arborists in the Pacific Northwest might consider the possibility of this pathogen when tree failure of *Acer* is encountered. The black, brittle, charcoal-like ascostromata produced by *Kretzshmaria* at the base dead stumps can sometimes grow very large, almost a meter across on very old highly decayed stumps, but on living trees they are often more cryptic, hidden in bark crevices or at ground level under vegetation, and infected trees show no swelling at ground level. When immature stromata develop in the spring, they are thinner, velvety and gray with white edges and a dusting of white conidia, and superficially almost lichen-like. Thus, this pathogen may be easily overlooked or discounted by arborists until a valuable ornamental tree fails.

To further confound diagnostic attempts in the absence of visible fruiting bodies, some forms of common instrumental analysis, including those based on penetrometers and acoustic diagnostic devices, may fail to detect wood decay caused by *K. deusta* (Guglielmo et al. 2012). However, cultures derived from decayed wood are very distinctive, as is the decay pattern in the wood.

Kretzschmaria colonies grow quickly on oatmeal agar at room temperature. The colonies are grey and velvety with white margins, and tend to distort the agar. Before the mycelium reaches the edge of the Petri plate, it tends to curl up and pulls the agar away from the bottom of the Petri dish. It then grows over the freshly exposed lower surface of the agar, resulting in a fungal-coated disc.

Cultures of K. deusta from Acer macrophyllum with advanced decay. Two-week-old colony starting to curl up on oatmeal agar.

Four days of growth of mycelium from decayed wood on 2% malt agar.

Wood decayed by *K. deusta* is brittle, but appears strong until it snaps. Decay columns occur in major roots and the main stem. Fractures may occur before advanced white rot develops. Preferential cellulose degradation causes wood to lose strength but still appear stiff and stable due to the preserved middle layer in the cells, which acts like a skeleton. The type of decay is classified as a “soft rot” due to this particular cell wall degradation pattern (Schwarze 2007). Symptoms are distinctive in stem cross sections of *Acer macrophyllum*. The advanced decay is whitish gray to yellowish tan, with a few scattered black zone lines, and this is where the fungus is most easily isolated. There is an obvious reaction zone between healthy and decayed wood. It is 1-2 cm in width, dark, and very moist when fresh. The reaction wood does not yield fungus cultures (Guglielmo et al. 2012).

Decayed Acer macrophyllum section with advanced decay and reaction zone. The remains of the black fruiting bodies are present on the exposed heartwood.

Literature cited:
Schwarze, F.W.M.R. (2007). Wood decay under the microscope. *Fungal Biology Reviews*, 21(4):133-170. DOI: 10.1016/j.fbr.2007.09.001.

Schwarze, F.W.M.R., Lonsdale, D., & Mattheck, C. (1995). Detectability of wood decay caused by *Ustulina deusta* in comparison with other tree-decay fungi. *European Journal of Forest Pathology*, 25:327-341. DOI: 10.1111/j.1439-0329.1995.tb01348.x.

Guglielmo, F., Michelotti, S., Nicolotti, G., & Gonthier, P. (2012). Population structure analysis provides insights into the infection biology and invasion strategies of *Kretzschmaria deusta* in trees. *Fungal Ecology*, 5(6):714-725. DOI: 10.1016/j.funeco.2012.06.001.

New and Updated Hazard Tree Management Products in the Rocky Mountain Region

James T Blodgett, Plant Pathologist, USDA Forest Service, Rocky Mountain Region, Forest Health Protection, Rapid City, South Dakota, USA
phone: 605-716-2783, E-mail: jblodgett@fs.fed.us

The purpose of the presentation was to generate discussion regarding various hazard tree (HT) products available in the USA and Canada. The first 8 minutes was a brief talk regarding the Rocky Mountain Region's (R2) eleven new and updated HT management products developed in 2017. Those products include the: 1) Guide to Hazard Tree Management (an all new summary of R2's HT methods); 2) Hazard Tree Management Training Supplement (a handout for R2 HT Management training to supplement the Guide); 3) twelve updated PowerPoints for HT Management training; 4) updated HT paper form; 5) HT *e*-form for Trimble (major update to the data dictionary files for use on any Trimble device); 6) Trimble Hazard Tree Evaluation Guide (updated directions for the Trimble HT *e*-form); 7) Survey123 HT *e*-form (a new form for the inspection of trees in developed forest sites that can be run on any smartphone, tablet, or computer using the program Survey123 by ESRI); 8) Survey123 Hazard Tree Evaluation Guide (directions for the smartphone/etc. *e*-form); 9) updated HT database (for entering, editing, and storing HT data; importing data from *e*-form; and summarizing/reporting data); 10) Hazard Tree Data Base User's Guide (updated directions for the HT data base); and 11) R2 HT Web page (updated, and soon to include the earlier mentioned products: http://www.fs.usda.gov/goto/r2/fh/hazard). Much dialogue regarding various HT products offered throughout the USA and Canada proceeded.

- Betsy Goodrich commented that Region 6 will also be using tablets for field data collection. She recommended that considerations should be made for how data is organized online. Jim clarified that the Hazard Tree Database is restricted by individual National Forest accounts.
- Phil Cannon asked about the status of the Tree Failure Database. Jim was using the International Tree Failure Database but it is no longer operational.
- Holly asked if Regional Recreation Staff is interested in Region 2's hazard tree collection data. Jim responded, not yet, the database is still really new. Holly suggested that the Recreation Staff might find it useful.

