Proceedings of the 64th Annual Western International Forest Disease Work Conference

Sitka Fine Arts Camp
Sitka, Alaska, U.S.A.
May 9-13, 2016

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Compiled by:

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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.

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Michael McWilliams

WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE 2016, SITKA, ALASKA

Monday, May 9, 2016

Time	Event	Moderator	Location/Description
8:30 - 3:30	Pre-meeting field trips	Robin Mulvey	Starrigaven Recreation Area or Local Hikes
4:30 - 7:30	Registration and Welcome Social		Sitka Sound Science Centre

Tuesday, May 10, 2016

Time	Event	Moderator	Location/Description
7:00 - 8:30	Registration		Sweetland Hall, Sitka Fine Arts Camp (SFAC)
7:00 - 8:30	Foliage and Twig Disease Committee Meeting	Harry Kope	Sweetland Hall, SFAC
8:30 - 9:00	Welcome, Introductions, Logistics	Paul Hennon, Robin Mulvey	Odess Theater, Allen Hall, SFAC
9:00 - 9:30	Keynote Speaker: Brenda Campen, *Sitka, Capital of Russian America - History and Heritage*	Paul Hennon	Odess Theater, Allen Hall, SFAC
9:30 - 9:40	2016 OAA Presentation	Kathy Lewis	Odess Theater, Allen Hall, SFAC
9:40 - 10:15	Graduate Student Introductions and Presentations (5 minutes each)	Betsy Goodrich	Odess Theater, Allen Hall, SFAC
10:45 - 12:00	PANEL - Foliar Fungi:	Jared LeBoldus	Odess Theater, Allen Hall, SFAC
10:45 - 11:10	Kathy Lewis, *Metabolite super heroes fight Dothistroma needle blight*		
11:10 - 11:35	Kelsey Dunnell, *The relationship between Septoria leaf spot and stem canker resistance*		
11:35 - 12:00	Patrick Bennett, *Genotypic Diversity and Population Structure of* Phaeocryptopus gaeumannii *in the Pacific Northwest: Implications for Swiss Needle Cast Management and Risk Assessment*		
12:00 - 1:30	Rust Committee Meeting	Helen Maffei	Sweetland Hall, SFAC

Time	Event	Moderator	Location/Description
1:30 - 3:00	PANEL - Tools for Mapping Root Diseases:	Blakey Lockman	Odess Theater, Allen Hall, SFAC
1:30 - 2:00	Geoff Quinn, *Operational Root Disease Mapping: Current Technologies.*		
2:00 - 2:30	Helen Maffei, *How LiDAR Intensity Can Help Map Root Disease and Individual Tree Decline*		
2:30 - 3:00	Matteo Garbelotto, *Spore Trapping and DNA Diagnostics: A Versatile Tool for Large Scale Mapping of Heterobasidion*		
3:20 - 5:20	PANEL - Signals of Climate Change from Species Shifts:	Alex Woods	Odess Theater, Allen Hall, SFAC
3:20 - 3:55	Alex Woods, *Warning Signals of Adverse Interactions between Climate Change and Native Stressors in Forests*		
3:55 - 4:30	Lauren Oakes, *Adapting Conservation and Resource Management Practices to Emerging Ecological Dynamics*		
4:30 - 5:05	David Price, *Detection of Climate Change Impacts in Canada's Northern Forests*		
5:05 - 5:20	Panel Discussion		
7:00 - 9:00	Poster Session, Silent Auction, Photo Contest, Ice Cream Social	Christy Cleaver, Sarah Navarro, Josh Bronson	Del Shirley Room, Allen Hall, SFAC

Wednesday, May 11, 2016

Time	Event	Moderator	Location/Description
7:00 - 8:30	Root Disease Committee Meeting	Blakey Lockman	Sweetland Hall, SFAC
8:30 - 10:00	PANEL - Landscape Dynamics of Forest Diseases in the Boreal Forest:	Lori Winton	Odess Theater, Allen Hall, SFAC
8:30 - 8:50	Lori Winton, *Landscape Pathology and Pathogen Distributions*		
8:50 - 9:15	Roger Ruess, *Cross-scale Controls Over Ecosystem Responses to Changing Disturbance Regimes in Alaska's Boreal Forest*		

Time	Event	Moderator	Location/Description
9:15 - 9:40	Gerry Adams, *Rhizosphere Pathogens in Riparian Forests: Alder* Phytophthoras *and* Pythiums		
9:40 – 10:00	Misha Yatskov, *Carbon Stores and Dynamics in Spruce-dominated Forests of Kenai Peninsula, Alaska Following the Spruce Bark Beetle Outbreak of the 1990s*		
10:30 - 11:30	SPECIAL PAPERS:	Harry Kope	Odess Theater, Allen Hall, SFAC
10:30 - 10:50	Nicholas Wilhelmi, *The Effects of Seed Source and Planting Environment on Douglas-fir Foliage Diseases*		
10:50 - 11:10	Mike Cruickshank, *Understanding Western Redcedar Butt Rot*		
11:10 - 11:30	Matteo Garbelotto, *Fungal Communities Involved in the Generation of Nests*		
11:30 - 12:45	Hazard Tree Committee Meeting	Kristen Chadwick	Sweetland Hall, SFAC
12:45 - 5:30	**FIELD TRIP**: Yellow-cedar Decline and Coastal Forests Depart (walking or in cars) from Sweetland Hall as a group at 12:45PM; boat will depart at 1PM	Paul Hennon and Robin Mulvey	Allen Marine Boat Cruise Crescent Harbor
6:00 - 8:00	Climate Change Committee Meeting	Alex Woods and Terry Shaw (for Susan Frankel)	Yaw Chapel, SFAC

Thursday, May 12, 2016

Time	Event	Moderator	Location/Description
7:00 - 8:30	Dwarf Mistletoe Committee Meeting	Dave Shaw	Sweetland Hall, SFAC
8:45 - 5:00	**FIELD TRIP**: Load buses at the Rasmuson Center, SFAC, at 8:45AM; depart promptly at 9:00AM	Robin Mulvey and Paul Hennon	All-day fieldtrip on the Sitka road system; bring handout included in registration packets
6:00 – 9:00	Banquet, Brian Geils, 2015 OAA Acceptance Speech, 7PM		Odess Theater, Allen Hall, SFAC

Friday, May 13, 2016

Time	Event	Moderator	Location/Description
7:00 - 8:30	Nursery Committee Meeting	Anna Leon	Sweetland Hall, SFAC
8:30 - 9:10	SPECIAL PAPERS:	Harry Kope	Sweetland Hall, SFAC
8:30 - 8:50	Amy C. Ramsey, *Western White Pine Resistance in Western Washington: Operational Planting and the Latest in Resistant Stock Types*.		
8:50 - 9:10	Jarred LeBoldus, *Web blight and red needle cast in the PNW: more surprises from Oregon*.		
9:10 - 10:15	Business Meeting	Paul Hennon	Sweetland Hall, SFAC
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2015 OUTSTANDING ACHIEVEMENT AWARD: BRIAN GEILS

The Outstanding Achievement Award (OAA) Committee: *Mike Cruickshank*,
Ellen Goheen, and *Kathy Lewis*

Brian Geils accepts his Outstanding Achievement Award at the 64th Annual WIFDWC in Sitka, Alaska. Without exception, the nomination letter and letters in support of the nomination described 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.

PANEL: FOLIAR FUNGI

**MODERATOR:
JARED LEBOLDUS**


2017 – Sesquicentennial (150 yrs.)
Alaska Purchase
150
O
OREGON STATE
I ♥ SOIL
. Join the conversation. Share the knowledge.

[*]UNDERSTANDING THE *POPULUS-SPHAERULINA MUSIVA* PATHOSYSTEM

Kelsey Dunnell[1]

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

The most economically important pathogen and major limiting factor to the production of hybrid poplar as a commercial crop for fiber and biofuel in North America is the fungus *Sphaerulina musiva* (Peck) Quaedvlieg, Verkley, and Crous (Syn. = *Septoria musiva* Peck), which causes Septoria leaf spot and stem canker. The leaf-spot disease may result in premature defoliation, potentially reducing yield. However, the stem cankers have the greatest impact on poplar plantations since girdling cankers weaken stems, increasing the risk of wind breakage or killing trees outright. The overall goal of my research is to develop a better understanding of the interaction between *S. musiva* and *Populus* spp., leading to improved integrated pest management strategies.

Although *P. nigra* is used in hybrid poplar breeding programs in the United States, there is no information available on its resistance to Septoria canker. Given that *P. nigra* and *S. musiva* have not coevolved together it is essential to determine if variation in resistance to Septoria canker exists in *P. nigra* in order to develop a successful breeding program. Therefore, the first objective of my research is to characterize the variability in resistance in the *Populus nigra* population.

It is also important to understand how selecting for resistance to cankers will impact the leaf spots, which are the primary source of inoculum. No studies have conducted an experiment to test this relationship, which could have important consequences for the long-term durability of resistance in plantations. Therefore, my second objective is to characterize the relationship between resistance to stem infection and resistance to leaf infection.

The literature indicates that the use of resistance genotypes is the best approach to manage *S. musiva*, so it is imperative that we know more about the mechanisms that underlie resistance/susceptibility in the *S. musiva* – *Populus* pathosystem. Using the inverse gene-for-gene model as a basis for the *S. musiva* – *Populus* interaction, it is hypothesized that the pathogen, a necrotroph, is using effectors in order to cause necrosis and incite disease. Since both *S. musiva* and *P. trichocarpa* have been sequenced, they provide a unique opportunity to further develop our understanding of their host-pathogen interactions. Therefore, my third objective is to use RNAseq to identify and validate candidate virulence factors in the *S. musiva* - *Populus* pathosystem in order to elucidate the mechanism(s) of virulence.

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[*] In: Goodrich, B. & P. Palacios (Comps). Proceedings of the 64th Annual Western International Forest Disease Work Conference, 2016 May 9-13, Sitka, AK

[*]HIERARCHICAL POPULATION STRUCTURE OF *PHAEOCRYPTOPUS GAEUMANNII* IN THE PACIFIC NORTHWEST: *FROM NEEDLES TO LANDSCAPES*

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

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

INTRODUCTION

Swiss needle cast (SNC), a foliage disease of Douglas-fir (*Pseudotsuga menziesii),* is caused by the physical blockage of the stomata by pseudothecial ascocarps of the fungus *Phaeocryptopus gaeumannii*. Occlusion of the stomata results in a decrease in the ability of the host to exchange gases with the environment leading to reduced carbon assimilation (Manter et al., 2000). This results in premature foliage loss and subsequent growth reduction due to decreased photosynthetic leaf area (Manter et al., 2003). Prior to the 1980's, it was known to cause severe disease only in exotic Douglas-fir plantings and was considered an innocuous needle endophyte throughout the native range of Douglas-fir, where it historically caused little impact (Hansen et al., 2000). It has since emerged as a significant forest health issue in the western Coast Ranges of Oregon and Washington for reasons that are not well understood. Climate has a significant influence on the abundance of *P. gaeumannii*, with factors such as mean-daily winter temperature and spring/summer precipitation being the best predictors of disease severity (Stone et al., 2008). Changes in the local climate on the Oregon coast, with winter temperatures increasing significantly in recent decades, may be a contributing factor to the intensification of SNC (Stone et al., 2008). There may also be variation in the virulence of two coexisting fungal lineages that may have some influence in the recent emergence (Winton, 2001). This study aims to determine the distributions of two previously identified cryptic lineages of *P. gaeumannii* in the Pacific Northwest, and assess spatial variation in genotypic diversity and population structure using DNA microsatellites known as simple sequence repeats (SSRs). This information will be important in determining whether the distribution of these lineages, or the genetic structure of their populations, is associated with SNC disease severity at the landscape level.

METHODS

The analyses presented here includes genotypes from isolates collected near Tillamook, Oregon and southwestern Washington in 2014 (Bennett and Stone, 2016) as well as 304 isolates collected from nine sites in western Washington in 2015 (Table 1, Figure 1). To determine whether geographic trends in the distributions of the two *P. gaeumannii* lineages similar to those observed for western Oregon also occurred in Washington, sites managed by the WA Department of Natural Resources (WA DNR) were selected along latitudinal transects from the coast to approximately 56 km inland (Figure 1). These transects consisted of five sites on the northern Olympic Peninsula and four sites along the northwestern edge of the Quinault Indian Reservation. Three to four shoots bearing ascomata of *P. gaeumannii* were collected from the mid-crowns of five haphazardly selected trees at each site. Foliage samples were stored in cooler boxes and returned to OSU where spores were isolated from this foliage within 72 h of collection for culturing and DNA extraction. Single-spore isolates of *P. gaeumannii* were obtained by suspending infected needles

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above the surface of water agar in Petri dishes, allowing ascospore discharge, and then isolating individual spores within 48 hours. Fungal isolations, culturing, genomic DNA extraction, PCR amplification, and microsatellite genotyping, and the population genetics analyses were performed using the methods described in Bennett and Stone (2016), with the microsatellite markers described in Winton et al. (2007).

Table 1. (A) Summary of sample sizes and diversity statistics for each of the WDNR sites sampled in 2015. **(B)** Summary statistics of the two Lineages from the 2015 Washington sites.

A

Site	N	MLG	Lineage 1	Lineage 2
WDNR70	27	21	18	9
WDNR71	8	8	6	2
WDNR49	47	40	33	14
WDNR68	31	27	29	2
WDNR66	54	39	53	1
WDNRQ	31	25	7	24
WDNR64	38	28	12	26
WDNR63	21	17	9	12
WDNR32	47	36	47	0
Total	**304**	**227**	**214**	**90**

N= sample size, MLG = number of multilocus genotypes

B

Lineage	N	MLG
1	214	143
2	90	84
Total	**304**	**227**

RESULTS AND DISCUSSION

Phylogeography

Both *P. gaeumannii* lineages previously identified in western Oregon were present and abundant in samples from the Olympic Peninsula and southwestern Washington. Lineage 1 was most abundant overall as it accounted for approximately 70%, or 214 of the 304 total isolates from Washington (Table 1B). Lineage 2 was detected at eight of the nine sites and accounted for 30% of the total isolates recovered. Lineage 2 had a greater diversity of multilocus genotypes (MLGs) than Lineage 1, with 85% and 69% of isolates exhibiting distinct MLGs in each lineage, respectively (Table 1B). The distributions of the two lineages in Washington closely resembled the geographic trends identified in our preliminary studies of their distributions in western Oregon (Bennett and Stone 2016). Sites within 40 km of the coast comprised mixtures of both lineages, with the greatest proportions of Lineage 2 occurring in stands nearest to the coast, while sites 40 km or more from the coast were predominantly Lineage 1. While isolates of Lineage 2 were detected at all of the sites sampled within 40 km of the coast, the coastal site near Queets (WDNRQ), in the Quinault Indian Nation, had particularly high proportions of this lineage (Figure 1). Approximately 40 km to the east, at the site near Quinault (WDNR32), Lineage 2 was totally absent. Although the relationship between the presence of either lineage and disease severity is not understood, in Oregon, the regions where these lineages co-occur correspond with the regions where the greatest SNC disease severity and growth impacts have been observed. It has also been observed that populations consisting of only one of the two lineages, such as the southern Oregon coast where Lineage 2 predominates (Winton 2001) and inland sites where populations consist exclusively of Lineage 1, generally have less severe defoliation due to SNC.

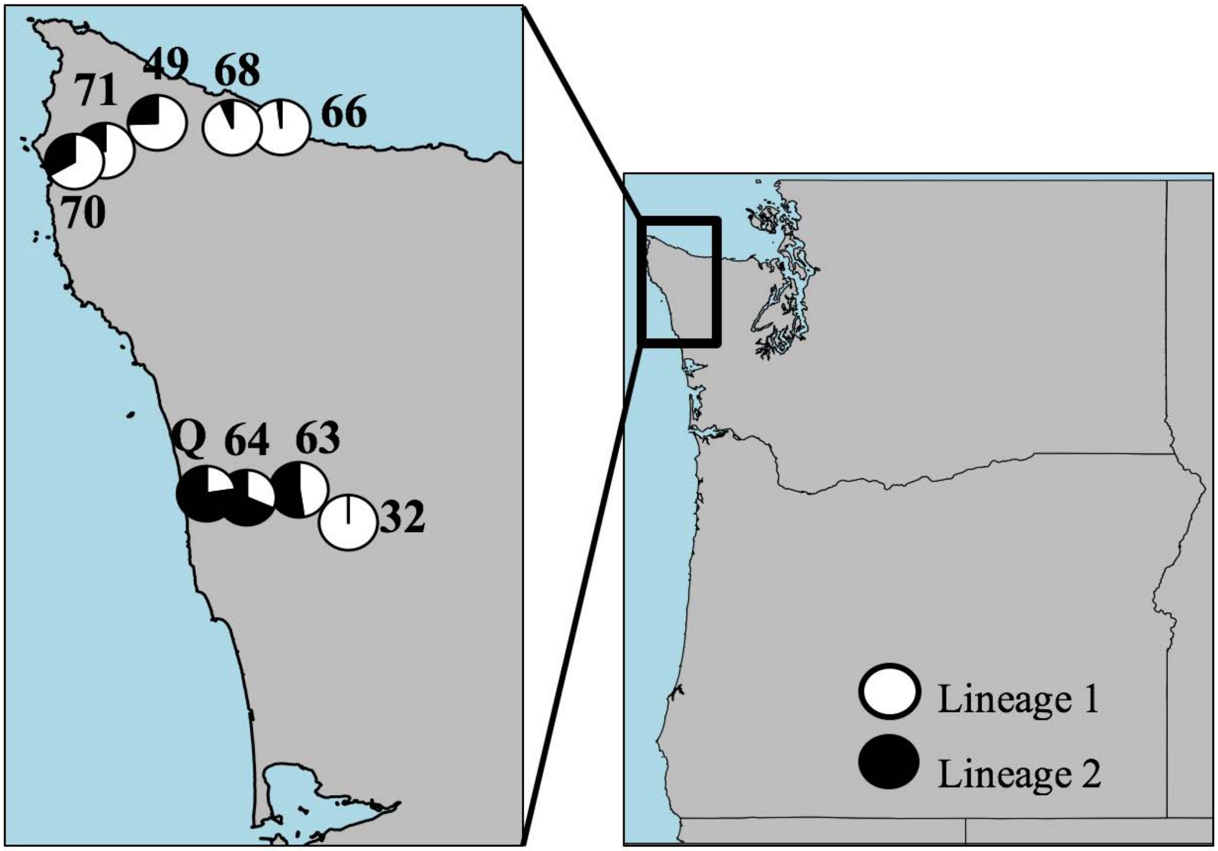


Figure 1. Map showing the distribution of the two lineages across the nine sampling sites. The labels next to each pie chart represent the site name as listed in Table 1A.