ROUND ROBIN (limited time allowed for one response)

Christy Cleaver described a new hazard tree field guide developed by Forest Health Protection forest pathologists of the U.S. Forest Service's Northern and Intermountain Regions. "A Guide to Identifying, Assessing, and Managing Hazard Trees in Developed Recreational Sites of the Northern Rocky Mountains and the Intermountain West" provides a method for assessing and rating hazard trees, detailed information on defects, and provides a data form for field data collection. The guide was at the publishers and would be printed soon and be made available online. Those wanting copies for distribution were suggested to contact Christy, Paul Zambino, Marcus Jackson, John Guyon, or Angel Saavedra, who can send them out after printing.

DWARF MISTLETOE COMMITTEE MEETING

Committee Chair: *Dave Shaw*

The Dwarf Mistletoe Committee met at WIFDWC on the morning of Friday, October 6th, and had a lightly attended session, which was still populated by a group with awesome mistletoe knowledge!

David Shaw had recently visited Chile and had photos of mistletoes from three families:

- Eremolepidaceae; *Antidaphne punctulata* (insect pollinated, and bird (mammal?) dispersed seed),
- Loranthaceae; *Tristerix corymposus* (bird pollinated and bird dispersed seed), and
- Misodendraceae; *Misodendrum punctulatum* (insect pollinated? and WIND dispersed seed).

In addition, David Shaw is a Coordinator, and Simon Shamoun is Deputy (as well as Macelo Wagner, from Argentina) for the IUFRO 7.02.11 Parasitic flowering plants in forests, technical group. We gave an update from the meeting in Ashland in July of 2016, which also resulted in a special section of Botany (see dwarf mistletoe articles in new publications). Our next meeting may occur in Brazil in 2019.

We also discussed a survey of limber pine dwarf mistletoe on whitebark pine at Newberry Crater, Oregon by Brent Oblinger (USFS FHP, Bend, Oregon). The infestation is particularly intense and relates to the mountain pine beetle epidemic which removed many trees in the larger size classes, while dwarf mistletoe is causing mortality and dieback in smaller size classes. A one-two punch on the host population.

Mike McWilliams (USFS FHP, La Grande, Oregon) showed some slides and discussed issues related to larch dwarf mistletoe in western larch he is working on with Blakey Lockman. Robert Mathiasen, from Northern Arizona University in Flagstaff, has previously done work on larch dwarf mistletoe and joined in the conversation. The issue is whether DMR 5 and 6 western larch trees produce abundant dwarf mistletoe seed, and the answer is YES.

Three papers that relate to this question are:

1. Smith, R.B. 1966. Hemlock and larch dwarf mistletoe seed dispersal. Forestry Chronicle 42: 395-401.
2. Mathiasen, R.L. 1998. Infection of young western larch by larch dwarf mistletoe in northern Idaho and western Montana. Western Journal of Applied Forestry 13: 41-46.
3. Jackson, M. B., Hayes, C. J., Taylor, J. E., & Ferguson, B. A. 2016. Effects of thinning and overstory removal on western larch and western larch dwarf mistletoe. Forest Science, 62(2), 190-199.

Robert Mathiasen continues to collaborate, especially with Sean Kenaley and Carolyn Daugherty, on taxonomy, management and ecology of dwarf mistletoes with a focus on the *Arceuthobium campylopodum* complex. Much controversy abounds concerning recent revisions of the Viscaceae in the Flora of North America and the Jepson Manual. For example, the publication: "Mathiasen, R.L., and S.C. Kenaley. 2016. The classification of California Viscaceae: An alternative perspective. Madrono 63: 8-33", has recently been published which clearly describes the issues involved. Our perspective is to stick with the Hawksworth and Wiens 1996 monograph classification.

Two papers have recently come out concerning relationships of oak mistletoe and dwarf mistletoe with wildlife:

1. Parker, T.J., Chambers, C.L., and Mathiasen, R.L. (2017). Dwarf mistletoe and breeding bird abundance in ponderosa pine forests. *Western North American Naturalist*, 77(1):40-50. DOI: 10.3398/064.077.0106.

2. Pritchard, K.R., Hagar, J.C., & Shaw, D.C. (2017). Oak mistletoe (*Phoradendron villosum*) is linked to microhabitat availability and avian diversity in Oregon white oak (*Quercus garryana*) woodlands. *Botany*, 95: 283-294. DOI: 10.1139/cjb-2016-0249.

New Publications on Dwarf Mistletoes (with one Phoradendron paper):

De Villier, J.A., Reblin, J.S., & Logan, B.A. (2017). Needle properties of host white spruce (*Picea glauca* [Moench] Voss) experiencing eastern dwarf mistletoe (*Arceuthobium pusillum* Peck) infections of differing severity. *Botany*, 95(3):295-305. DOI: 10.1139/cjb-2016-0254.

Hampel, L.D., Cheeptham, N., Flood, N.J., & Friedman, C.R. (2017). Plants, fungi, and freeloaders: examining temporal changes in the “taxonomic richness” of endopytic fungi in the dwarf mistletoe *Arceuthobium americanum* over its growing season. *Botany*, 95(3):323-335. DOI: 10.1139/cjb-2016-0240.

Hoyt, H.M., Hornsby, W., Huang, C.-H., et al. (2017). Dwarf mistletoe control on the Mescalero Apache Indian Reservation, New Mexico. *Journal of Forestry*, 115(5):379-384. DOI: 10.5849/jof.16-049.

Jackson, M.B., Hayes, C.J., Taylor, J.E., & Ferguson, B.A. (2016). Effects of thinning and overstory removal on western larch and western larch dwarf mistletoe. *Forest Science*, 62(2), 190-199. DOI: 10.5849/forsci.15-073.

Kenaley, S.C., Mathiasen, R.L., & Daugherty, C.M. (2016). Morphological evidence for continued species recognition among white pine dwarf mistletoes (Viscaceae): *Arceuthobium apachecum, A. blumeri, A. californicum, A. cyanomcarpum, and A. monticola. Journal of the Botanical Research Institute of Texas*, 10(2):361-383.

Klutsch, J.G., Najar, A., Sherwood, P., et al. (2017). Susceptibility of jack pine to *Grosmannia clavigera* depends on the differential effect on host defense chemicals by dwarf mistletoe infection. *Journal of Chemical Ecology*, 43:506-518.

Klutsch, J.G., Najar, A., Cale, J., & Erbilgin, N. (2016). Direction of interaction between mountain pine beetle (*Dendroctonus ponderosae*) and resource sharing wood boring beetles depends on plant parasite infection. *Oecologia*, 182(1):1-12. DOI: 10.1007/s00442-016-3559-8.

Mathiasen, R.L. & Kenaley, S.C. (2015). A morphometric analysis of *Arceuthobium campylopodum, A. laricis, and A. tsugense* (Viscaceae). *Phytologia*, 97: 200-218.

Mathiasen, R.L., & Kenaley, S.C. (2016). The classification of California Viscaceae: An alternative perspective. *Madrono*, 63(1):8-33. DOI: 10.3120/0024-9637-63.1.8.

Mathiasen, R.L., Kenaley, S.C., & Daugherty, C.M. (2016). A morphometric analysis of *Arceuthobium campylopodum* and *Arceuthobium divaricatum* (Viscaceae). *Aliso*, 34(1):9-23. DOI: 10.5642/aliso.20163401.03.

Mathiasen, R.L., & Kenaley, S.C. (2017). *Arceuthobium tsugense* (Viscaceae): four subspecies with contrasting morphologies and host distributions. *Journal of the Botanical Research Institute of Texas*, 11(2):363-390.

Parker, T.J., Chambers, C.L., & Mathiasen, R.L. (2017). Dwarf mistletoe and breeding bird abundance in ponderosa pine forests. *Western North American Naturalist*, 77(1):40-50. DOI: 10.3398/064.077.0106.

Pritchard, K.R., Hagar, J.C., & Shaw, D.C. (2017). Oak mistletoe (*Phoradendron villosum*) is linked to microhabitat availability and avian diversity in Oregon white oak (*Quercus garryana*) woodlands. *Botany*, 95(3):283-294. DOI: 10.1139/cjb-2016-0249.

Ritter, S.M., Hoffman, C.M., Ex, S.A., & Stewart, J.E. (2016). Impacts of lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) infestation on stand structure and fuel load in lodgepole pine dominated forests in central Colorado. *Botany*, 95(3):307-321. DOI: 10.1139/cjb-2016-0255.

Shaw, D.C. & Agne, M.C. (2017). Fire and dwarf mistletoe (Viscaceae: *Arceuthobium* species) in western North America: contrasting *Arceuthobium tsugense* and *Arceuthobium americanum*. *Botany*, 95(3):231-246. DOI: 10.1139/cjb-2016-0245.

Ziegler, D.J. & Friedman, C.R. (2017). Vegetative and floral development in the pistillate plant of *Arceuthobium americanum* (lodgeople pine dwarf mistletoe): an environmental scanning electron microscopy study of its phenology and shoot organization. *Botany*, 95(3):337-346. DOI: 10.1139/cjb-2016-0253.

Ziegler, D.J. & Friedman, C.R. (2017). Morphology and stomatal density of developing *Arceuthobium americanum* (lodgepole pine dwarf mistletoe) fruit: a qualitative and quantitative analysis using environmental scanning electron microscopy. *Botany*, 95(3):347-356. DOI: 10.1139/cjb-2016-0187.

USFS Reports:

Oblinger, B. (2017). Incidence and severity of limber pine dwarf mistletoe (*Arceuthobium cyanocarpum* (A. Nelson ex Rydberg) Coulter & Nelson) on whitebark pine (*Pinus albicaulis* Engelm.) at Newberry Crater. USFS Forest Health Protection, Bend, Oregon. Contact Brent Oblinger: boblinger@fs.fed.us.

Arceuthobium cyanocarpum close-up on Pinus albicaulis on Newberry Crater, Deschutes National Forest. Phot: Brent Oblinger.

OTHER REPORTS

BUSINESS MEETING MINUTES, 65TH WIFDWC

Secretary: *Christy Cleaver*

The WIFDWC business meeting was called to order by the Conference Chair, Harry Kope, at 10:30 AM on Thursday, October 5, 2017. There were 50 people in attendance.

The chair called for a moment of silence to remember Gordon Wallis and Richard (Dick) Smith, WIFDWC members who have passed in the last year.

OLD BUSINESS

A motion to adopt the WIFDWC 2016 business meeting minutes without revision was made by Walt Thies. The motion was seconded by Dave Shaw and passed.