Population Structure

We aimed to assess population structure, or the occurrence of genetic subdivision within populations, at several spatial scales ranging from sites to needles. The discriminant analysis of principal components (DAPC) revealed that the sites were genetically differentiated with coastal (0-16 km inland), intermediate (24-40 km inland), and inland sites (40-56 km inland) separating into distinct genetic clusters in both the northwestern Oregon sites (near Tillamook, OR) (Figure 2) as well as the transects sampled in Washington (Figure 3). These results suggest that genetically distinct populations of *P. gaeumannii* occur within the SNC epidemic areas and that these populations may exhibit some level of local adaptation. This level of genetic differentiation could also occur due to limitations on spore dispersal distance. These observations of the distributions of the two lineages in Washington have also reaffirmed our previous observations that the areas with the greatest disease severity, as assessed by aerial surveys, occur where the ranges of the two lineages overlap near the coast. This trend of greater disease severity where the lineages coexist may be related to competition between isolates of the two lineages, but more likely reflects climatic preferences of the two lineages. These lineages might coexist in these areas simply because the coastal climate in the Sitka Spruce vegetative zone is particularly conducive to dispersal, infection, and reproduction of these fungi.

With these data, we have also made the first observation of Lineages 1 and 2 co-occurring within a single needle (Figure 4). A total of six isolates were genotyped from a single needle from the WDNRQ site (near Queets, WA), and eleven isolates were genotyped from a single needle from WDNR66 (near Pysht, WA). Of the six isolates collected from the tree at WDNRQ, four were identified as Lineage 2, and two were identified as Lineage 1. All of the isolates from the second needle were identified as Lineage 1 (Figure 4). It is not known whether co-occurrence of both lineages within needles is significant to disease, but if both cryptic species are in very close spatial proximity to one another it is likely that they are competing for space and resources.

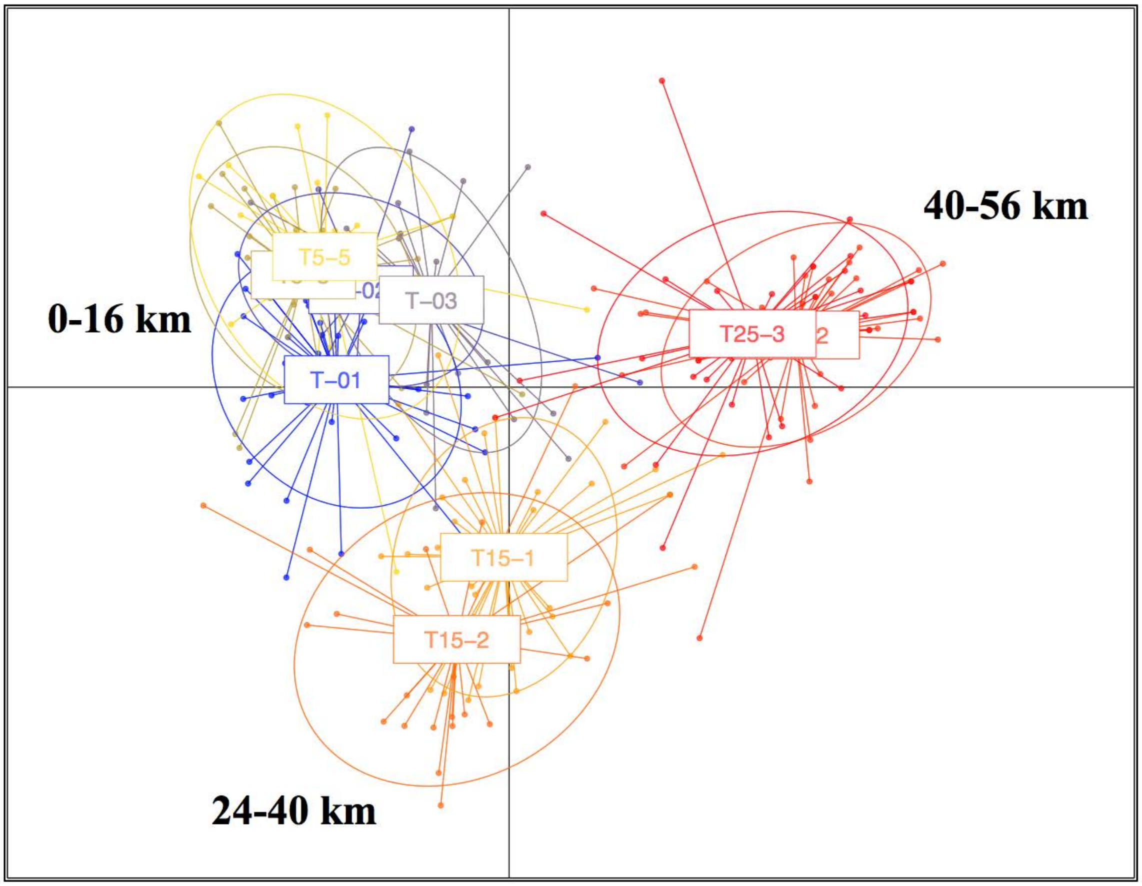
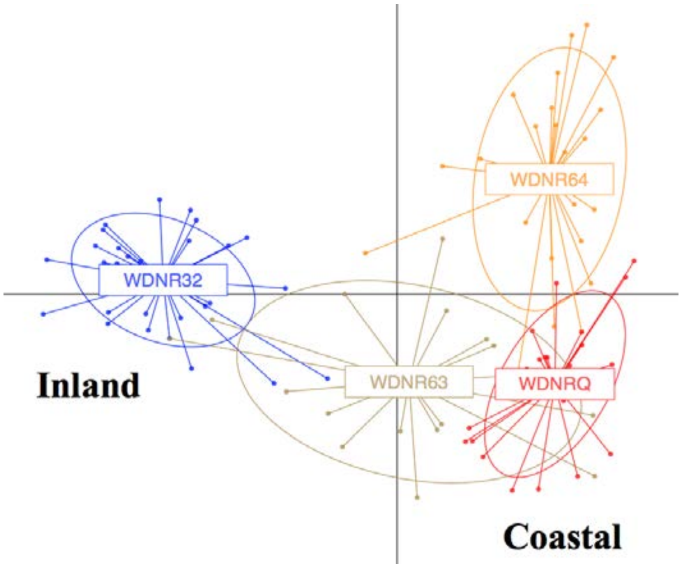


Figure 2. DAPC scatterplot showing genetic differentiation between sampling sites at various distances from the coast near Tillamook, Oregon (sampled in 2014).

Implications for Management

The relationship between presence, or relative abundance, of the two lineages and disease severity is not clear. It is known that both lineages of *P. gaeumannii* are able to cause disease and there is currently no strong evidence to suggest that either lineage is more virulent. Disease severity (i.e. defoliation) is related to the abundance of *P. gaeumannii* in needles, which in turn is related to environmental factors favorable to growth and reproduction of the fungus--abundant precipitation during May-June, and mild winter (Dec-Feb) temperatures. Both lineages are present in areas with the most severe disease but whether this is somehow due to competition or synergy, or simply to conditions that are very favorable for *P. gaeumannii,* is not clear. Recent trends in climate warming as well as expansion of Douglas-fir forestry to sites at higher risk of SNC both appear to be involved in increasing in SNC severity in the region. There is no evidence of specific resistance to infection by either lineage in Douglas-fir. Because the physiological mechanism of disease (the inhibition of gas exchange due to stomatal occlusion) does not involve direct cell penetration by *P. gaeumannii*, it is unlikely that typical wound or pathogen-specific resistance reactions function in this host-parasite system. Considerable variation in foliage retention and growth among Douglas-fir provenances affected by SNC has been observed, at least where disease severity is moderate, though the specific genetic and morphological factors mediating this tolerance have yet to be investigated.

A.



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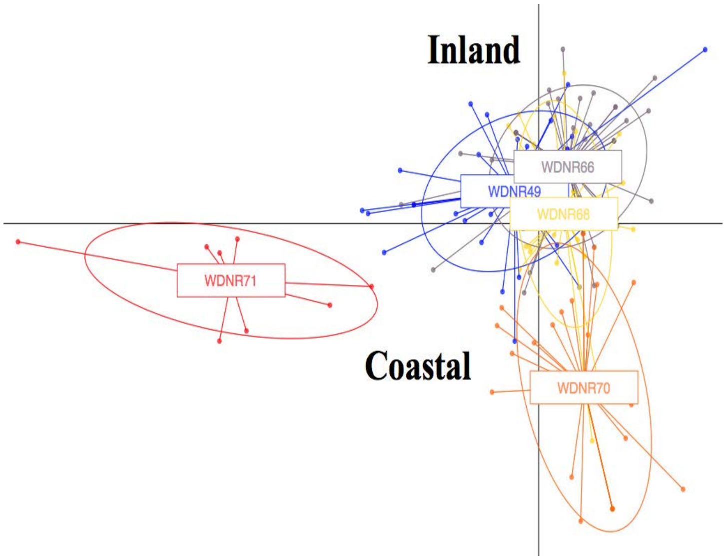

Figure 3. Discriminant analysis of principal components (DAPC) scatter plots showing genetic differentiation between isolates from each of the sampling sites. Each point represents an isolate, and the colors and labels correspond to sample sites listed in Table 1. **(A)** Differentiation between inland and coastal sites from the southern transect (Quinault) shown in Figure 1. **(B)** Differentiation between inland and coastal sites in the northern transect (Olympic Peninsula) shown in Figure 1.

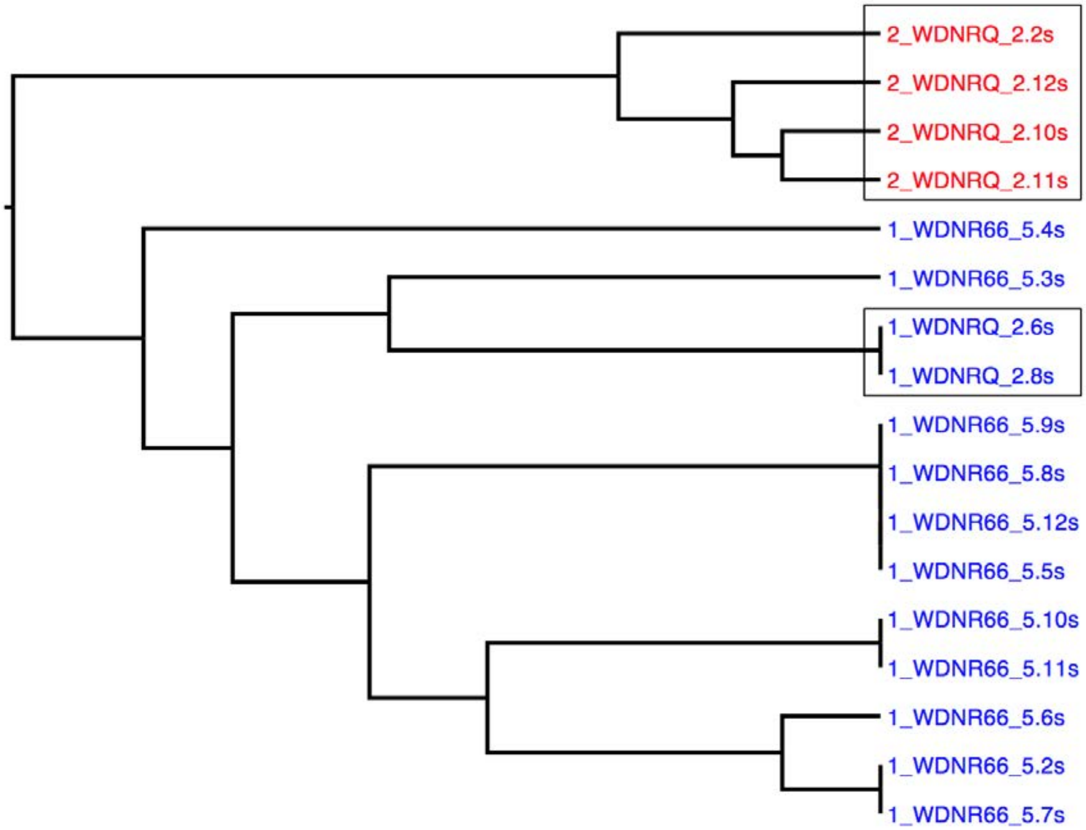

Figure 4. UPGMA dendrogram showing relationships between isolates collected from individual needles. The 6 isolates collected from a single needle at the WDNRQ (Queets) site include both Lineages 1 and 2, as indicated by the boxes. The 11 isolates from a single needle from WDNR66 are all Lineage 1. The labels for the taxa represent Lineage…Site…Tree…Isolate.

ACKNOWLEDGEMENTS

Special thanks to Dan Omdal and Amy Ramsey (WA DNR) for their guidance in selecting sites and collecting foliage samples. The Washington Department of Natural Resources and Jim Hargrove (Quinault Indian Nation) provided funding for this research. Their contributions to this research effort are greatly appreciated. The kind folks at WIFDWC provided travel funds for this research to be presented at the 2016 meeting in Sitka, Alaska.

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PANEL: TOOLS FOR MAPPING ROOT DISEASE

MODERATOR:
BLAKEY LOCKMAN

*MAPPING ROOT DISEASE SYMPTOMS IN A SMALL SCALE DRAINAGE BASIN THROUGH MULTI-TEMPORAL LIDAR AND SPECTROSCOPY

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ABSTRACT

To support forest management operations for residential drinking water quality and quantity, a study was conducted to identify likely areas affected by root disease. A multi-temporal lidar surface model identified locations of toppled trees. The lidar product was used to sample regions in an airborne imaging spectrometer (AIS) dataset collected at the initial sampling date. The AIS data was used to produce relative estimates of canopy chlorophyll through the continuum removal approach. The union of spatially autocorrelated windthrow and spatially autocorrelated poor health identified likely root disease infection areas. The analysis suggests that between sampling dates more than 3,200 trees were toppled, 10% of which occurred in spatial concentrations. In 2006 there was 73ha of forest classified as spatially correlated poor health, which decreased to 65ha in 2012. Ultimately, 10.3ha were identified as potential root disease sites experiencing spatially autocorrelated windthrow and poor health in 2006.

INTRODUCTION

The quality and quantity of the water resource is intimately associated with the condition of the forest vegetation in a given drainage basin. The services provided by forested areas include, among others, increased infiltration rates and soil moisture capacity thereby slowing overland runoff and the consequent soil erosion. In turn, healthy forests maintain the quality of the water resource by decreasing sediment load and turbidity, the largest single water pollutant in the United States. Forests also maintain lower dissolved elements, cooler temperatures, and higher dissolved oxygen all of which contribute to higher quality water, irrespective of resource use (Chang 2003).

Forests of the Pacific Northwest are affected by root disease, a natural disturbance agent that has the potential to increase stream sediment load and decrease slope stability by increasing the occurrence of windthrow. Root disease constitutes a considerable risk to water quality.

Root disease is economically important, causing significantly reduced wood production and quality in the primary host, Douglas-fir (*Pseudotsuga menziesii*). Lost revenue for the North American economy is estimated to be \$314-330M USD annually (4.4M m^3 lost volume (Thies and Sturrock 1995), \$70-75 USD/m^3 average grade west cascades Douglas-fir (Clyde 2016).

The two prominent root disease agents are the fungi *Phellinus sulphurascens* and *Armillaria ostoyae*, which travel, as mycelium (vegetative phase), between roots of adjacent trees. Structural stability of the root systems and nutrient transport from roots to crowns are compromised as lignin and cellulose are metabolized. Therefore, symptomatic infected forest stands are expressed as increased windthrow events,

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which manifest changes in canopy gap structure and reduced foliar chlorophyll at a greater rate relative to unaffected stands. Given the pathology of the disease, the symptoms of root disease have a tendency to be co-located and spatially autocorrelated.

Previous research investigating root disease and the foliage of infected trees through laboratory pigment assays and spectroscopy (Quinn 2010) and particularly (Quinn, Niemann, and Goodenough 2010) is extended here by incorporating a multi temporal sampling of airborne lidar and imaging spectroscopy.

METHODS

A high priority forest management unit within the Greater Victoria Water Supply Area (GVWSA) on Vancouver Island, British Columbia, Canada, was selected as the study area. The species composition within the GVWSA is predominantly Douglas-fir. Structurally, the forest area is composed of a mosaic of stand ages resulting from limited forestry activity and regeneration following wildfire. The topography of the 498ha study site is illustrated in Figure 1.