A motion to accept the Treasurer's report was made by Stefan Zeglen, seconded by Dave Shaw, and passed.

NEW BUSINESS

The chair thanked the meeting organizers, local arrangements, and committee chairs for the Parksville meeting.

Committee reports were not given during the business meeting, since time was limited and not all committees had met yet. (Business meeting held mid-conference)

Committee Updates

Paul Zambino was acting rust committee chair and was nominated as co-committee chair along with Jane Stewart during the rust committee meeting. A motion to accept the nomination was made by Phil Cannon, was seconded by Jared LeBoldus, and passed.

Elisa Becker had been nominated earlier in 2017 as the Historian. A motion to accept the nomination was made by Dave Shaw, was seconded by Holly Kearns, and passed.

Danny Norlander had been nominated earlier in 2017 as the Web Coordinator. A motion to accept the nomination was made by Dave Shaw, was seconded by Holly Kearns, and passed.

There were no nominations again this year for the Outstanding Achievement Award (OAA). The chair encouraged members to consider worthy candidates for nominations for next year. The OAA committee contains members that cycle out every three years and there were personnel changes this year. The current committee consists of Jared LeBoldus, Anna Leon, with Ellen Goheen rotating off. The group agreed that Jared still fulfills the required academic and international representation since he is both a beaver (professor at Oregon State) and a moose (Canadian). Phil Cannon nominated Pete Angwin, who was not present, to the OAA committee. A motion to accept the nomination was made by Jane Stewart, was seconded by Kelly Burns, and passed. Through discussion, the group was reminded that the OAA committee member is not required to attend WIFDWC.

Student travel award committee members are not required to rotate out like OAA committee members. The current committee members are Betsy Goodrich, Dave Shaw, Harry Kope, and Jared LeBoldus. Each agreed to stay on as committee members. Betsy reported that seven graduate students were awarded student travel awards and hailed from four different universities. Holly Kearns, Treasurer, reported that about $1000 was raised during the silent auction for the student travel awards.

Next WIFDWC

Kelly Burns presented the meeting location for the next WIFDWC, which will be in Estes Park, Colorado in May of 2019. Spring was presented as an ideal season to host in this location due to having better weather and avoiding peak tourism seasons. The slate of candidates for the 2019 meeting Executive Committee was: Conference Chair (Kelly Burns), Program Chair (Amy Ramsey), Local Arrangements (Jane Stewart and Jim Blodgett), Secretary (Katie McKeever), Treasurer (Holly Kearns). Betsy Goodrich made a motion to accept nominations, was seconded by Holly Kearns, and passed. (*Secretary Note: Interim Program Chair was not discussed during the business meeting but the Conference Chair assigned Michael Murray as such. Jane Stewart has replaced Amy Ramsey as Program Chair and Kelly Burns has also been added to Local Arrangements).

Future WIFDWC

Since there had been several recent coastal meetings, the chair reminded the group that the next few should be inland. At the last business meeting it was brought up that WIFDWC has not been held in Regions 1 and 3 in a while. Christy Cleaver and Paul Zambino (Region 1) proposed holding the 67th WIFDWC in Coeur d'Alene, Idaho in spring of 2020.

Walt Thies asked if we were intentionally moving to holding two meetings every three years. The group discussed the seasonality of meetings and how holding the meeting in spring vs. fall depended upon several factors including, weather, U.S. Forest Service (USFS) employees unlikely to be approved for two meetings within the same fiscal year, field seasons, and universities in session during the fall. (*Secretary Note: The bylaws in Article 7, Meetings, Date state: "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").

Joint WIFDWC and WIFIWC Meeting

The group also discussed the merits of holding joint meetings with the Western Forest Insect Work Conference (WFIWC), as have happened in the past. Bob Mathiasen suggested that they don't usually work well because WFIWC usually holds concurrent sessions. Harry Kope agreed. Walt reminded the group that meetings once alternated between spring and fall to favor universities. Kelly Burns suggested this would be difficult with the upcoming meeting since it would be just 6-7 months from the current meeting. Blakey Lockman explained that October isn't great for USFS employees since it is the beginning of the fiscal year. Approval for attendance this year came just days prior to the meeting. She discussed the unsure future of the USFS meetings management process and how the entomologists would like joint reasoning to attend WFIWC since their approval numbers have been much lower than ours (pathologists are tied to National Research and Development whereas the entomologists are tied to the local level). There was some additional discussion on when to hold the Coeur d'Alene meeting. Stefan Zeglen reminded everyone that it is up to the organizing committee to determine the time of year to meet. The group decided that May would be fine to hold the Estes Park meeting and that the vote to hold the meeting then had already been accepted.

A motion to accept the May 2019 Estes Park organizing committee was made by Betsy Goodrich, was seconded by Holly Kearns, and passed.

Website Update

Danny Norlander gave a presentation on the new WIFDWC website and how it can be easily viewed on both a tablet and computer. He suggested presentations and conference information could be posted to the website and used on tablets and phones during the meeting in lieu of handouts. Presentations could be loaded the morning of and only those attending the meeting would have access. It cost $300 to buy the website but it was $12 per year to keep WIFDWC.org. He further explained functions and potential opportunities including a blog with job postings, housing published papers, and posting the WIFDWC proceedings prior to 2004 (currently available on a CD created by Fred Baker). A straw poll showed that the majority of attendees would like to have all proceedings available on the website. It was brought to attention that Patsy Palacios at Utah State University should be contacted for copyright information and ability to post the remaining proceedings to the website. Anyone may submit photos to be posted on the website.

Treasurers Update

Holly Kearns, Treasurer, reported that 15 graduate students, 47 regular members, and 4 retirees registered for the 2017 meeting. The meeting organizers did well spending available money, however, the Hazard Tree Workshop made money. International travel funds were spent to bring Dean Meason to speak and that there was still $5,756.64 remaining.

Holly Kearns reported that $2150 was awarded to graduate students for travel with some coming from silent auction donations and the remaining coming from a portion of registration fees ($15). Walt Thies motioned to raise the portion of registration fees used for the student travel awards to $25. The motion was seconded by Stefan Zeglen and passed. Holly clarified that the increase will apply to future meetings and is not visible during the online registration process.

WIFDWC Support for Outside Causes

The letter of support for Guidelines to Minimize *Phytophthora* Pathogens in Restoration Nurseries was discussed during the nursery committee meeting. The request for WIFDWC support came from Susan Frankel and the committee was unsure whether WIFDWC was able to provide support. The group discussed how to address these types of requests in the future. One suggestion was to give the committee the ability to create an ad hoc committee to review the request. Harry Kope noted that the bylaws state that the conference chair has the ability to set up an ad hoc committee without the need to vote which would allow for more timely response versus waiting for the next business meeting. Bob Mathiasen asked why an ad hoc committee would be needed if the nursery committee is willing to review requests. Paul Zambino voiced support for an ad hoc committee that would consist of non-USFS employees since federal employees cannot lobby for regulations. Phil Cannon stated that the California Pest Council will meet in five weeks and will pass a motion to advocate for support of the guidelines. Harry concluded that the ad hoc committee will need to be cautious of federal employees.

Close

At the close of new business, a motion was made by Mike McWilliams to adjourn the business meeting, seconded by Blakey Lockman, and the motion was passed. The business meeting ended by 11:26 AM on Thursday, October 5th.

TREASURER'S REPORT, 65th WIFDWC

Submitted by: *Holly Kearns*

The 65th annual WIFDWC in Parksville, British Columbia had 77 attendees including 47 regular members, 15 graduate students, 4 retirees, and 11 guests. The following is a summary of transactions for the WIFDWC accounts from 1/1/2017 through 12/31/2017. The WIFDWC Federal Tax Identification Number is available upon request.

	Income / Expense	Balance	Total Account
All WIFDWC Accounts balance 12/31/16			**$37,486.80**
WIFDWC Meeting Account balance 12/31/16		$24,060.18	
65th WIFDWC			
Total registration	19,265.28		
Hotel meeting rooms, meals & breaks	-14,889.42		
Field trip transportation	-2,423.77		
Field trip supplies and snacks	-1,567.42		
Souvenirs	-1,494.69		
Office supplies	-129.37		
Invited speaker expenses	-4,050.00		
Regular member registration fees to STA Fund	-705.00		
Other Account Activity			
2016 Proceedings (printing and formatting)	-2,782.96		
WIFDWC.org website and domain name	-311.00		
Stamps and Envelopes	-21.59		
WIFDWC Meeting Account balance 12/31/17		**$14,950.24**	
Hazard Tree Committee Account balance 12/31/16		$3,509.98	
Proceeds from 2016 Hazard Tree Workshop, Bend, OR	4,792.93		
Hazard Tree Committee Account balance 12/31/17		**$8,302.91**	
Student Travel Award Fund balance 12/31/16		$2,160.00	
2017 Student Travel Awards	-2,150.00		
2017 Silent auction proceeds	1,123.00		
2017 Regular registration fees (47 @ $15)	705.00		
Student Travel Award Fund balance 12/31/17		**$1,838.00**	
International Sponsorship Fund balance 12/31/16		$7,756.64	
International Travel - Dean Meason, New Zealand	-2,000.00		
International Sponsorship Fund balance		**$5,756.64**	
All WIFDWC Accounts balance 12/31/17			**$30,847.79**

STUDENT AWARDS COMMITTEE REPORT

Betsy Goodrich, Dave Shaw, Harry Kope and *Jared LeBoldus*

The Student Travel Award Committee was thrilled to assist so many students with their travel to WIFDWC. We reviewed seven excellent applications and, in the end, gave out travel awards totaling $2150. All students presented research summaries in the Graduate Student Flash n' Dash session and PhD students also presented expanded papers on various panels.

Congratulations once again to the following students:

Kiah Allen, Vanessa Comeau, Bradley Lalande, Yung-Hsiang (Sky) Lan, K.A. Leddy, Ryan Lenz and Grace Sumampong.

Thanks again to all of those people who donated items for the auction. Through their generous donations and the excellent participation of the attendees the silent auction raised $1,123.00, similar to the year earlier. In addition, there were 47 regular WIFDWC member registrations which added $705.00 to the student travel account which now has a balance of $1,838.00.

WIFDWC 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.

Year	Recipient	Meeting	Comments
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	No award given		
2017	No award given		

WIFDWC OUTSTANDING ACHIEVEMENT AWARD 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

STANDING COMMITTEES AND CHAIRS, 1994—2017

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 and J. Stewart	2017—present
Disease Control[a]	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[b]	H. Kope	2007—present
Climate Change[c]	S. Frankel	2007—2008
	S. Frankel & D. Shaw	2009—2014
	S. Frankel, D. Shaw & A. Woods	2015—present

[a] Disease Control committee was disbanded in 2002.