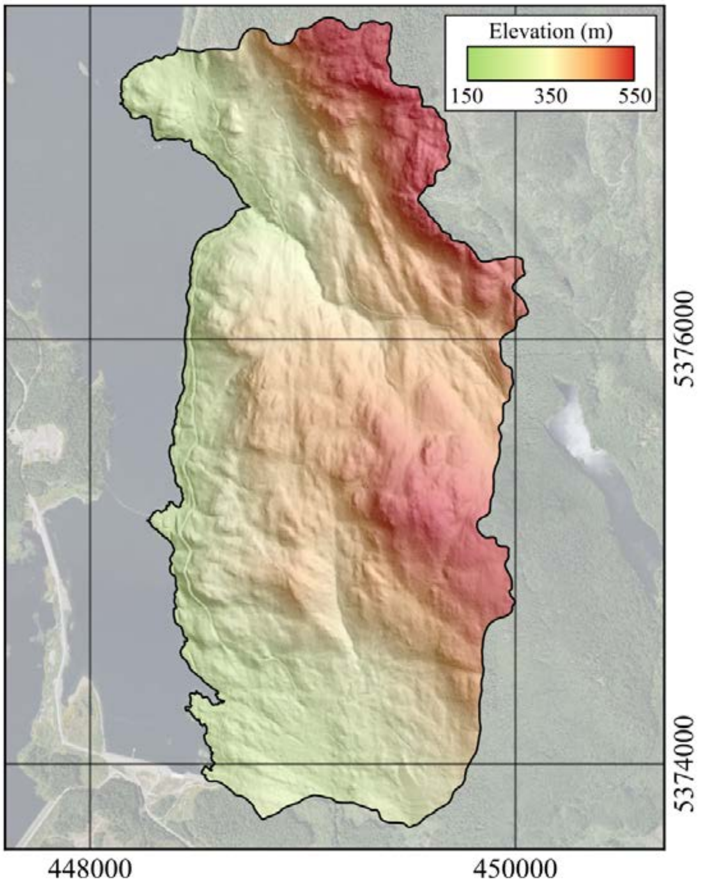

Figure 1. The Trestle forest management unit within the GVWSA, Vancouver Island, British Columbia, Canada. The site has 419m of relief (183-602m msl), slopes up to 73° with a median of 15°, azimuths largely in the 240° direction. Elevation and shaded relief overlaid on 30cm orthomosaic.

In late July of 2006 an airborne remote sensing campaign was initiated by the regional government (Watershed Protection Division of the Capital Regional District), which collected airborne lidar and nominally 2m spatial resolution full range (400-2500nm, ~3nm FWHM) AIS. A similar dataset was collected in late September 2012, lidar point density was equivalent, but only the VNIR instrument was used (FWHM: ~5nm). A ground campaign was conducted concurrently that deployed ground calibration targets (4.9x3.7m). The selection of ground targets was supported by a lab based BRDF study (Quinn et al. 2015).

In support of both processing and analysis of the AIS, the lidar data were classified, normalized, and raster products were generated (DSM: digital surface model and CHM: canopy height model). To facilitate sample collection in AIS processing a delta-DSM (dDSM: DSM_{2012}-DSM_{2006}) was used to identify individual windthrown trees. Individual windthrow events were identified by a segmentation of the dDSM, where differences less than -4m and populations greater than 9 (queens contiguity) were retained.

AIS data were processed to orthorectified surface reflectance. The geometry of the data was calibrated through time synchronized INS (inertial navigation system) and lidar intensity rasters from data flown over the Victoria International Airport. The 2012 AIS were processed to a 1.5m grid while the 2006 were processed to a 2m resolution.

The raw AIS were transformed to radiance through Specim's Caligeo software. Radiance data were converted to reflectance through the FLAASH implementation of MODTRAN (maritime mid-latitude summer). Deployed calibration target spectra were extracted from the unrectified 2012 reflectance data and were used with ASD collected field spectra to derive an empirical line correction (ELC). The dark calibration target was severely affected by adjacency scattering, in its place a mean dark open water spectrum from the reservoir was used as the subtractive correction in ELC. A temporally invariant feature common to both AIS datasets was used to force-fit the 2006 FLAASH reflectance to the 2012 ELC corrected data.

In order to reduce confounding effects of shadow and non-treed regions, the data were masked with their respective CHM (>4m). In addition, shadow cells were eliminated using a visible albedo (Σ450-700nm) of the FLAASH output; any pixel with a negative vis-albedo was omitted. The data were submitted to a continuum removal (CR), the absorption feature defined by the green peak and the NIR plateau (550-750nm). The CR data were inverted, summed, and multiplied by their respective mean FWHM. The result of the CR processing is a unitless metric representing the area of the absorption feature under investigation (CRTA). Although the CRTA can empirically be translated to absolute chlorophyll (Quinn, Visintini, and Niemann 2010), the extraordinarily high costs of foliar sampling and the complications of sampling to adequately represent a canopy may yield unreliable values. This study opted for working with the area metric as a surrogate for a relative measure of canopy chlorophyll.

The CRTA data were then submitted to a spatial analysis to indicate the degree of spatial autocorrelation. The Getis-Ord Gi statistic (Equation1) was selected as a local indicator of spatial autocorrelation (LISA) (O'Sullivan and Unwin 2003). The Getis statistic was selected over others, as it is capable of identifying both spatially autocorrelated high values and spatially autocorrelated low values. An additional advantage of this statistic is that it is a z-score so values can be interpreted in terms of their significance and probability of occurrence. The statistic was computed at multiple lag distances, given the symptoms of the disease operate at scales from the individual crown to the stand level. Since there can be no assurances on the size of infection sites, lag distances up to ~25m were used to evaluate plot sizes up to ~50m in diameter. Areas that were identified as having spatially autocorrelated low chlorophyll and windthrow are characterized as having a higher likelihood of root disease.

$$G_i^* = \frac{\sum w_{i,j} x_j - \bar{X} \sum w_{i,j}}{S \sqrt{\left[n \sum w_{i,j}^2 - \left(\sum w_{i,j} \right)^2 \right] / n - 1}} \qquad \text{[Equation 1]}$$

where: $x_{i,j}$ is either the CRTA or dDSM of the center pixel in neighborhood j and $w_{i,j}$ is the spatial weight from i to j, $\bar{X}$ and S are the global mean and standard deviation respectively

In addition, the lidar and AIS products were investigate to provide an indication on whether the AIS approach is sensitive to the physiological changes that may be occurring within the canopy.

RESULTS

The dDSM data analysis proved to be a valuable source of information. There was considerable high spatial frequency noise in positive values of the dDSM, which appeared less coherent than the more aggregated negative values. Top height gains were relatively small in magnitude, yet values as high as 43m were found. These large increases were attributed to dissimilar footprint sizes and crown expansion, as they tended to occur on the periphery of crowns. The dDSM of the management unit suggested that within the six years between the airborne surveys 3,205 new contiguous canopy gaps were formed that were at least 9m^2 in area each. The height of the wind thrown trees ranged up to 63m tall. The summed new gap area was 7.98ha, which represents 1.6% of the management unit area. The LISA analysis suggested that 11% of the windthrown segments occur within areas prone to windthrow, that is, statistically significant spatially autocorrelated decreases in the dDSM. According to the dDSM with a 40m neighborhood the affected area was 41ha. The dDSM successfully mapped regions of age dependent productivity, where younger stands had a pronounced and contiguous positive top height growth between the two sampling dates, presumably due to both high crown closure and high growth rates of younger stands. The dDSM also identified regions of concentrated windthrow events these were confirmed through spatial analysis. The most obvious windthrow region was located near the reservoir in the southwest of the study site, while all others appeared to be much smaller scale disturbances.

The absorption feature analysis demonstrated greater relative chlorophyll levels with less variability in the 2006 data than the 2012; these differences are addressed in the discussion. There were strikingly consistent spatial patterns in health across the management unit area between the two dates. The age dependent expression of productivity was again evident in the three young stands, which exhibited spatially autocorrelated high relative chlorophyll. The younger stands are located in the northwest, south and to the east. In reference to the consistent lower health regions, there were spatial concentrations of low chlorophyll in the northeast of the study area and a region that extended along the north slope of a bisecting valley (Figure 2). Qualitatively, the low health regions occurred in the same areas between the two dates, the exception being a region in the southwest quadrant. An apparent difference in the chlorophyll levels suggests that in 2006 a region was experiencing a stress that was not detected in the 2012 data. There appeared to be very little expansion of poor health areas from 2006 to 2012, a condition that would not be expected from root disease infected areas. In fact the opposite was observed, where in some areas the statistically significant spatial clusters of low relative chlorophyll were larger in 2006 than in 2012. The total area of significant spatially autocorrelated poor health was 73.4ha in 2006 and 65.2ha in 2012. The significant spatially autocorrelated windthrow and poor health in 2006 suggested a diseased area of 10.3ha (Figure 2b).

Windthrown objects were evaluated for their relative chlorophyll levels in 2006. The distribution of the segment objects' mean chlorophyll area metric produced a central tendency that was low relative to that of the global study area. 2,145 of the total 3,205 segments (67%) had lower than average chlorophyll levels. Despite this finding there was not always good correspondence between smaller windthrow event and low chlorophyll.

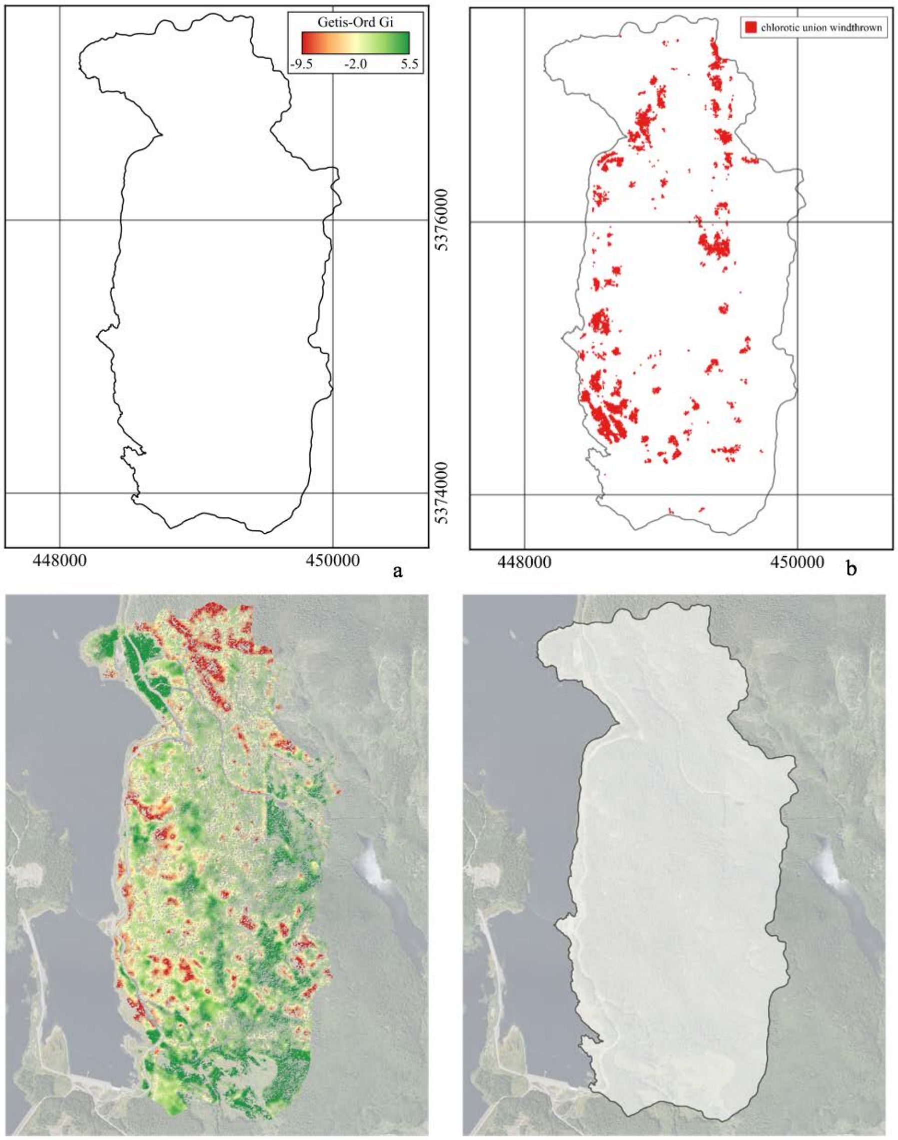

Figure 2. (a) 2006 Spatially autocorrelated low chlorophyll, as represented by the area of the normalized chlorophyll absorption feature. Values less than -1.96 represent statistically significant spatial clusters of low productivity. **(b)** The union of spatially autocorrelated 2006 poor health and spatially autocorrelated windthrow is used to identify likely regions of active root disease.

DISCUSSION AND CONCLUSIONS

Forest health was mapped across a small forest management unit within the Greater Victoria Water Supply Area. The processing stream developed here leveraged on a multi-temporal airborne lidar dataset to provide definitive reference data for diseased and otherwise healthy or asymptomatic forest. This study demonstrated that almost 70% of tree crowns that would ultimately be windthrown by 2012 were physiologically stressed in 2006. These findings are promising and reinforce the varied utility offered by multi sensor integration, however more research is required to evaluate confounding issues uncovered in the process.

Considerable effort was directed towards maintaining the integrity of the data used in this study. Exclusion of areas with low signal to noise yielded sparse AIS data. The 2012 data experienced shadows and unsampled regions attributed to variations in attitude and platform velocity. Younger stands that in the 2006 data did not meet height requirements for lidar forest thresholding, by 2012 had grown to heights above that threshold; all these attributes contribute to the differing spatial sampling distributions between the two years. As these data were referenced to the global distribution it would be expected that differences between the two dates could be the product of differences in the post-filtered dataset ground sampling.

From a theoretical perspective, the CRTA is not exclusively a function of chlorophyll, therefore it is conceivable that the signal reported here is inflated for regions of higher LAI (Quinn, Visintini, and Niemann 2012). Conversely, low LAI or stem densities in some regions of the study area may also have reduced measured relative chlorophyll through spectral mixing of less drought tolerant understory vegetation, which were desiccated, chlorotic or necrotic at the time the survey was conducted. The differences in the CRTA distributions suggest that the forest cover of the management unit in 2012 was experiencing higher levels of stress than the 2006 year. This observation would be supported by the fact that the late summer of 2012 was experiencing a significant drought event relative to that of 2006, as evidenced by observations of reservoir levels and exposed ground cover vegetation in the accompanying orthophotography. It is recognized however that the differences in location and dispersion of these distributions may be influenced by the slightly different spatial resolutions. The smaller footprint of the 2012 AIS data is expected to increase variability and reduce absolute chlorophyll intercepted by the footprint and thus reduce the location of the distribution. These traits are reflected in the distributions. It is suspected that the observed differences in the health between the two dates are also affected by the larger resolution of the 2006 data where the larger footprint may be contaminated by mixing of chlorotic shrub layer vegetation. As a result, it cannot be definitively stated whether the observed differences are derived from physiological differences of the target or by the physics of the sampled ground area and chlorophyll absorption.

Future efforts in progress include an infield validation campaign to derive an estimate for the accuracy of the derived process and for the parameterization of the approach for appropriate scales of analysis and dDSM magnitude. Field campaigns will visit identified potential root disease affected areas to observe the presence of residual inoculum in windthrown root mats, in addition to fine scale photography from UAV platforms.

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*HOW AIRBORNE LIDAR CAN HELP MAP ROOT DISEASE AND INDIVIDUAL TREE DECLINE

Helen Maffei[1] *and Brian Wing*[2]

[1]Western Wildland Environmental Threat Assessment Center, USDA Forest Service, Prineville, OR. [2]Pacific Southwest Research Station, USDA Forest Service, Redding, CA

This presentation provides an overview of ongoing work that is focused on utilizing individual live, dead and declining tree patterns to identify root disease centers using airborne Light Detection and Ranging (LiDAR). This work is a collaboration between USDA Forest Service Central Oregon Forest Health Protection (FHP), USDA Forest Service Pacific Southwest Experiment Station (PSW) and the USDA Forest Service Western Wildland Threat Assessment Center (WWETAC).

Root disease is a common feature of central Oregon landscapes. Where it exists on managed lands, it can severely limit expectations that depend on the growth and sustainability of large host trees over time. Being able to identify root disease centers can help managers prioritize treatments, while also providing increased efficiency for assessing potential hazards (e.g., road side hazard trees).

Both the Deschutes and Ochoco NFs have complete LiDAR coverage on all forested lands. The point cloud density (8-12 pulses/m^2) is sufficient to map both forest and geographic characteristics. Raw LiDAR data comes as three-dimensional point cloud (Figure 1).

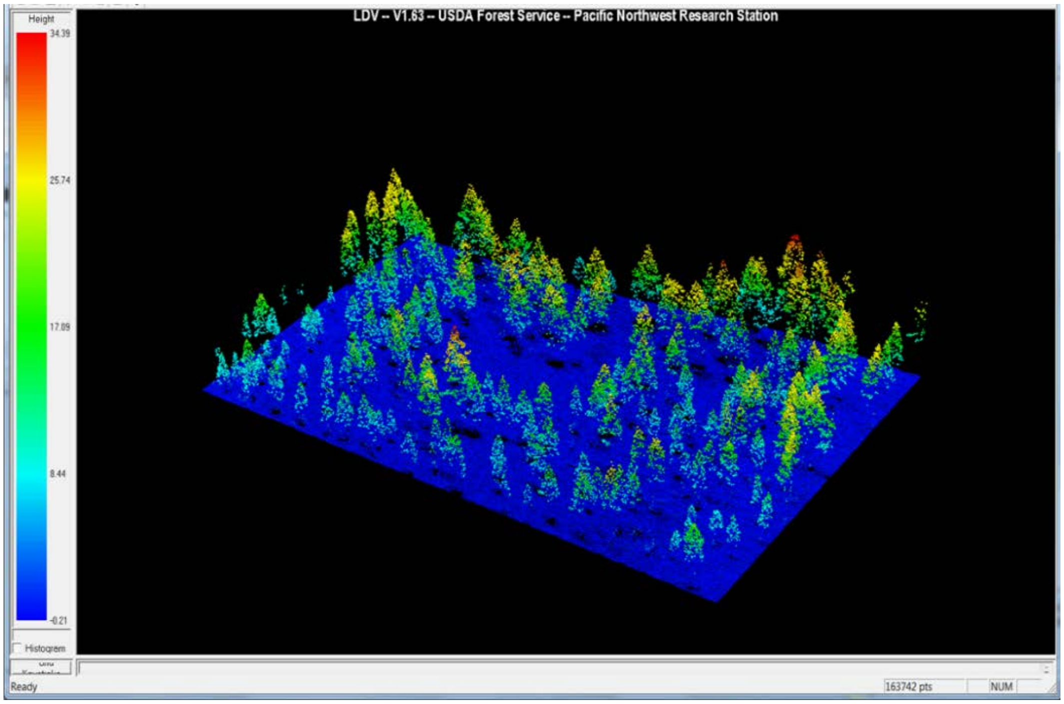

Figure 1. LiDAR three-dimensional point cloud data. Color ramp signifies height above the ground.

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For LiDAR to have practical utility, the point cloud must be summarized to useful metrics. A number of metrics have been generated for the Deschutes and Ochoco NFs. Some examples of vegetation metrics include; individual trees (live or dead), basal area, canopy cover, trees per acre by size class, biomass, volume, and forest structure indices. These metrics are routinely used as an aid to project planning by Deschutes NF and Ochoco NF personnel. Broad coverage and usage of LiDAR where it is available, as well as the ability to accurately map individual trees and distinguish whether they are live or dead lead us to investigate the ability of the technology to predict and map the extent of root disease.

CURRENT WORK

Areas infested with root disease often exhibit the following tree and forest structural attributes (Figure 2): 1) canopy openings with decreased density around the openings, 2) higher proportion of dead, down and dying trees inside and around the edges of openings, 3) tree regeneration or brush in openings, 4) progressively higher proportions of older dead and down in the center, and 5) progressively decreased canopy cover from original host trees outward to the opening perimeter. The method being developed and tested is focused on capitalizing on these attributes by utilizing LiDAR's (near-infrared) unique ability to accurately identify canopy gaps as well as dead and dying trees.

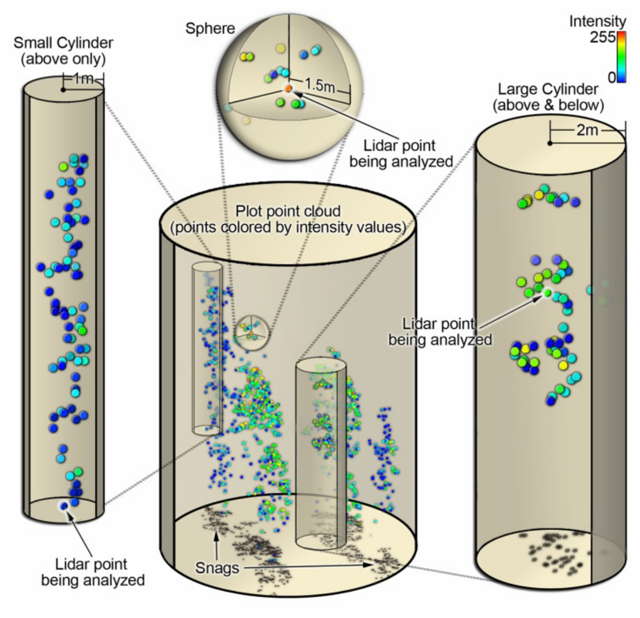
Figure 2. Example of how laminated root disease centers exhibit a characteristic progressive pattern of decline and mortality.

The method applies a two-step process to predict the occurrence of root disease centers using LiDAR. First, canopy characteristics that are indicative of root disease centers across the landscape are identified using LiDAR-derived canopy cover metrics (i.e., open canopy gaps). Next, the relationship of dead, dying and trees species within and around these canopy gaps is assessed to identify potential root disease centers. Fine scale patterns of individual LiDAR-derived dead and dying trees associated with canopy gaps, as well as likely occurrence of host trees are used to help distinguish root disease mortality from other gap causing agents (i.e., wildfires and bark beetles).

LIDAR-DERIVED TREE CONDITION BASE MAP

A suite of LiDAR-derived raster and individual tree metrics were created to develop a fine scale spatial base map. The map was used as the foundation to analyze the spatial inter-relationships among the four indicators of root disease and identify potential root disease centers: 1) canopy gaps indicating potential root disease centers, 2) individual live and dead trees, 3) dying or trees with unhealthy crowns, and 4) host and non-host trees. There are several techniques that can be used to identify canopy gaps using LiDAR data. For this project, a high-resolution LiDAR-derived canopy cover raster layer (3x3m grid cells) was utilized to identify canopy gaps. The method was chosen because it's relatively simple to apply and does not require any field validation data. Canopy gaps are located by identifying areas of six or more adjacent grid cells with canopy cover values < 20%. These identified canopy gaps are then extracted and added to the base map for further analysis.

Individual trees were identified using a standard LiDAR individual tree delineation procedure (Vauhkonen et al., 2011). The method first generates a canopy height model where the modeled surface adheres to the top of the forest canopy. Next, individual trees are identified using an automated procedure that identifies individual peaks in the canopy height model. The method produces x- and y-coordinates for each identified tree along with an estimate of each tree's height. Diameter at Breast Height (DBH) was then estimated for each tree using local height vs. DBH regression equations based on plant association types. This technique is highly accurate for the identifying trees with exposed tops and less accurate for trees with tops located under or intermixed with neighboring tree canopies. The individual tree stem map layer was then used in the next step to determine live and dead distinctions, crown health classifications, and species assignments for each tree.



Individual tree live and dead distinctions, crown health classifications, and species assignments were completed using the LiDAR intensity-based neighborhood attribute filtering methods and variables developed from Wing et al., 2015. Wing (2015) was focused on detecting individual dead trees by applying an automated filtering algorithm that utilized three-dimensional local neighborhood LiDAR point-based intensity and density statistics to remove LiDAR points associated with live trees and retain LiDAR points associated with dead trees (Figure 3).

Figure 3. Depiction of the three 3D neighborhood filtering variables used in Wing et al., 2015.

LiDAR intensity and its relationship with foliage and branches was utilized to filter the points into live and dead tree classifications (Figure 4). The same local neighborhood 'sphere' variable used in the study to help filter the points is used in this project to apply crown health classifications and species assignments. The 'sphere' local neighborhood intensity-based variable provides unique characteristics that can be used to identify local areas within crowns that lack foliage (i.e., unhealthy crowns with more branches exposed) (Figure 5). This variable was assessed and summarized for each tree to provide overall crown health classifications. Tree crowns with dense foliage and lacking dead branches had lower crown health ratings, while tree crowns with sparse foliage had higher crown health ratings. Crown health ratings ranged from 1 to 5; a crown health of rating of 5 is commensurate with a dead tree.

The 'sphere' local neighborhood variable also provided the ability to distinguish between fir and pine trees. The relationship of the variable's values located at the tops of the trees was found to be uniquely different for pine versus fir or Douglas fir trees and this relationship was utilized to assign pine or fir species designations to each tree (Figure 6). The tree points with their live, dead, crown health, and species attributes were then added to the base map to analyze the spatial inter-relationships among the four indicators of root disease and identify potential root disease centers.

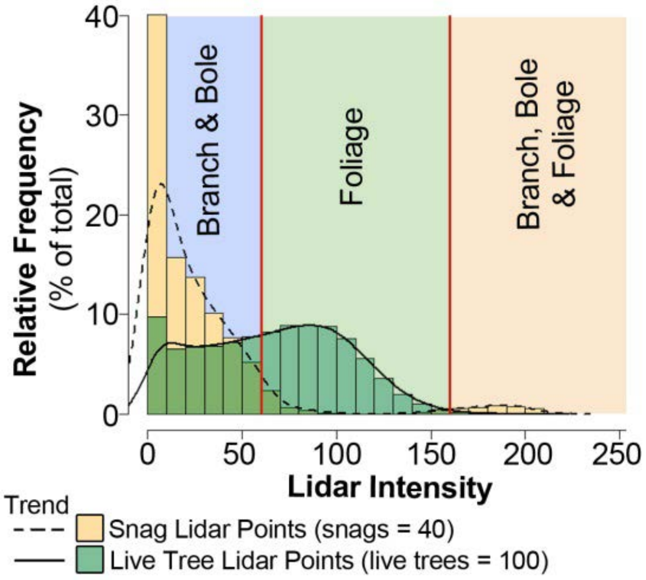


Figure 4. Individual live tree and snal intensity historgrams summarizing the intensity dynamics in relation to live and dead trees.

Currently, investigations are underway to assess the ability of the method to identify potential root disease centers on a 40 acre mixed conifer study area located on Ochoco NF that's infested with laminated root disease caused by the fungus *Phellinus sulphurascens*. An array of analysis methods for the base map data are being developed and assessed to identify the best methods for identifying potential root disease centers. Results are expected to be published in a peer-reviewed journal.

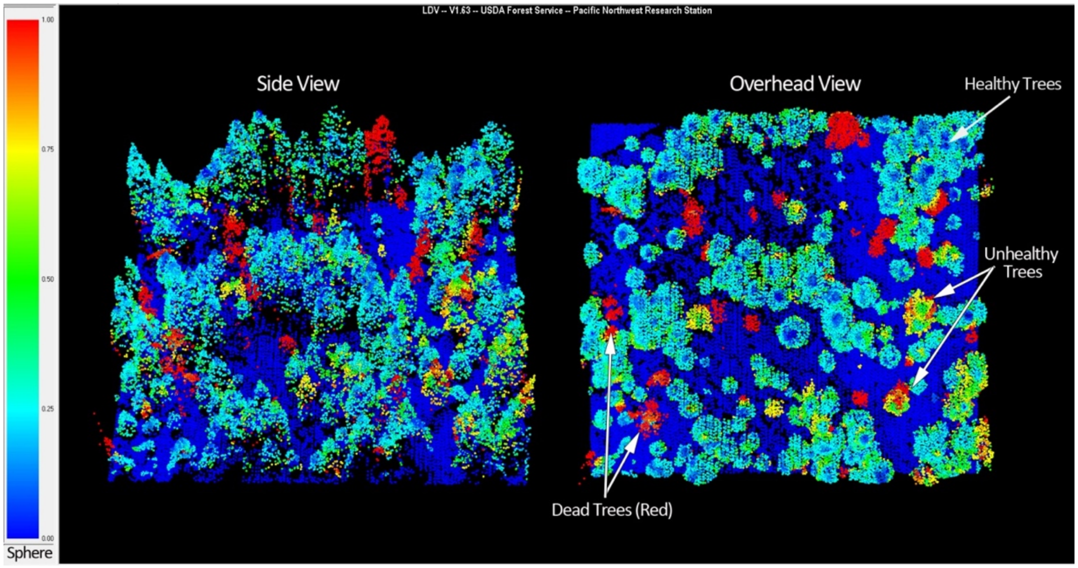


Figure 5. Lidar point cloud from study area with points colored by the 'sphere' local neighborhood variable values. (Values near 1 (red) are associated with woody branches and values near 0 (blue) are associated with dense foliage.)

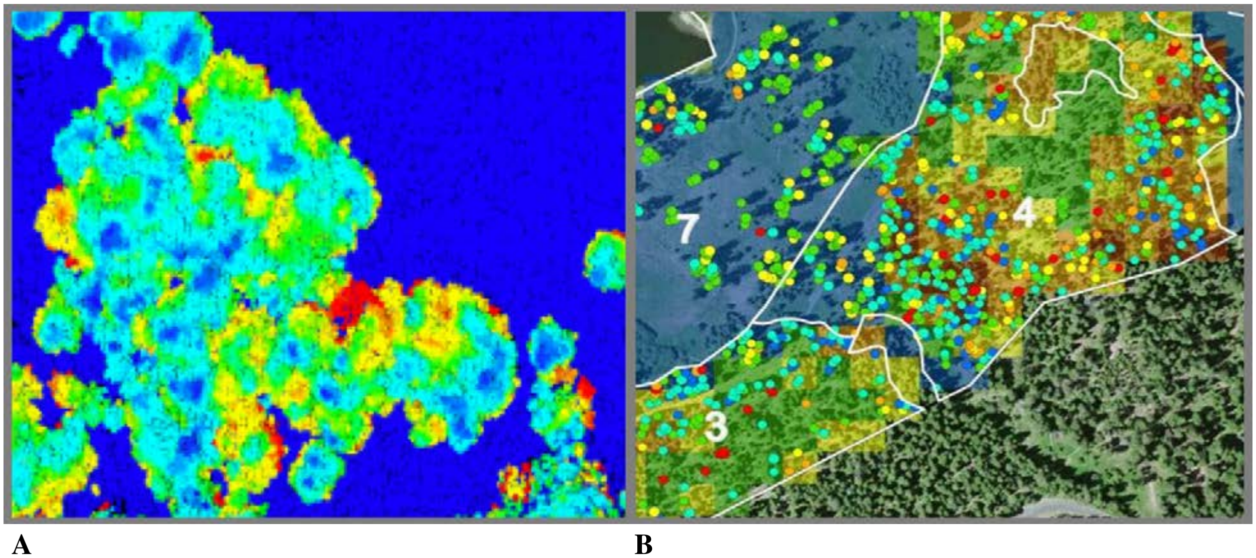


Figure 6. (A) Example of LiDAR ‘sphere’ intensity variable values at tree tops (Dark blue tops indicate fir and Douglas-fir, green tops indicate ponderosa pine). **(B)** Example map of individual large trees attributed by LiDAR species and crown health classifications (Living host (fir and Douglas-fir) represented by turquoise, ponderosa pine by green, declining trees yellow, dead trees red.

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PANEL: SIGNALS OF CLIMATE CHANGE FOR SPECIES SHIFTS

MODERATOR:
ALEX WOODS

[*]WARNING SIGNALS OF ADVERSE INTERACTIONS BETWEEN CLIMATE CHANGE AND NATIVE STRESSORS IN FORESTS

Alex Woods[1], K. David Coates[1], Martin Watts[2], Vanessa Foord[3], Erin Holtzman

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INTRODUCTION

Gradual increases in chronic stressors as the climate warms, such as forest pathogens or unusual weather events, will likely alter individual tree survival and growth with unknown consequences for ecosystem services at larger geographic scales (Price et al. 2013, Ennos 2015, Flower & Gonzalex-Meler 2015). This is especially the case for slow biotic and abiotic stressors that cause damage and result in diffuse mortality in managed forests (e.g., Heineman et al. 2010, Woods & Coates 2013). In combination, multiple stressors could result in a major loss of forest productivity due to cumulative effects of stem mortality, reduced growth rates, and physical damage that reduces timber quality and value (Roach *et al*. 2015). As the climate changes, it is essential to understand the complex interactions occurring in managed forests as a result of changing disturbance drivers, which in turn determine long-term productivity.

In our study, we examine the direct effects of chronic stressors on patterns of tree development in managed stands across a wide expanse of northern British Columbia (BC), Canada and explore the interactions that may be occurring between tree species, abiotic events, and pests and pathogens under a changing climate. Our study area covers the northern most extent of large scale commercial forest management in western North America and given that high-latitude ecosystems are expected to respond first to climate change (Bunn et al. 2007) it represents the front line of where we might first expect climate change interactions with chronic stressors in managed forests. Over our study area, mean annual temperature has increased by 1.1ºC in the last century and annual precipitation has increased by 8%; with that in the summer increasing by 18%. Our objectives are to establish a baseline assessment of mid-rotation managed forests in this area and to quantify the degree to which chronic stressors under the influence of climate change may have already affected these forests.

METHODS

We examined 176 randomly selected even-aged stands, 15-40 years old, based on the last date of harvest of the previous mature stand. We observed 33 different disturbance agents that negatively impacted individual trees and this wide variety of disturbance agents is one of the key findings from our study. Across all management units, tree species and diameters classes, 18% of sampled trees were damaged to the point that they were deemed unacceptable based on established damage criteria. These trees are unlikely to reach rotation age (due to agents that kill) or are so damaged they would be culled at time of harvest or have significant losses in milling operations (due to agents that maim) (Koch 1996). The majority (65%) of damaged trees ≥7.5 cm dbh were affected by agents that maim, including scarring from animal feeding, forks and broken tops due to abiotic events such as heavy snowfalls, forking caused by insect feeding on

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tree leaders and disease induced defects including western gall rust stem infections. Since maiming agents do not typically kill larger trees, their incidence in stands tends to increase over time.

RESULTS

No single disturbance agent dominated. The cumulative impact of multiple types of disturbances resulted in defects, growth reductions and mortality. There were strong species-specific differences in incidence and extent of damage. We observed particularly high levels of damage in lodgepole pine where, on average, 27% of the trees were affected. Much lower levels of damage were recorded for interior spruce (6%) and for subalpine fir (5%). We also found a consistent trend towards higher proportions of trees being damaged as diameter increased in the two most extensively managed tree species, lodgepole pine and interior spruce (Figure 1). Competition negatively affected 9% of all trees. Disturbances of some kind affected 17% of all trees and for those with diameters at breast height of greater than 7.5 cm, disturbance agents accounted for > 99% of all compromised trees.