[b] Foliar and Twig Diseases committee was made full charter member in 2009.

[c] 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 October 5, 2017.

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

I. Standing Committees – as designated in the by-laws, and
II. 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.

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.

PAST ANNUAL MEETING LOCATIONS AND OFFICERS, 1953—2017

Annual	Year	Location	Chairperson	Secretary-Treasurer	Program Chair	Local Arrangements
1	1953	Victoria, BC	R. Foster			
2	1954	Berkeley, CA	W. Wagener	P. Lightle		
3	1955	Spokane, WA	V. Nordin	C. Leaphart	G. Thomas	
4	1956	El Paso, TX	L. Gill	R. Davidson	V. Nordin	
5	1957	Salem, OR	G. Thomas	T. Childs	R. Gilbertson	
6	1958	Vancouver, BC	J. Kimmey	H. Offord	A. Parker	
7	1959	Pullman, WA	H. Offord	R. Foster	C. Shaw	
8	1960	Centralia, WA	A. Parker	F. Hawksworth	J. Parmeter	K. Shea
9	1961	Banff, AB	F. Hawksworth	J. Parmeter	A. Molnar	G. Thomas
10	1962	Victoria, BC	J. Parmeter	C. Shaw	K. Shea	R. McMinn
11	1963	Jackson, WY	C. Shaw	J. Bier	R. Scharpf	L. Farmer
12	1964	Berkeley, CA	K. Shea	R. Scharpf	C. Leaphart	H. Offord
13	1965	Kelowna, BC	J. Bier	H. Whitney	R. Bega	A. Molnar
14	1966	Bend, OR	C. Leaphart	D. Graham	G. Pentland	D. Graham
15	1967	Santa Fe, NM	A. Molnar	E. Wicker	L. Weir	P. Lightle
16	1968	Coeur D'Alene, ID	S. Andrews	R. McMinn	J. Stewart	C. Leaphart
17	1969	Olympia, WA	G. Wallis	R. Gilbertson	F. Hawksworth	K. Russell
18	1970	Harrison Hot Spring, BC	R. Scharpf	H. Toko	A. Harvey	J. Roff
19	1971	Medford, OR	J. Baranyay	D. Graham	R. Smith	H. Bynum
20	1972	Victoria, BC	P. Lightle	A. McCain	L. Weir	D. Morrison
21	1973	Estes Park, CO	E. Wicker	R. Loomis	R. Gilbertson	J. Laut
22	1974	Monterey, CA	R. Bega	D. Hocking	J. Parmeter	
23	1975	Missoula, MT	H. Whitney	J. Byler	E. Wicker	O. Dooling
24	1976	Coos Bay, OR	L. Roth	K. Russell	L. Weir	J. Hadfield
25	1977	Victoria, BC	D. Graham	J. Laut	E. Nelson	W. Bloomberg
26	1978	Tucson, AZ	R. Smith	D. Drummond	L. Weir	R.Gilbertson
27	1979	Salem, OR	T. Laurent	T. Hinds	B. van der Kamp	L. Weir
28	1980	Pingree Park, CO	R. Gilbertson	O. Dooling	J. Laut	M. Schomaker
29	1981	Vernon, BC	L. Weir	C.G. Shaw III	J. Schwandt	D. Morrison R. Hunt
30	1982	Fallen Leaf Lake, CA	W. Bloomberg	W. Jacobi	E. Hansen	F. Cobb J. Parmeter
31	1983	Coeur d'Alene, ID	J. Laut	S. Dubreuil	D. Johnson	J. Schwandt J. Byler
32	1984	Taos, NM	T. Hinds	R. Hunt	J. Byler	J. Beatty E. Wood
33	1985	Olympia, WA	F. Cobb	W. Thies	R. Edmonds	K. Russell
34	1986	Juneau, AK	K. Russell	S. Cooley	J. Laut	C.G. Shaw III
35	1987	Nanaimo, BC	J. Muir	G. DeNitto	J. Beatty	J. Kumi
36	1988	Park City, UT	J. Byler	B. van der Kamp	J. Pronos	F. Baker
37	1989	Bend, OR	D. Goheen	R. James	E. Hansen	A. Kanaskie

Meetings and Officers, 1953—2017 (cont.)

Annual	Year	Location	Chairperson	Secretary	Treasurer	Program Chair	Local Arrangements	Historian	Web Coordinat
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		J. Adams
48	2000	Waikoloa, HI	W. Jacobi	P. Angwin	J. Schwandt	S. Hagle	J. Beatty		
49	2001	Carmel, CA	D. Johnson	K. Marshall	J. Schwandt	A. Kanaskie	S. Frankel		
50	2002	Powell River, BC	B. van der Kamp	H. Maffei	J. Schwandt	P. Hennon	S. Zeglen R. Diprose		
51	2003	Grants Pass, OR	E. Hansen	B. Geils	J. Schwandt	H. Merler	E. Michaels Goheen		
52	2004	San Diego, CA	E. Goheen	B. Lockman	J. Schwandt	H. Merler K. Lesiw	J. Pronos J. Kliejunas S. Smith		
53	2005	Jackson, WY	M. Fairweather	H. Merler J. Guyon	J. Schwandt	K. Burns	J. Hoffman F. Baker J. Guyon		
54	2006	Smithers, BC	K. Lewis	M. Jackson	J. Schwandt	B. Lockman	A. Woods		
55	2007	Sedona, AZ	S. Zeglen	M. McWilliams	J. Schwandt	J. Worrall	M. Fairweather B. Geils B. Mathiason		
56	2008	Missoula, MT	G. DeNitto	F. Baker	J. Schwandt	W. Littke	B. Lockman M. Jackson		

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

Meetings and Officers, 1953—2017 (cont.)