We looked more closely at the variability of damage in top height trees (the largest 100 dbh trees per ha) and crop trees (the largest 800 dbh trees per ha) in contrast to the population of all trees ≥7.5 cm dbh. If damage was evenly distributed across tree sizes, then the percent of basal area damaged in the top 100 and top 800 trees per ha 1:1 graphs should be the same. Top height trees are typically assumed to suffer little damage (Zeide & Zakrzewski, 1993) but we found this not to be the case in approximately half (85 of 175 stands) of the stands we assessed (Figure 2, note horizontal cluster of data points representing no top height tree damage). Instead, we found strong evidence of greater variability in damage and, in more than one third (64 of 175 stands) of the stands, more damage in top height trees (Figure 2). The productivity that can be expected from individual stands had high levels of uncertainty due to the increasing levels of damage as tree size increased. We believe heavily damaged lodgepole pine-leading stands are undergoing a gradual regime shift from productive high yielding systems to pest and damage prone low yield systems aided and abetted by a changing climate.

DISCUSSION

A changing climate is probably one of the most critical external drivers of forest dynamics. The climate of northern latitude forests in British Columbia, Canada, has been steadily changing since monitoring began in our study area (1895) and increasingly so since the 1970s (Wang et al. 2012). Altered temperature and precipitation regimes have been shown to indirectly affect the ability of trees to resist forest pests and pathogens (Woods et al. 2005, Weed et al. 2013, Allen et al. 2015). Warmer and wetter conditions in spring and summer months favour hard pine rusts (Krebill 1965, Woods 2014, Reich et al. 2015) and have previously been linked to increased hard pine rust incidence in the study area (Woods 2011). Warmer winters have been clearly linked to the mountain pine beetle epidemic in BC (Carroll et al. 2004) and may have contributed to heavier snow loads, which often cause tree defects. It is in this era of a rapidly changing climate that we have examined the direct effects of such internal slow drivers of ecosystem change (chronic stressors such as pests, pathogens and abiotic events) on patterns of tree and stand development in managed stands across a wide expanse of northern BC.

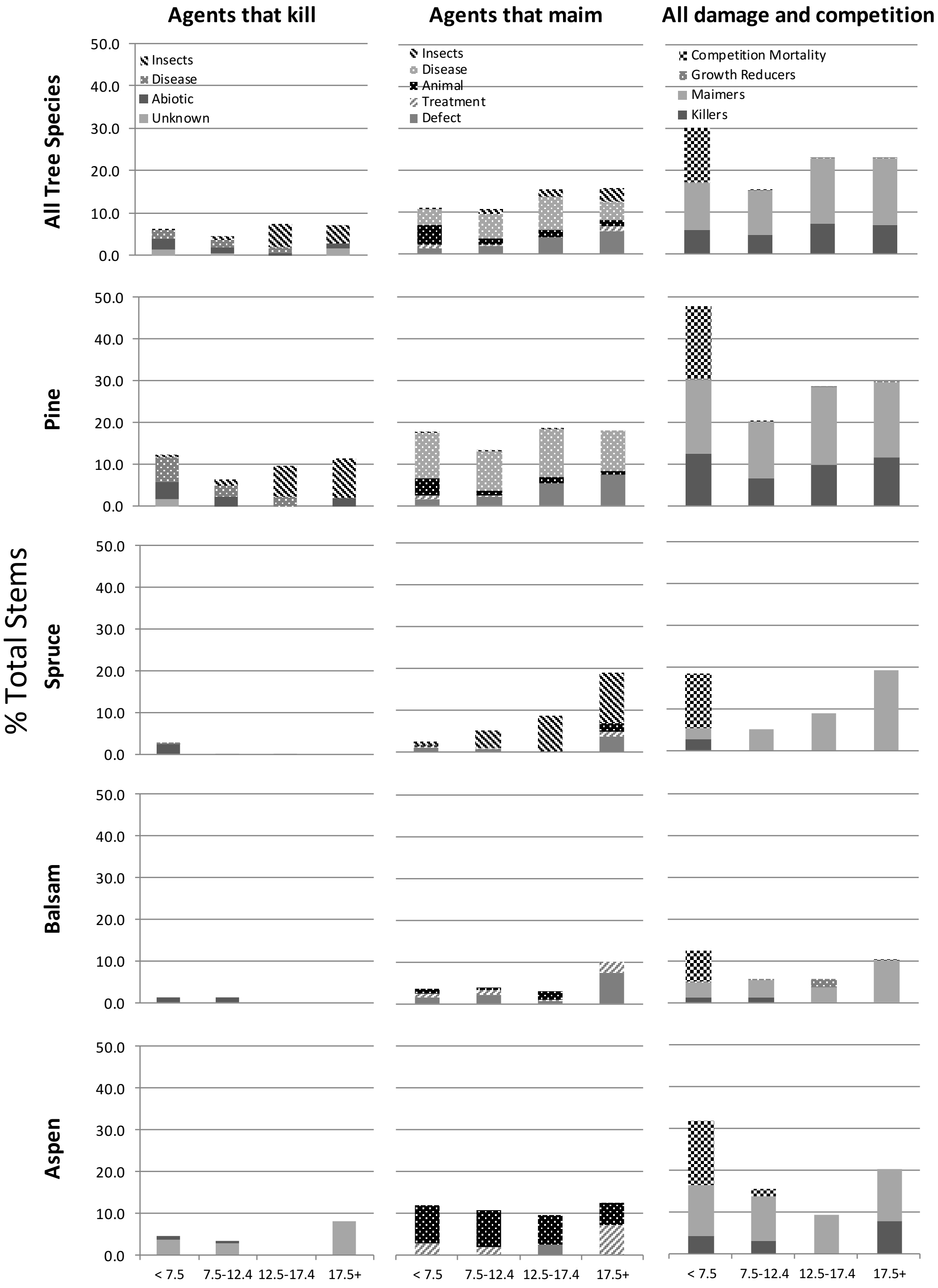

Figure 1. Area weighted average percent of total stems/ha by diameter class, compromised by disturbance agents that kill, those that maim and by all disturbance agents and competition combined for the four most prevalent tree species and all species combined for 176 stands aged 15-40 across northern BC, Canada.

Competition has been long considered the primary driver of forest dynamics in even-aged stands (Bazazz 1990). In the 15-40 year old stands we studied it was clear that disturbance, and not competition, was the dominant driver of forest dynamics (mortality, growth and physical damage), especially for the dominant trees most counted upon for stand productivity and timber supply. Of greater concern is the fact that four of the five most prevalent types of damage we observed, western gall rust, comandra blister rust, forks and crooks and snowpress, could have increased in frequency as a result of the environmental changes that have already occurred. Proof of such links would require extensive long term monitoring data which currently does not exist, but given the magnitude and direction of climatic change already experienced, increased rates of disturbance and resulting damage would be expected.

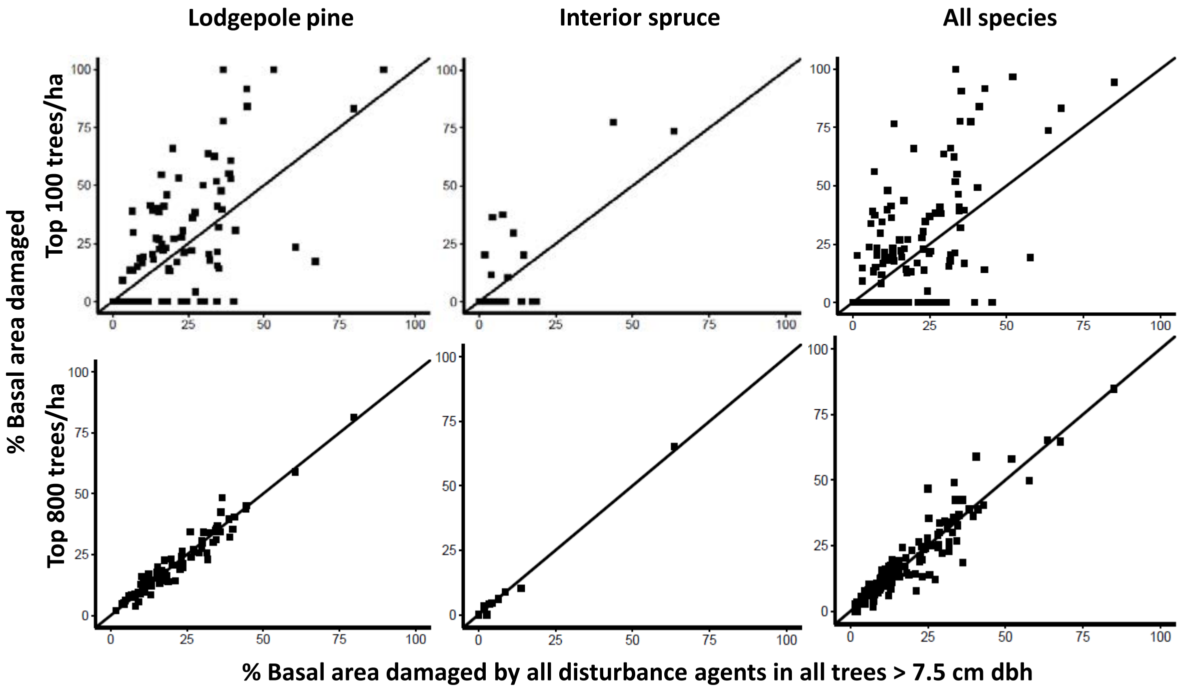

Figure 2. The percent of lodgepole pine, interior spruce and all tree species combined basal area (m2/ha) that is damaged in the largest diameter 100 and 800 stems per ha in contrast to the percent of basal area that is damaged for the entire sample (all pine, spruce or all tree species combined >7.5 cm dbh). If the point is above the 1:1 line, it indicates that cohort of trees has more damage than the entire sample while if below the line it has less. Each point represents an individual stand.

The increased variation in the percent of basal area damaged in the largest trees that we observed challenges long held growth and yield beliefs (Woods and Coates 2013) and may represent something more fundamental. Increased variance around a stable state, such as stand productivity, caused by chronic stressors, or slow drivers of internal change, may indicate the presence of a regime shift or a tipping point (Walker et al. 2012, Price et al. 2013). Shifts in climate are arguably the most pervasive slow drivers of ecological change and regime shifts (Hughes et al. 2013).

The combination of physical damage, growth reductions and diffuse mortality observed in pine-leading stands across northern BC, resulting in the loss of dominant trees, are likely to have long-lasting legacies for stand productivity. As multiple chronic stressors overcome the ecological resilience of a system, alternate stable states are possible. The challenge of identifying such regime shifts in forests is difficult due to their slow development. One of the great problems with the type of gradual regime shift we have described, in contrast with a rapid regime shift, is a social one: convincing enough people to confront business-as-usual before time runs out to reverse unwanted gradual regime shifts (Hughes et al. 2013). Gradual regime shifts are much more likely to go unnoticed or to be ignored. Slow regime shifts provide a false sense of security, effectively concealing evidence of poorly thought out management practices and providing little warning of future declines (Hughes et al. 2013).

We have shown that slow biotic and abiotic forcing factors are prevalent and in conjunction with a changing climate, they could disrupt forest production, alter the resilience of forests and affect ecological interactions. As the climate changes, there is considerably less understanding of how forests will respond to gradual increases in slow chronic stressors such as forest pathogens. The development of appropriate, novel forest management approaches that adequately consider uncertainty and adaptability are hampered by the continuing focus on production of a few goods or objectives, strong control of forest structure and composition, and most importantly the absence of a global scientific framework and long-term vision (Messier et al. 2014).

Current yield models used in forestry typically often ignore the effect of multiple slow stressors and their cumulative impact on growth rates, physical damage and mortality in managed stands. Unless these impacts are accounted for in models, their yield projections will be increasingly unreliable as climate continues to change (Kirilenko & Sedjo 2007). Forest managers need to consider and evaluate the short- and long-term viability of specific practices in a framework that minimizes risk and reduces the chance of undesirable future outcomes.

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[*]CONSERVATION IN A SOCIAL-ECOLOGICAL SYSTEM EXPERIENCING CLIMATE-INDUCED TREE MORTALITY: THE HEALTH STATUS OF YELLOW-CEDAR (*CALLITROPSIS NOOTKATENSIS*) IN GLACIER BAY NATIONAL PARK AND PRESERVE

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Climate change alters species distributions and assemblages across land designations, posing new challenges for land management and nature conservation. The purpose of our study was to examine the current ecological condition of a valuable species, consider the predicted future effects of climate change on that species in a protected area, and assess the perspectives held by forest users and managers on future adaptive practices. We mapped the distribution of yellow-cedar (*Callitropsis nootkatensis*) and examined its health status in Glacier Bay National Park and Preserve (GLBA) by comparing forest structure, tree stress indicators, and associated thermal regimes between forests inside GLBA and forests at the dieback's latitudinal limit, where mortality extends southward. Yellow-cedar trees inside the park were healthy and relatively unstressed compared to trees outside the park that exhibited reduced crown fullness and increased foliar damage. We modeled future vulnerability of yellow-cedar in GLBA by considering well-documented risk factors for mortality (soil drainage, snow cover) under climate scenarios (present to 2099). Our results indicated future expected dieback occurring within park boundaries. Interviews with forest users and managers revealed strong support for increased monitoring to inform interventions outside protected areas, improving management collaboration across land designations, and using a portfolio of future adaptations on actively managed lands (e.g., assisted migration, protecting live trees from harvests). Study participants who perceived humans as separate from nature were more opposed to interventions (e.g., planting trees) in protected areas. Linking social and ecological analyses, our study provides an interdisciplinary approach to identify system-specific metrics (e.g., stress indicators) that can better connect monitoring with management, and adaptation strategies for species impacted by climate change (Figure 1).

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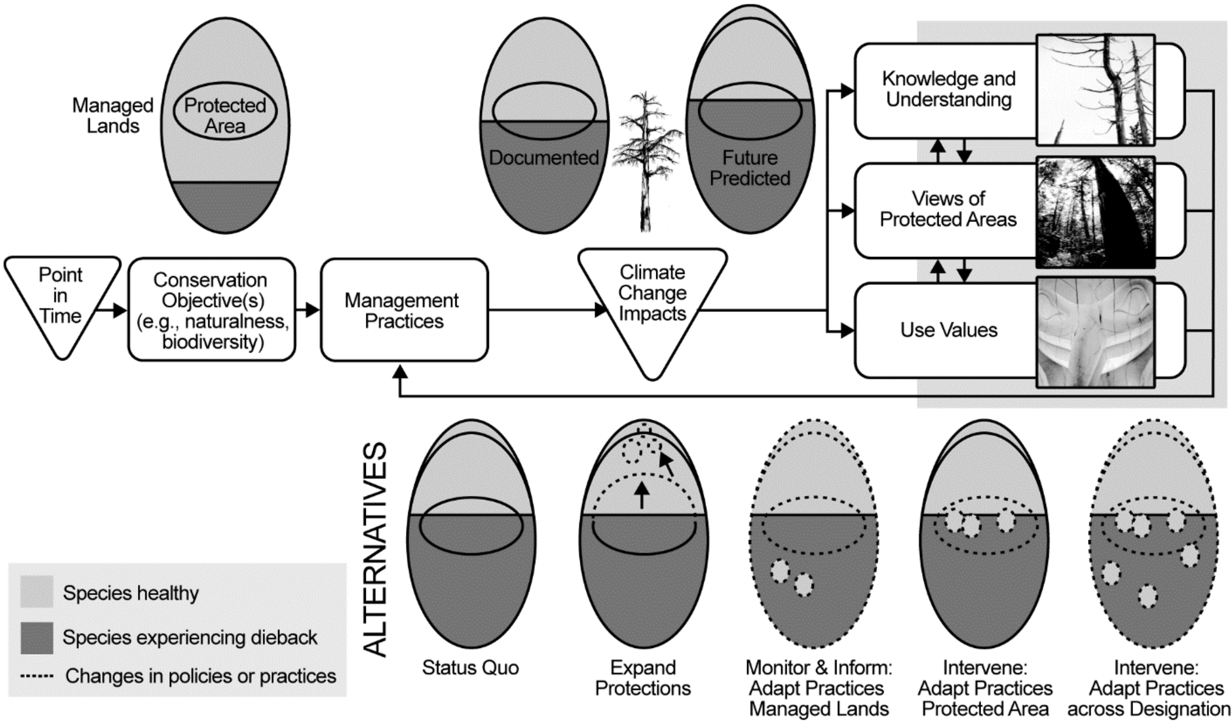

Figure 1. Organizing framework that integrates social and ecological variables relevant to adaptive management and conservation of a climate-sensitive species. The framework identifies key social and ecological factors that influence perceptions of adaptive practices (management alternatives to the status quo) across the species distribution (large oval) in protected areas and actively managed lands. Extended oval indicates possible range expansion to higher latitudes or elevations.

[*]DETECTION OF CLIMATE CHANGE IMPACTS IN CANADA'S NORTHERN FORESTS

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BACKGROUND

Since 1950, Canada's annual mean temperature has increased by about 1.5 °C. Average precipitation amounts also appear to have increased, but the trend is less clear. Northern Canada has undergone even more rapid warming since the 1970s, with average temperatures now comparable to (and possibly exceeding) those which occurred at the peak of the Holocene Thermal Maximum, some 7,000 years ago. For example, the mean temperature of the Mackenzie Delta region has warmed by about 2.5 °C since 1970. There is compelling evidence that a portion of recent warming trends is attributable to human influences on global climate, related mainly to rising CO_2 concentrations. Since 1850, atmospheric CO_2 levels have risen by about 50%, and are now (2016) evidently the highest in more than 2 million years (Bartoli et al. 2010).

A warmer atmosphere is likely to be a more dynamic system, meaning that historical weather extremes will become more frequent and/or more extreme. Climate variability occurs at multiple time scales and can drive episodic events at local to regional spatial scales. As one example, the El Niño event of 2014–2016 has proved one of the strongest on record, and likely contributed to two unusually mild winters in western Canada. These conditions also led to extreme wildfire seasons in 2014 and 2015, followed by an exceptionally dry early spring in 2016, which triggered the catastrophic fire surrounding Fort McMurray at the time of WIFDWC. It remains an open question whether El Niño events will become even more intense with future climate warming, but this appears quite possible.

Paleo evidence (e.g., tree rings, charcoal deposits, lake sediments) and recent field observations indicate that recent warming is driving several climate-related threats to Canada's boreal ecosystems. Price et al. (2013) attempted to identify all the major climate-driven processes operating in the forest ecosystems of Canada's boreal zone. An emergent theme was the possible existence of several climate-sensitive "tipping elements" in these ecosystems (see Lenton 2008). If there is a sufficient and sustained change in regional climate, one or more of these various tipping elements could be forced past a "tipping point", triggering a relatively permanent (generally degraded) change in ecosystem structure. Possible consequences include loss of conifers and transition to a less productive deciduous-dominated forest, or even complete loss of tree cover in some regions.

We believe climate change is already causing serious and pervasive structural damage to boreal ecosystem integrity over extensive areas of Canada's northern boreal biome. Ecosystem-scale processes of concern include: drought effects on tree growth, regeneration success and survival; increased severity of fires in forests and peatlands; stand-killing insect pests invading from more southerly regions, and mortality of forests growing on degrading permafrost soils. Many of these processes can interact to produce more

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damaging outcomes: e.g., drought can reduce tree defences against attacks by insects and/or pathogens; affected trees may increase fuel accumulations and hence wildfire severity. There is potential for multiple tipping points to be crossed. Hence we believe, given current projections of future climate warming, there is a very high probability of widespread, and largely irreversible, losses in boreal ecosystem structure and function within a few decades. Some of these changes have the potential to cause significant climate feedbacks, both positive and negative.

INSECTS AND DISEASES

Historically, northern regions have been a climatic barrier to the spread of endemic (and invasive) forest insects and pathogens, rendering northern boreal forests relatively protected, because successful pest establishment requires suitable environmental conditions when the host is susceptible. Adult insect pests (in particular) are very mobile, however, allowing them to spread rapidly when given the opportunity offered by warmer weather. The ongoing major outbreak of spruce budworm (*Choristoneura fumiferana* Clemens) in northern Quebec, and recent observations of defoliation close to the Arctic coast in NWT, are unprecedented in recorded history, and suggest the natural protection of a cold climate is already being eroded by recent warming. Moreover, relative lack of past exposure of northern trees to insect and pathogens could mean they have little biological resistance to attack, compared to more adapted genotypes of the same species at lower latitudes. Hence we see a possible tipping point where progressive warming could allow explosive outbreaks of forest pests (i.e., defoliators or bark beetles) in large areas occupied by extremely vulnerable host species, resulting in catastrophic losses. Similarly, dispersal of fungal spores may allow relatively rapid infection of areas occupied by previously unexposed ("naïve") host species.

Within limits, warmer conditions accelerate insect phenology and population growth, assuming water and food resources are non-limiting. Larvae will advance through more development stages—meaning they get bigger faster, and eat more voraciously. Insects that typically complete a life cycle over two seasons may be able to complete it in one. Milder winters generally reduce mortality of eggs, larvae or pupae, allowing faster population growth the following spring. All of these factors can contribute to an endemic species becoming an explosive epidemic pest—and the potential for a tipping point to be crossed. It is also possible that conditions will become too warm for some pests to thrive. Their development may become less synchronized with the host species' phenology, or their own physiology may be compromised by higher temperatures. Hence some pests will be restricted to a zone of optimal temperature which gradually shifts to higher latitudes and/or higher elevations.

In addition to spruce budworm, forest tent caterpillar (*Malacosoma disstria* Hubner) has recently been observed causing extensive damage north of Great Slave Lake in NWT. Similarly, observed past warming trends in southern Alaska, the Yukon and most recently in northern B.C., appear well-correlated with damaging outbreaks of spruce bark beetle (*Dendroctonus rufipennis* Kirby), which is a widespread endemic species in the northern boreal. In 2012, mountain pine beetle (*Dendroctonus ponderosae* Hopkins) was detected for the first time attacking jack pine just north of the Alberta-NWT border. Pathogenic fungi such as *Dothistroma septosporum* (Dorog.) Morelet, where sporulation is directly influenced by environmental conditions, may also be a widespread threat in generally warmer conditions as reported recently by Woods et al. (2016) in northern B.C. Other pathogens, such as root disease agents that are influenced by host condition, may increase in severity as environmental conditions become more stressful for the host (Sturrock et al. 2011). Some fungal pathogens are carried by insect vectors, such as the stain and wilt fungi (*Ophiostoma*, *Grosmania* and *Leptographium sp*.) transmitted by mountain pine beetles (Sturrock et al.

2011). Other diseases appear to have uncertain, and possibly complex, causes generally triggered by some form of climatic stress (notably drought) including "aspen decline" and "balsam poplar decline" seen in NWT and in the Yukon, respectively.

DROUGHT

A general truism is that a warmer atmosphere will hold more water vapour, but, the resulting increase in average precipitation will not match the average increase in evaporative demand (with possible exceptions at local to regional spatial scales). Hence, we expect Canada's northern climate to become generally drier as it becomes warmer. Low annual precipitation already characterizes the climate of the boreal forest regions immediately east of the Rocky Mountains, meaning that some of these natural ecosystems are already water-limited and therefore likely to encounter drought stress in "drier than normal" years. CFS researcher Ted Hogg developed the Climatic Moisture Index (CMI), as an index of annual regional water balance (represented as potential evapotranspiration minus precipitation), and found that when long-term average CMI < 0, the landscape is generally unable to support continuous forest cover (e.g., Hogg et al. 1997). The isoline of CMI = 0 then is a proxy for the southern limit of Canada's boreal forest where it borders the prairies in the west.

We have projected changes in CMI and other drought indices into the future using several climate model projections of future temperature and precipitation. These invariably show that large areas, notably in northern Alberta, and in the southern portions of the Yukon and NWT, could very easily shift to moisture regimes where long-term average CMI < 0 (Wang et al. 2014), suggesting boreal forest cover could be lost—and a tipping point crossed—within a few decades. However, the dynamics would be different for peatland systems in these regions, which may then become the moist sites providing refuges for upland forest vegetation (Schneider et al. 2015; see also D'Orangeville et al. 2016).

WILDFIRES

A clear trend of increasing area burned is not yet discernible in the existing database of past forest fires in the Canadian northern boreal. Due to limited resources, detection (and active suppression) of large fires distant from communities, and the subsequent mapping of their boundaries and unburned "islands" within them, were not carried out rigorously prior to 1980. Since then, area burned is estimated to have averaged about 2 million ha per year, with large fire years in 1980-81, 1989, and the mid-1990s, and most recently in 2011 and 2014-2016. Nevertheless there are strong correlations between the occurrence of drier-than-normal years and extreme fire years (with large area burned). Given the anticipated general warming and drying trend, there is strong consensus among Canadian forest fire experts that climate change is likely to make extreme fire years more frequent in coming decades (e.g., Flannigan et al. 2008). While this is seen as a likely pan-Canadian trend, the drought-prone regions of northeastern B.C., northern Alberta and Saskatchewan, and southern Yukon and NWT are among those most likely to incur increased losses from fire.

Large-scale forest mortality caused by drought, and/or by insects or pathogens (which are often more damaging when trees are drought-stressed) increases wildfire fuel availability. Intuitively, this should contribute to increased fire occurrence (e.g., in conifer stands killed by pine beetle), but actual evidence of such an effect is scarce. It is possible that large-scale mortality caused by insects or diseases does not increase the number of fires, but rather, makes them more intense. This may, in turn, promote more rapid changes in forest structure.

Pre-fire stress and mortality in forest stands are also likely to reduce post-fire seed production, resulting in lower regeneration rates, particularly in conifers. With warmer conditions, increasingly frequent fires will destroy regenerating stands before they can produce viable seed banks. Hence, in a relatively short time, many tree seed sources could be destroyed, leading to species impoverishment and a tipping point where forest composition changes. Only deciduous pioneers that produce buoyant wind-borne seeds (poplars and birches), may be able to seed in from further afield (Fig 1). There are observations of such fire-induced changes, notably in the Yukon, where white spruce-dominated forest seems to have transitioned to a prairie–parkland system dominated by aspen (Hogg and Wein 2005; Johnstone et al. 2010) and in the southern boreal of Saskatchewan, near Prince Albert, where jack pine forest has failed to regenerate causing transition to grassland. Similar regeneration failures have been observed following fires in 2011 (Alberta; Pinno et al. 2013), 2013 (Eastmain, Québec) and 2014 (Wood Buffalo, NWT; see Figure 1).

Figure 1. Site of a major 2014 fire in Wood Buffalo National Park, NWT. Very little organic residue remains above-ground and regeneration is non-existent. Bouyant seeds of deciduous species (aspen and birch) should be expected to arrive and establish over time, but coniferous cover is gone; hence a change in forest type has occurred.

PERMAFROST

Approximately 1 million km^2 of Canada's boreal forest is estimated to be growing on sites underlain by permafrost. Because they are located mainly in the discontinuous and sporadic permafrost zones, these forested permafrost soils are in the front line for thawing and degradation. Permafrost is typically protected by surface vegetation and soil organic layers (saturated or dry peaty soils both provide effective insulation against heat penetration), even in regions where mean annual air temperature is above freezing. However, removal of the vegetation and organic material, for example when fires burn in from surrounding upland forest areas, can cause rapid permafrost loss and transformation of the landscape (e.g., Robinson and Moore 2000).

Studies at multiple locations across Canada suggest that until circa 1850, the southern limit of the discontinuous permafrost zone had been relatively stable for several centuries, approximately 200 km south of where it is now. The northward shift in the boundary was widely observed to have accelerated after 1970. All permafrost regions are now reported to be warming—which would be expected given the relatively rapid warming seen at high-latitudes in recent decades. Changes in annual thaw depth and in the extent of thermokarst (permafrost collapse) have been mapped over time, and confirm the general trend (e.g., Smith 2011). Hence, many areas that before 1850 would have remained frozen are now undergoing (largely irreversible) degradation, or are highly vulnerable. As climate warming continues, the degrading and vulnerable regions will extend northward. Permafrost is also highly vulnerable to human activities such as road and pipeline construction, and cut lines for forestry or mining, which typically create grids of permafrost-free wetlands. In general, any disturbance which leads to localized thawing can further accelerate degradation of intervening permafrost areas.

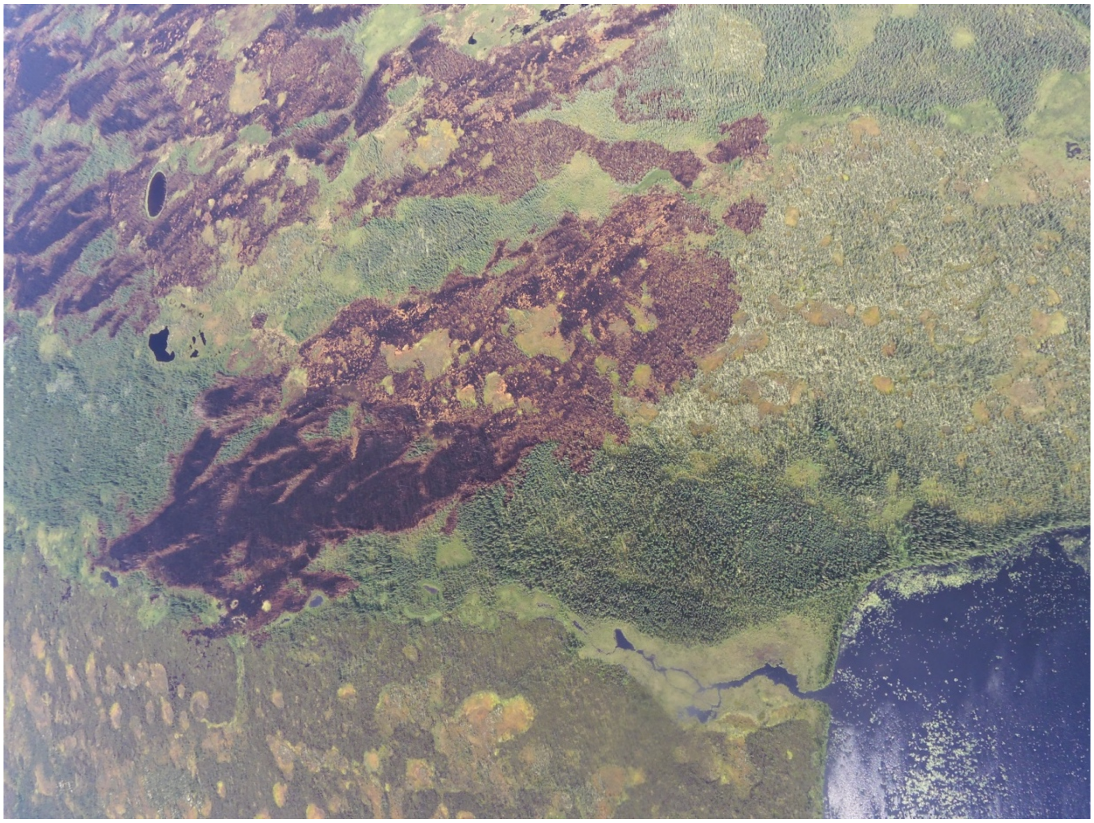

Figure 2. An example of the fire resistance of permafrost thaw from aerial images of Wood Buffalo National Park. The light green patches between the trees are the thaw pools, which do not carry fire. Light coloured treed areas are spruce/lichen mix, which burns extremely well.

As of 2005, approximately 22% of Canadian permafrost was considered to be in a "lagged response phase" meaning the local climate was too warm for permafrost to persist: soils remained frozen only because of the protection given by vegetation and organic matter cover. Any disturbance which removes the vegetation is therefore very likely to trigger degradation—the tipping point will be crossed.

Projecting the long-term future of permafrost melting is challenging: various estimates based on process models suggest a major impact could occur sometime between the late 21st and late 22nd century or even later. However, boreal ecosystems located on permafrost will almost certainly be the first to undergo systematic change. Permafrost thaw leads to the "drunken forest" response, where trees can take on a dramatic lean due to destabilisation of the soil—with black spruce being particularly affected. Waterlogging ensues, causing tree mortality and a potential negative feedback on local wildfire occurrence (Figure 2). Individual sites may then transition to wetlands or to drier upland ecosystems, depending on local topography. Such changes can be expected to occur on a vast scale, with serious implications for local wildlife and other forest benefits. In the longer term, there is the likely large-scale release of organic carbon as methane or CO_2, due to accelerated decomposition and fires, causing a positive climate feedback. It is unlikely that the eventual establishment of more productive forest cover will offset the releases of these greenhouse gases (e.g., Abbott et al. 2016; Robinson and Moore 2000). Recent estimates suggest an eventual increase of atmospheric CO_2 levels in the range 60 to 110 ppm (e.g., Schaefer et al. 2011; Schaphoff et al. 2013).

IMPLICATIONS FOR FOREST INSECT AND DISEASE MANAGEMENT

Nearly all aspects of boreal forest ecology can be described as climate-sensitive. There is much evidence, both published and recently observed, to demonstrate that a warmer climate has already contributed to increased moisture deficits, notably in Canada's northwestern boreal, which have contributed to increased fire occurrence and weakened resistance to insect pests. In turn, both insects and pathogens have been the likely beneficiaries of warmer conditions, although a clear delineation of increased geographic spread of specific fungal pathogens is lacking at present.

A major concern is the relative lack of comprehensive information about the occurrence and spatial distributions of pests, and in particular, of pathogenic fungi in Canada's northern forests. Efforts are being made, such as the PathMAP project lead by Rona Sturrock, to consolidate and integrate existing databases into consistent spatial formats, but there is a clear need to expand this effort to detect and map the current distribution of key organisms (particularly pathogens which are often harder to detect in their early stages). In addition, there is an urgent need for a long-term monitoring program, using the latest available technologies. This will require a new level of collaboration between federal and provincial governments, and perhaps involving university researchers, to build and maintain the databases and make them widely accessible. Such datasets will also be essential to test and validate models used to project potential future impacts of insects and pathogens on boreal forest dynamics, as the northern climate continues to warm.

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PANEL: LANDSCAPE DYNAMICS OF FOREST DISEASE IN THE BOREAL FOREST

MODERATOR:
LORETTA WINTON

[*]LANDSCAPE PATHOLOGY AND PATHOGEN DISTRIBUTIONS IN ALASKA'S BOREAL FOREST

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Forest pathologists study tree diseases at scales that have predominantly ranged from molecules (DNA diagnosis and populations genetics), microbes (fungal taxonomy and ecology), individual trees (disease expression), to local tree populations (pathogen spread and forestry). However, Holdenrieder et al. (2004) pointed out that forest tree diseases have an inherent landscape perspective in which spatial distributions of both hosts and pathogens influence each other. For example, spatial patterns of host and non-host vegetation influence rates of pathogen spread and severity of disease. Mortality effects of disease can alter the host landscape patterns of forest structure and composition (Castello et al. 1995), which in turn can help drive succession and influence carbon flux. Underlying landscape features such as topography, lakes, streams, and soils influence both host and pathogen populations through ecosystem connectivity and spatial heterogeneity in the abiotic environment.