Annual	Year	Location	Chairperson	Secretary	Treasurer	Program Chair	Local Arrangements	Historian	Web Coordinator
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		
59	2011	Leavenworth, WA	P. Angwin	S. Zeglen	H. Kearns	A. Kanaskie	G. Filip A. Saavedra A. Ramsey-Kroll D. Omdal		
60	2012	Tahoe City, CA	A. Woods	J. Browning	H. Kearns	P Hennon	P. Cannon B. Woodruff		
61	2013	Waterton Lakes National Park, AB	R. Reich	K. Chadwick	H. Kearns	B. Lockman	T. Ramsfield		
62	2014	Cedar City, UT	M. McWilliams	M. Murray	H. Kearns	J. Worrall	J. Guyon		
63	2015	Newport, OR	A. Kanaskie	A. Ramsey	H. Kearns	E. Goheen	K. Chadwick A. Kanaskie G. Filip D. Shaw		S. Romero
64	2016	Sitka, AK	P. Hennon	B. Goodrich	H. Kearns	H. Kope	R. Mulvey P. Hennon		B. Lilly
65	2017	Parksville, BC	H. Kope	C. Cleaver	H. Kearns	D. Shaw	S. Zeglen	E. Becker	D. Norlander

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.

IN MEMORIAM
Gordon William Wallis 1925-2016

Gordon was born October 20, 1925 in Lloydminster, Saskatchewan and died November 8, 2016 in Victoria, British Columbia. Gordon was survived by Rita, his wife of 59 years (now deceased) and is survived by daughters Hilary and Jenifer and two granddaughters.

After high school, Gordon enlisted in the Royal Canadian Navy, serving from 1943 to 1946. He completed a BSF in Forestry at the University of British Columbia in spring 1951 and without delay joined the Forest Biology Laboratory in Victoria as a research officer studying the biology and control of *Poria weirii* on Douglas-fir. During the 1950s, Gordon twice took educational leave to earn an MSc at Wisconsin with Dr. A.J. Riker and a PhD at Cambridge with Dr. John Rishbeth. His PhD research on *Fomes annosus* included a study of infection of pine roots and a survey of the disease in East Anglian pine plantations.

Gordon resumed his research on *P. weirii* after his PhD, including studies of initiation and spread in Douglas-fir, susceptibility of other species in fir-leading stands, and control using fertilizers. In the mid-1960s, Gordon initiated studies on the occurrence and damage caused by *Fomes annosus* (now *Heterobasidion occidentale*) in commercially-thinned stands.

A guidebook titled "Common Tree Diseases of British Columbia" has been the most widely distributed publication of the Pacific Forestry Centre, with literally thousands of copies in circulation. Gordon had a role in the preparation of the first edition in 1969 with Ray Foster and of the revision in 1996 with Eric Allen and Duncan Morrison.

In 1976, Gordon published "*Phellinus (Poria) weirii* Root Rot; Detection and Management Proposals in Douglas-fir Stands" a "how to" summary of research on the disease in the Pacific Northwest. Publication was followed, over the next four years, by 45 field workshops for government and industry practitioners throughout the southern half of BC. In addition to *P. weirii*, participants were introduced to Armillaria, annosus and blackstain root diseases. Following these workshops, there was a huge increase in awareness of the importance of root disease in forest management which later resulted in research opportunities.

In a B.C. Parks campground in1978, a large, old-growth Douglas-fir with Schweinitzii butt rot failed, killing two campers. This tragedy led to a B.C. Parks – Canadian Forest Service project to publish "Tree Hazards in Recreation Sites in British Columbia: Management Guidelines" by Wallis, Morrison and Ross, to conduct hazard assessments in all campgrounds and to train Parks personnel in hazard tree recognition and abatement at workshops throughout the Parks system.

Gordon was a founding member of WIFDWC (1953), chaired the 1969 meeting in Olympia and served as "historian" until retirement. He was also active in the IUFRO Working Party on root and butt rots, chairing the 1978 meeting in Germany.

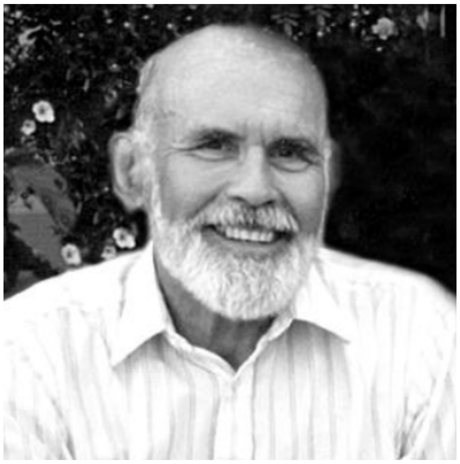
Gordon retired in November 1983 after 35 years of service to Canada. In retirement, Gordon enjoyed golfing with Rita, tending his garden and hybridizing lilies.