Accurate mapping of pathogen locations and current impacts to host species is a key component to monitoring forest diseases and tracking their regional development. Such basic information is also necessary for detecting or predicting changes in disease distribution, severity, and ecosystem impacts. Precise reporting is also important for identifying novel pathogen introductions and assessing the risk of spread. Although explicitly georeferenced occurrences of forest diseases have historically been sparsely recorded, new online databases are being generated from research projects, monitoring systems, and formal literature reports (Purse & Golding 2015). Pasiecznik *et al*. (2004) states "Never before has the need for accurate distribution data for plant pests been so important" and describes the most comprehensive and authoritative of these databases. The European and Mediterranean Plant Protection Organization (EPPO) database (https://gd.eppo.int/) contains information on over 73,000 species of plants, pests, and pathogens of interest to agriculture, forestry, and plant protection. It derives from the professionally printed Distribution Maps of Plant Diseases first published in 1942 and is distributed jointly with the international organization CABI (Centre for Agriculture and Bioscience International). For example, the database contains detailed information on the geographical distribution (with a world map), host plants, photos, and categorization (quarantine status) of *Chrysomyxa arctostaphyli* (spruce broom rust), which is very common in many parts of Alaska. Comparable databased information is not available in the United States. This is a critical deficiency that is particularly troubling in Alaska, where average temperature increases over the past 60 years is more than twice that of the rest of the U.S. Recent analyses of plant pathogen records and distribution maps have demonstrated that pathogens are moving polewards under a changing climate and global economy (Bebber et al. 2013, Britton & Liebhold 2013). In Europe, large-scale, regular tree health monitoring that includes both abiotic and biotic causes have been achieved by close partnerships between forest inventory programs and insect and disease survey professionals. For example, analysis of Finland's national forest inventory plots has revealed useful information about widespread outbreaks of insects and fungi (eg. Scleroderris canker and spruce needle rust) in the increase phase, which could provide lead time for management decisions (Nevalainen et al. 2010).

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Very little large-scale or georeferenced data of forest diseases in Alaska's boreal forest are available because of scarce resources and vast terrain. In addition, most forest pathogens are not conducive to aerial detection. The consequences of this lack of data include Alaska not being represented in the National Root Disease paper (Lockman et al. 2016), nor are any Alaskan pathogen data available at the Forest Health Technology Enterprise Team (FHTET) forest health portal (http://foresthealth.fs.usda.gov/portal). However, two key developments are now addressing this deficiency in Southcentral and Interior Alaska: increasingly affordable and easy to use smart device technologies (which combine GPS, photographic, and drop-down list recordkeeping and data submission) and collaborative partnerships with forest inventory programs. In boreal Alaska, the Cooperative Alaska Forest Inventory, Department of Defense Forest Management program, and Bonanza Creek Long-Term Ecological Research site are each recording disease and insect occurrence and severity on individual trees within permanent plots. This complements the standard inventory measurements of tree growth, vegetation, soils, and other stand and environmental variables. Nearly 3000 permanent plots are being monitored on a 5 or 10 year rotation (Figure 1).

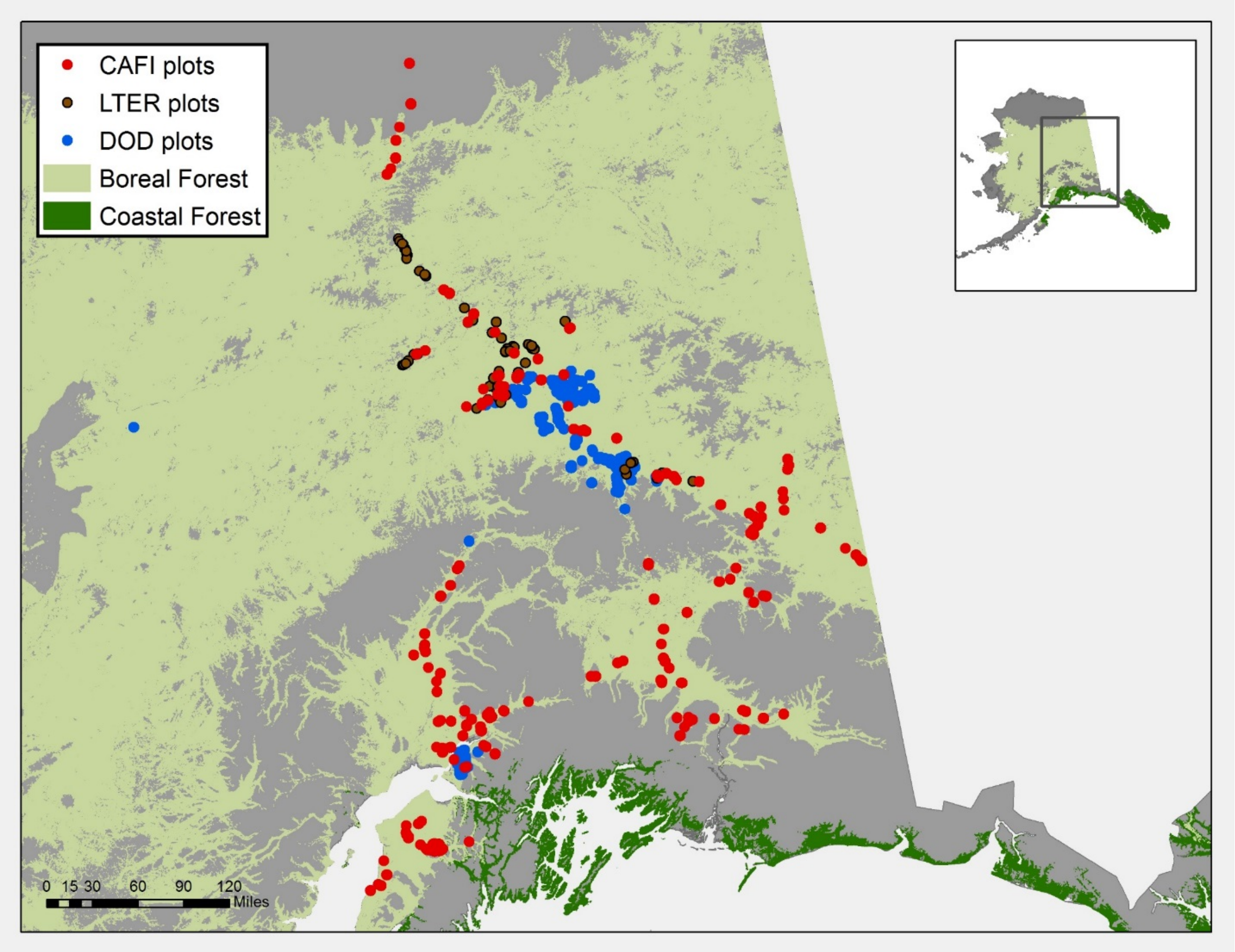

Figure 1. Nearly 3000 forest inventory plots are monitored by the Cooperative Alaska Forest Inventory (CAFI), Department of Defense (DOD), and Bonanza Creek Long-Term Ecological Research program (BZ-LTER).

Through these permanent plot networks we have, for the first time, documented widespread and significant mortality caused by an aggressive canker of (as yet) undetermined etiology. Elongated cankers run along the bole and can girdle and kill trees within a single season (Figure 2). Cankers are sometimes colorfully orange but are usually subtle in appearance and may be slightly sunken. At four permanent plots measured in 2015 in Interior Alaska, the canker affected 5% to 20% of aspen trees on the plots and about 30% of infected trees died within the year (FS-R10-FHP 2015). Whether this large amount of aspen mortality is a sudden phenomenon, has been slowly increasing, or remains in a static state is, among many other forest health questions, something that should be answerable through meta-analysis of the data from the three inventories.

Figure 2. Aggressive, elongated canker running up the bole on a nearly dead aspen. The bark has been shaved away to reveal the margin between live and dead tissue on two cankers which are merging to girdle the tree. To the left is a tree that was killed by canker previously.

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*CROSS-SCALE CONTROLS OVER RESPONSES OF THE ALASKAN BOREAL FOREST TO CHANGING DISTURBANCE REGIMES

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The regional landscape of interior Alaska is heterogeneous, dominated by a mosaic of wetlands, floodplains, and upland forests in varying stages of successional development adapted to and controlled by climatic extremes, cryospheric processes, and fire (Chapin et al. 2010, Jorgenson et al. 2010). Interactions between ecosystem dynamics and disturbance regimes across the region have remained resilient to climate fluctuations since black spruce spread to dominate the forest approximately 6,000 years ago (Hu et al. 2006, Higuera et al. 2009, Kelly et al. 2013). For thousands of years, this shifting landscape mosaic has been influenced by vertebrate and invertebrate herbivores, large carnivores, and humans, entraining a trophic web that remains relatively intact (Nelson 1973, Huntington et al. 2006, Natcher et al. 2007). However, rapid climate change over the past century has altered linkages and feedbacks among biophysical, ecological and socio-economic drivers to substantially transform the regional boreal forest landscape (Chapin et al. 2014). Alaska has warmed more than twice as rapidly as the contiguous U.S. over the past century, with some of the largest annual air temperature increases occurring in interior boreal forests (Bieniek et al. 2014, Chapin et al. 2014). This warmer and drier climate has triggered unprecedented changes in the fire regime and permafrost thaw, and species invasions and range shifts, resulting in major alterations to the structure and functioning of ecosystems across the boreal landscape and changes in the access and use of ecosystem services by Alaskans.

Vegetation changes resulting from warming, altered disturbance regimes, and insect and pathogen outbreaks have the potential to influence vertebrate herbivore populations, including caribou (Joly et al. 2011, Joly et al. 2012), moose (Brown et al. 2015, Lord and Kielland 2015, Tape et al. 2016), ptarmigan (Christie et al. 2014) and snowshoe hares (Kielland et al. 2010, Tape et al. 2015). Plant-herbivore and plant-pathogen interactions strongly influence plant growth, and community composition (Nossov et al. 2011, Feng et al. 2012, Bryant et al. 2014, Christie et al. 2015, Christie and Ruess 2015), and feedbacks controlling herbivore fecundity through impacts on forage quality and abundance (Seaton et al. 2011, Paragi et al. 2015).

Changing disturbance regimes are also affecting the complex interactions among vertebrate and invertebrate herbivores and plant pathogens. For example, browsing by moose and snowshoe hares promotes the dominance of chemically-defended alders (N-fixing species), which strongly influence N cycling (Uliassi and Ruess 2002, Nossov et al. 2011, Ruess et al. 2013), but the recent spread of the fungal stem canker on thin-leaf alder (*Valsa melanodiscus*) has led to widespread mortality of thin-leaf alder in riparian habitats throughout interior Alaska (Ruess et al. 2009). Mortality is particularly high where outbreaks of the alder canker and an invasive sawfly (*Monsoma pulveratum*) co-occur south of the Alaska Range (Ruess et al. 2009, USDA 2015), and alders are being replaced by an invasive bird cherry (*Prunus padus*), leading to potential consequences for freshwater foodwebs (Roon et al. 2014). Related stem cankers are now rapidly spreading to infect Siberian alder throughout the interior, and have been noted on red alder in southeast Alaska.

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Trembling aspen, a preferred forage species for moose (Seaton et al. 2011), is predicted to increase in abundance on drying slopes following high severity fires (Johnstone et al. 2010), but the long-term impacts of the aspen leaf miner (*Phyllocnistis populiella*), which has been at outbreak densities for over a decade in interior Alaska, on aspen growth and stand biomass are uncertain. Recently, a "running canker" has infected aspen throughout Alaska. The fungus is yet to be identified, and it is unknown whether the extent and impacts of the outbreak are novel. However, impacts on successional dynamics, associated rates and patterns of ecosystem carbon storage (Alexander and Mack 2016), and future fire behavior could be dramatic given the likelihood for community shifts, particularly in mixed conifer-hardwood stands. Other invertebrate herbivores, such as the willow leaf blotch miner (*Micurapteryx salicifolliela)*, are impacting important vertebrate forage species. The Bonanza Creek Long-Term Ecological Research program (BNZ LTER), co-funded by the National Science Foundation and the U.S. Forest Service, has implemented an experiment examining the interactions between moose browsing and leaf blotch miner on community dynamics and biogeochemical cycling in early-successional floodplain forests along the Tanana River.

The BNZ LTER recently established a regional network of long-term study sites focusing on how Alaska's changing fire regime in black spruce forests is altering successional pathways and transforming landscape structure and function (http://www.lter.uaf.edu/research/study-sites-regional). Three broad age classes represent time since the last fire; young stands (<15 yr), intermediate-age stands (40-60 yr), and mature stands (> 80 yr) stands. All stands were black spruce prior to being burned, but many of the young stands in particular, have lost permafrost and transitioned to hardwoods following the increase in high severity fires over the past 15 years. Variation among stands within age classes captures heterogeneity within and among burn scars in a number of interrelated factors, including landscape type and structure, burn severity, topography, site moisture, organic matter thickness, hardwood : conifer dominance, and herbivory. In addition to monitoring of climate, vegetation composition, biomass and production, and vertebrate herbivory, the BNZ LTER is collaborating with USDA FHP to monitor insects and plant pathogens on overstory tree species, which are all individually marked within study plots. In particular, the program will track the spread of these alder and aspen cankers and study the underlying mechanisms for the apparent outbreaks, as well as the implications for successional dynamics and ecosystem responses to a changing fire regime. A key objective of this collaboration is to work with boreal forest ecosystem modelers to integrate dynamics and consequences of insect and pathogen outbreaks into projections of regional vegetation and ecosystem carbon balance response to environmental change (Genet et al. 2016, Rupp et al. 2016).

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[*]RHIZOSPHERE PATHOGENS IN THE RIPARIAN FORESTS: ALDER *PYTHIUM* AND *PHYTOPHTHORA* SPECIES

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Thin-leaf alder, *Alnus tenuifolia,* has a broad distribution from the southern Rocky Mountains where it occurs between 2000-3000m altitude, to SouthCentral and interior of Alaska where it occurs from sea level and higher. In this report, we compare the species of oomycetous plant pathogens in *Pythium* and *Phytophthora* that we found residing in the rhizosphere beneath declining alder in 30 plots of Alaska and compare them to those in 30 plots of the southern Rocky Mountains. The importance of *Pythium* and *Phytophthora* species in the rhizosphere is characterized by the Jansen-Connell hypothesis which describes the pathogens as acting as host-specific, density-dependent, and distance-dependent pathogens driving higher tree diversity in the maturing forest following early succession.

The *Pythium* and *Phytophthora* species were identified by homology to barcode sequences of the mitochondrial cytochrome oxidase subunit I (COI) and the internal transcribe spacer region of the nuclear ribosomal repeat unit (ITS). The COI sequences were generated and aligned by two undergraduate research students Elayna Brown and James McDonald at University of Nebraska Lincoln. Other contributors to the research included Mursel Catal, Department of Plant Protection, Akdeniz Üniversity, Antalya, Turkey; Prissana Wiriyajitsomboon, Department of Microbiology, Kasetsart University, Bangkok, Thailand; James J. Worrall, Forest Health Management, USDA Forest Service, Gunnison, Colorado; and Lori M. Trummer formerly Forest Health Protection, USDA Forest Service, Anchorage, Alaska.

The diversity among the species of *Pythium* and among species of *Phytophthora* have led to representing them in well-supported clades in published literature. The diversity among *Pythium* species in DNA sequences is so great that precise identification of the unknown strain can only be determined following phylogenetic analysis delimiting the analyses to the appropriate clade. The result of this is that at least 12 phylogram trees are needed to resent the results of our identifications.

In summary, many strains in Clade B of *Pythium* from Alaska (but not from the Rocky Mountains) could not be assigned to a particular species but were homologous in sequence to a group of species including: *Py. dissotocum, Py. coloratum, Py. diclinum, Py. lutarium* and *Py. dictyosporium.* In a Rocky Mountain native plant nursery, but not elsewhere *Py. kashmirense* occurred frequently. Additionally, and undescribed species present in Alaska and the Rocky Mountains is within the population of the undescribed species of *Pythium* sp. AL-2010 P8204 reported in Robideau et al 2011 *Molecular Ecology Resources* 11(6): 1002-1011. In Clade F of *Pythium, Py. sylvaticum, Py. attrantheridium,* and an undescribed *Py.* sp. nearest NCBI isolate ZSF0069 were found in Alaska only. In Alaska and the Rocky Mountains, the species found included *Py. intermedium* and *Py. macrosporum* in the riparian ecosystems, and *Py. irregulare* and *Py. cylindrosporium* were recovered from Alaska, and the Rocky Mountain nursery. In Clade F *Pythium anandrum* was found only in Alaska, and *Py.undulatum* exhibited considerable genetic variation in Alaska and in the Rocky Mountains. A species in Clade I, *Py. heterothallica* exhibited considerable genetic

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variation and was recovered only in Alaska. In Clade K, *Phytopythium montanum* and an undescribed species homologous in ITS sequence at 99% but only at 96% in COI sequence to *Phytopythium citrinum, Py. sterilum* and *Py. litorale* was recovered. It was closest in homology to Genbank #EU000154 *Phytopythium* sp. isolate 93-70P. *Pythium* species in other Clades A, C, D, E, G, H, and J were not recovered in either region.