Gordon was my mentor at the Pacific Forestry Centre. I was his student assistant during the summer of 1965. He taught me how to do field work, especially the value of careful root excavation by hand to understand the interaction of hosts and root disease pathogens. Mentoring under Gordon continued after I joined PFC in 1966: publishing, conducting workshops, dealing with managers and arranging for me to do a PhD under Rishbeth. I owe him many thanks.

Duncan Morrison

IN MEMORIAM

Richard Barrie Smith 1934-2017



Dick was born in Vernon BC on April 18, 1934. He died in the Kiwanis Pavilion, Victoria BC on July 15, 2017, after a lengthy battle with Alzheimer's disease. He grew up on the Avonlea chicken farm outside of Vernon. In Victoria he and Ann had two children and he enjoyed playing rugby.

Dick obtained his BSc and PhD in Forestry from UBC and his MF from Yale. The ecologist, V. Krajina, was his PhD supervisor. This was during the formative years for the Biogeoclimatic zones for BC. For this purpose, Dick became an expert on forest soils. However, when he joined the CFS in Victoria he was assigned to work on decay and dwarf mistletoes. The decay study was on commercially thinned Douglas-fir which had been felled during different months to determine when trees could be felled with minimal loss to decay.

He became an expert not just of BC dwarf mistletoes, but of all dwarf mistletoes that could potentially establish in BC. At the Pacific Forestry Centre he had a common garden of potential hosts and inoculated them with BC mistletoe species, or putative species, to determine host ranges. In the field he determined distribution ranges, plant colours, measured shoots, noted flowering and fruiting times. To determine the distance that seeds were shot from fruits he placed seed traps around infection foci. Knowledge of host specificity and distance seeds travelled lead to recommendations for leave trees when harvesting mixed stands and buffer zones around infested stands with limited species diversity, such as western hemlock. He collaborated on bio-control of dwarf mistletoes with Art Parker and Al Funk. Eventually, he got back to his soil roots and studied slumping with and without logging roads particularly in Haida Gwaii.

Frequently at WIFDWC meetings there were two Dick Smiths – one employed by the USFS and the other by the CFS. A standing WIFDWC question was "where is" or "who is" the "REAL Dick Smith?"

<u>The Duhamel Road story</u>: First you need to know that Dick never travelled faster than 49 mph in a 50 mph zone, and he drove similarly slow in other speed zones. He was very cautious so that passengers felt very secure. I was with him in Nelson BC in the summer of 1965 to re-examine some of his PhD soil pits. Once in Nelson Dick exited the vehicle at a few locations while I was ordered to remain. I asked him what was going on. He replied that some cars had gone off the Duhamel road and that's where we were going. At that time I was unaware that it was a dirt road built about 1900 and that it had not been maintained for many years. From the highway we headed up and up the Duhamel road eventually coming to an old wooden bridge about 20 m long. There was lots of signage on the bridge that was hard to read because the vehicle never slowed down. I did manage to read "Bridge Condemned". I knew Dick was a cautious driver and he would not do anything unsafe and perhaps going quickly over the bridge was better than going slowly? Next we came to a creek and the bridge over it was gone. Dick stopped the vehicle just into the water and ordered me out to hunt up bridge remains from over the bank. He sat in the driver's seat pointing out which rocks I was to relocate as board supports until he was satisfied he could drive though. Remember this was before the CFS purchased 4-wheel drives and used chain saws. We proceeded further and found the forest lighting up as if we were coming to a large clear-cut, but it was a huge slump of the sandy mountain. The road in front of us was gone. I was confident that Dick would stop and survey the situation and conclude that the soil pit would not be re-examined. But no, the vehicle did not slow it continued onward and I saw on the other side of the slump, about two and a half soccer fields away, and at a higher elevation the continuation of the road. The vehicle flipped sideways hugging the steep incline with all four wheels. The view out the passenger window was down the mountain rather than across. And down there was a jack pot of forest with three vehicles laying against it. The vehicle I was in, the one driven by a "madman", managed not to slide down the mountain, but actually gained elevation so when reaching the other side the vehicle plopped down onto the road from above. We continued in silence. At last

we were close to the summit of the pass, but before, there was another old wooden bridge. This bridge had no signage and made the earlier condemned bridge seem regal. It was difficult to estimate the length of the bridge because a forest was growing up through it. I was sent out front with an axe to hack away alders and willows. The deck boards were not across the direction of travel but in-line with it. Dick did a good job of evading locations where the deck boards were missing, but he could not anticipate which board would next break beneath our wheels. Fortunately, the vehicle crawled out of each new break. Eventually, the alders and willows became too numerous and too large to remove with an axe. Dick backed out with the vehicle jerking up and down through the newly created breaks. I walked. From there we tried to hike onward but extensive beaver flooding forced Dick to invent a detour route. The detour was my first experience with devil's club. Hiking further up the side of the mountain, for an hour or so, I was amazed how readily Dick located the pit. We dug a clean pit face, photographed it and measured its various layers. Then we got out of there.

Dick was my mentor and he stimulated me to work on dwarf mistletoes for my honours thesis. I admired him greatly.

Ric Hunt, November 2017.

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Left to right: Stefan Zeglen, Christy Cleaver with Juniper Miller, Holly Kearns.