An inventory of *Phytophthora* species in the rhizosphere beneath declining alders was tallied in order to aid in determining whether any increase in severity or range expansion of tree mortality might be due to introduction of exotic pathogens such as *Ph. ramorum, Ph. kernoviae, Ph. alni, Ph. cinnamomi* or *Ph. lateralis*. These latter species were not recovered in our sampling although an undescribed species in Clade 8 which we tentatively call *Ph.* "not-ramorum" was isolated repeatedly only from Quartz Creek plot in the Kenai Peninsula, Alaska. *Phytophthora uniformis, Ph. cambivora*, *Ph. borealis, Ph. pseudosyringae, Ph. rosacearum, Ph. cactorum*, *Ph. gallica* were recovered only in Alaska and additionally recovered was a *Halophytophthora* sp. different than the one we reported from Alaska streams in Hansen et al 2011 *Mycologia* 103(1): 22–35. *Phytophthora syringae, Ph. siskiyouensis* and *Ph. infestans* were recovered only in the Rocky Mountains. It was a surprise to discover *Ph. infestans* in three distant locations but the mitochondrial haplotype was the same as that occurring in local potato plantings. In Alaska and the Rocky Mountains a number of species in Clade 6 which historically have been difficult to differentiate but recently have become better delimited were present including *Ph. gonapodyides*, *Ph. megasperma, Ph. riparia, Ph. lacustris*, *Ph.* taxon oaksoil, *Ph. mississippiae, Ph.* taxon hungarica, *Ph.* taxon forestsoil and one we refer to provisionally as *Ph.* taxon CAL-2011b BR333 due to its sequence homology with that reported by Robideau et al 2011 as unidentified CAL-2011b strain BR333.

In conclusion, the oomycetes reported as pathogenic specifically on *Alnus tenuifolia* recovered in this study include *Ph. siskiyouensis* in the southern Rocky Mountains only, *Ph. uniformis* in south central and interior Alaska only, *Ph. gallica* in Fairbanks (interior Alaska), *Ph.* "not-ramorum" in the Kenai (southcentral Alaska), and *Ph. lacustris* and *Ph. gonapodyides* in the Rocky Mountains and in southcentral and interior Alaska. These species are mostly capable of causing only localized disease symptoms particularly cankers. Presumably, the species that appear restricted in distribution in Alaska, *Ph. gallica* and *Ph.* "not-ramorum" are likely to expand their range within Alaska because both are likely recently introduced species.

Thin-leaf alder is facing changing climate, greater frequency of climate extremes, numerous fungal stem pathogens, an invasive leaf miner, sawfly and other arthropod herbivory, population changes in moose, and numerous established and presumably new root infecting oomycetes. Stand health in alder will likely reflect the presence of these stress agents.

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*CARBON STORES AND DYNAMICS IN SPRUCE-DOMINATED FORESTS OF KENAI PENINSULA, ALASKA FOLLOWING THE SPRUCE BARK BEETLE OUTBREAK OF THE 1990S

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Progressive rise in temperatures in northern latitudes could potentially increase the frequency and severity of disturbances in forest ecosystems, transferring large amounts of live biomass to coarse woody debris (CWD) pools that emit carbon (C) in form of carbon dioxide (CO_2). The type of CWD created by these disturbances may determine the rate and amount of C transfer as well as the length of time the disturbed landscape remains a C source. We studied the effect of a large-scale disturbance on CWD dynamics in spruce-dominated forests of Kenai Peninsula, Alaska by determining CWD decomposition rate-constants using the chronosequence and decomposition-vectors approaches and modeling CWD dynamics after a hypothetical bark beetle outbreak versus a windthrow. Decomposition rate-constants from the chronosequence ranged between -0.015 yr^{-1} and -0.022 yr^{-1} for logs and -0.003 yr^{-1} and +0.002 yr^{-1} for snags. Decomposition rate-constants for logs from the decomposition-vectors ranged between -0.045 yr^{-1} and +0.003 yr^{-1} among decomposition phases and -0.048 yr^{-1} and +0.006 yr^{-1} among decay classes. The modeling exercise showed that relative to log generating disturbances those creating snags delayed C flux from CWD to the atmosphere, produced a smaller magnitude C flux, and have a potential to store 10% to 66% more C in the system over time.

Post-disturbance forest management strategies provide avenues for mitigating global climate change through curbing carbon dioxide emissions and storing C in forests or forest products. Using model simulations, we evaluated the effect of several management strategies on C stores and emissions following a spruce bark beetle outbreak on Kenai Peninsula, Alaska for three possible tree regeneration scenarios including no-, immediate, and delayed regeneration. System C storing potential was assessed under delayed regeneration for management ranging from “leave-as-is” to “salvage-and-utilization”. Immediate tree regeneration led to the recovery of disturbed areas to steady-state pre-disturbance C stores of 49.27 Mg C ha-1 25 years earlier than regeneration delayed by 25 years. Lack of regeneration, representing a permanent loss of tree cover on disturbed portion of the landscape, caused a permanent decrease in wood C stores to a lower steady-state level of 31.51 Mg C ha-1. The “leave-as-is” management stored more C in the short-run, whereas “salvage-and-utilization” management stored more C in the long-run. Among the “salvage-and-utilization” scenarios, biomass fuels with fossil fuel substitution provided larger C storage assuming the substitution is permanent. Because a reduction in near-term emissions may be a more robust strategy than

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reducing long-term emissions, the “leave-as-is” scenarios may offer more immediate contribution to mitigation of global climate change.

PANEL: SPECIAL PAPERS

MODERATOR:
HARRY KOPE

*UNDERSTANDING WESTERN REDCEDAR BUTT ROT

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INTRODUCTION

Western redcedar is one of the most valuable conifers in North America. Most of the cedar in North American grows in BC with smaller amounts in Washington, Oregon, Idaho and Alaska. Cedar produces high value products, but its initial slow growth requires value enhancing strategies that are low cost or realized in shorter time periods. It also appears to withstand a number of serious root disease organisms without mortality or growth impact. Its value is derived mainly through its superior in service decay resistance, natural attractiveness, and low worldwide availability.

Paradoxically, in contrast to cedar's high in service decay resistance, cedar is the conifer with the highest volume of internal butt decay in nature. Estimates of butt decay in mature cedar in BC average 30%, mainly in the lower bole, cedar's most serious downgrade. In 2001, it was estimated to have caused a loss of close to one billion dollars ($CAD) of value from cedar. A suite of fungi have been identified as causing butt decay in work done over 50 years ago, but nothing is known about the timing and sequence of the infection. Little is known about where the primary inoculum resides, how it gets into the tree, how it spreads between trees, and what cultural, stand or climatic conditions are conducive to the disease. Little is also known about the heartwood extractives and how effective they are at decay resistance and if resistance also occurs at the cambium. Nothing is known about butt decay incidence and volume in second growth cedar.

A stump removal trial was established in 1968 to control Phellinus and Armillaria root diseases near Skimikin BC. This site was sampled to determine the incidence of decay in planted cedar in mixture and monoculture.

METHODS

The Skimikin experimental site is a 2.56 ha rectangular block that was conventionally harvested, and then stumps were removed in one half of the block. The trial is currently 50 years old. Sixty-four 20x20 m square plots were established and species monocultures and mixtures were randomly assigned to the plots. Western redcedar was paired with Douglas-fir, lodgepole pine, paper birch and in monoculture with 3 replicates on each side of the stump treatment. Trees were planted at 1.5 m spacing and mixtures were planted in alternate rows in 1967. Cedar and birch were hand transplanted from wild seedlings near the site since seed was not available at that time. The trees were monitored every 5 years and cause of death was noted. Known root disease organisms on site are *Armillaria ostoyae* and *Phellinus sulphurascens*.

We used a Resistograph tool to drill one hole at the base of every 5th cedar tree in each plot for cedar monoculture and cedar-birch plots (220 total). The machine measures a surrogate of wood density and can easily detect pockets of rot. The data were analysed for incidence of decay using a logistic mixed model

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with stump treatment and species as fixed effects and plot as a random effect. Some wood chips were taken out of lesions using a 6 mm drill bit and the organisms were identified using DNA analysis.

RESULTS

Survival of cedar in monoculture and mixture was poor during the first 5 years after planting where most plots had only 50-60% of the trees remaining. Following this, survival was good with only a few trees dying to Armillaria root disease and more recently to drought. Volume of cedar after 45 years in each stump treatment and species mix was about the same for monocultures and for cedar-birch (about 250 m^3/ha in monoculture) but volumes were greater in unstumped plots of cedar with pine and Douglas-fir. Site index for stumped plots (average 22.5 m) was between 1-4 m taller than in the unstumped plots.

The incidence of decay was the same between the cedar and cedar in birch at about 8%, but was 5.3 times higher ($p=0.02$) in the unstumped plots at 18% of trees. Three fungi were identified from the decayed cedar wood, *Seimatosporium lichenicola*, *Epicoccum nigrum*, and *Fomitopsis pinicola*. Lesions caused by *Armillaria ostoyae* were common at the base of cedar trees in the unstumped plots. *A. ostoyae* had spread from some of these lesions and were colonizing the living redcedar stem. One *A. ostoyae* lesion at the base of one cedar tree in an area adjacent to the study plot was sawn through with a chainsaw and examined. Decay was occurring behind the lesion.

DISCUSSION AND CONCLUSIONS

It is not clear what role stumps play in cedar butt decay. Lesions formed by *A. ostoyae* are very common on the interior of BC and are quite frequent on coastal areas although not as extensive. *A. ostoyae* is not high on the list of organisms causing cedar butt rot. Stumps may be acting as a reservoir of the butt rot decay fungi or they may be acting as a food base for *A. ostoyae* which in turn creates infection courts for the other decay fungi, or both. In support of *A. ostoyae* creating infection courts for other fungi is that this fungus causes more damage in the interior areas of southern BC also where cedar butt rot also is more extensive. Until further sampling is done this cannot be resolved. If stumps are acting as a food base for butt rot decay fungi it is not clear how the fungi are getting into the stump.

Survival of cedar after initial planting mortality was very good up to 45 year of age. Mortality increased slightly after age 35 in some of the mixtures notably with Douglas-fir where cedar is smaller in diameter than any of the other mixtures and maybe under more competition. Drought mortality appears to have increased slightly since age 45 in cedar. Spreading lesions in cedar from old basal scars caused by *A. ostoyae* had never been observed before, but there had been a drought the previous year and very dry conditions the year of sampling. The site is productive but maybe becoming on the dry side for cedar.

The volume of cedar in monoculture was similar between stump treatments indicating that it is probably tolerant to both root diseases on site. Cedar volume was greater in the unstumped plots with cedar paired with Douglas-fir or pine because the two known root diseases were killing the fir and pine in those plots which allowed the cedar less competition. If dryer and warmer years occur more frequently, mortality of cedar to Armillaria root disease may become more common and the unstumped plots may have lower survival and volumes. This is unfortunate since its designation as disease tolerant to Armillaria and Phellinus root diseases make it an attractive choice to be planted or favoured where the diseases are killing other conifers.

*WEB BLIGHT AND PHYTOPHTHORA NEEDLE CAST IN THE PNW: MORE SURPRISES FROM OREGON

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In the late winter and early spring of 2015 an unusual needle cast syndrome was observed in Douglas-fir at scattered locations in the central Oregon Coast Range. The disease developed rapidly and reached alarming intensity on some trees. Affected trees were most visible on the edges of stands, where they exhibited one-sided defoliation, often tapering upwards from the bottom of the live crown. Especially on lower branches, all needles might be cast, although buds were not usually killed. On some trees dead needles were persistent, attached by a webbing of hyphae. In some locations the cast needles accumulated dramatically, and often included an unusual proportion of green needles. Isolations yielded two pathogens: the recently described *Phytophthora pluvialis* and an undescribed basidiomycete, *Rhizoctonia* species. *P. pluvialis* has been recovered from rain traps beneath tanoak, Douglas-fir (*Pseudotsuga menziesii*) plantations, and mixed Douglas-fir western hemlock (*Tsuga heterophylla*) in Oregon and Washington: from Douglas-fir needles on trees exhibiting needle cast; from forest streams; and canopy drip in western Oregon and Washington. A foliar web blight of Douglas-fir and true fir caused by a bi-nucleate *Rhizoctonia*-species has been observed in some Christmas tree plantations in Oregon since 1996. The disease can kill patches of foliage rendering trees unmarketable. DNA sequence analysis places the web-blight fungus in the genus *Rhizoctonia*. This pathogen has also been isolated from symptomatic western hemlock, Sitka spruce (*Picea sitchensis*), and mountain hemlock (*Tsuga mertensiana*) in Pacific Northwest forests.

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MOUNT

*WESTERN WHITE PINE RESISTANCE IN WESTERN WASHINGTON: OPERATIONAL PLANTING AND THE LATEST IN RESISTANT STOCK TYPES

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INTRODUCTION

Western white pine (*Pinus monticola* Dougl., WWP) is a native conifer species in western North America. The species is susceptible to the introduced fungal pathogen *Cronartium ribicola* J.C. Fisch., the causative agent of white pine blister rust (WPBR). The impacts of WPBR have reduced the incidence of WWP in natural ecosystems as well as led to a reluctance in using the species in both restoration and reforestation. Research and operational programs to develop genetic resistance to WPBR have been ongoing for more than five decades, with regional programs based in Oregon (OR), Idaho (ID), British Columbia (BC) and California. Progeny of thousands of parent trees have been screened for rust resistance in short-term artificial inoculation trials and several types of resistance have been uncovered. Seed orchards have been established using the products of the earlier resistance work and breeding to increase the level of genetic resistance continues.

In western Washington (WA) Douglas-fir forests, laminated root rot is caused by the fungus *Phellinus sulphurascens* Pilát and is one of the primary disturbance agents. The disease can cause decreased tree growth and mortality in its host, with impacts occurring across multiple stand ages and harvest rotations. While there are multiple management strategies than can be implemented based on the severity and distribution of root disease, mitigation is often carried out during the reforestation stage by planting affected areas with less susceptible species. On Washington Department of Natural Resources (WA DNR) managed lands, the alternate species are often the immune red alder, the resistant western redcedar, and occasionally western hemlock, grand fir and western white pine intermixed with the highly susceptible Douglas-fir.

This study examines the current WPBR incidence and impacts in operational plantings of WWP and compares the results to the most recent data from a series of WWP field trials examining a diverse set of WPBR resistant families and orchard families.

METHODS

Thirty-five WA DNR sites with operationally planted WWP that is now 9-14 years old were assessed for WPBR incidence and severity across western WA. Outplantings originated from seed from the Inland Empire Tree Improvement Coop, Moscow, ID seed orchard. Aspect, elevation and plant associations were recorded for each site. The first 100 trees accessed were examined for WPBR cankers and overall tree health. Only the most severe canker class was recorded for each tree. Canker classes included: dead from WPBR, no infections, on the bole, within 6 in (7.5 cm) of the bole, 6 to 24 in (7.5-60 cm) from the bole,

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and greater than 24 in (60 cm) from the bole. For analysis of operationally planted sites, mortality causing infections were defined as either infections directly on the bole or within six in of the bole.

Six, three-acre sites were established in 2006 across western Washington. A total of thirty-six seedlots were planted across the sites, with 1269-1365 individual seedlings planted at each site. The study design consisted of seven blocks, or reps, per site and three to seven seedlings per seedlot per block. The seedlots originated from many areas across the region, including the Gifford Pinchot National Forest (NF), Mt. Baker/Snoqualmie NF, Olympic NF, Wenatchee NF and Colville NF in Washington; Mt Hood NF, Umpqua NF, Confederated Tribes of Warm Springs in Oregon; British Columbia; and the Bingham seed orchard in Idaho.

White pine blister rust incidence and severity assessments were made in 2010, 2011, 2013 and 2015. During the assessments tree damage, tree vigor, rust severity, including the number of white pine blister rust cankers, were measured. During the 2013 and 2015 assessments, tree height and reproductive status were recorded. For analysis of WPBR resistance trial sites, mortality causing infections were defined only as infections on the bole since distances from the bole to the canker were not measured in the assessments on these sites.

Incidence and severity of WPBR were summarized and operationally planted WWP and individual families from the WPBR resistance trials were compared.

RESULTS AND DISCUSSION

Significant variability occurred in WPBR infection levels across all sites. The average percent of uninfected trees on the operationally planted sites ranged from 5 to 100, with a mean of 59% among all sites. Average white pine blister rust caused mortality ranged from 0 to 61%, with a mean of 7% among all sites. An average of 34% of the trees across all sites had cankers that caused mortality or were likely to cause mortality, defined as infections on or within 6 in (7.5 cm) of the bole.

Among the 36 seedlots examined in the resistance field trials, infection levels and mortality caused by rust ranged from 0-100%, depending on seedlot and site (Figure 1). Six seedlots had an average of 34% or greater of mortality causing cankers, including those that were on the bole and had not yet caused mortality. Three seed orchard seedlots were included in the trials and had an average of 26, 34, and 36% of mortality and likely to cause mortality cankers, defined in this trial series as infections on the bole. The seed orchard seedlots blister rust infection levels were similar to those observed in the operational planting assessments. Five seedlots had an average of 10-20% mortality causing and likely to cause mortality cankers and four seedlots had an average of less than 10% cankers. Included in these is a highly resistant seedlot with 0% infection on two of the six sites.

It should be noted that 27 out of 36 seedlots in the WPBR resistance trials have an average of less than 30% mortality and likely to cause mortality cankers, less than the 34% average found in the operationally WWP planted assessments. This data suggests that there are seedlots available with greater WPBR resistance levels than are currently being operationally planted. A more detailed analysis is required to suggest specific high performing WWP that, in regards to growth and WPBR resistance, may be good candidates for incorporating into existing and new WWP seed orchards. These trials will continue to be assessed to evaluate the resistance over time, but early indications show the potential of planting resistant WWP in many sites in Washington.

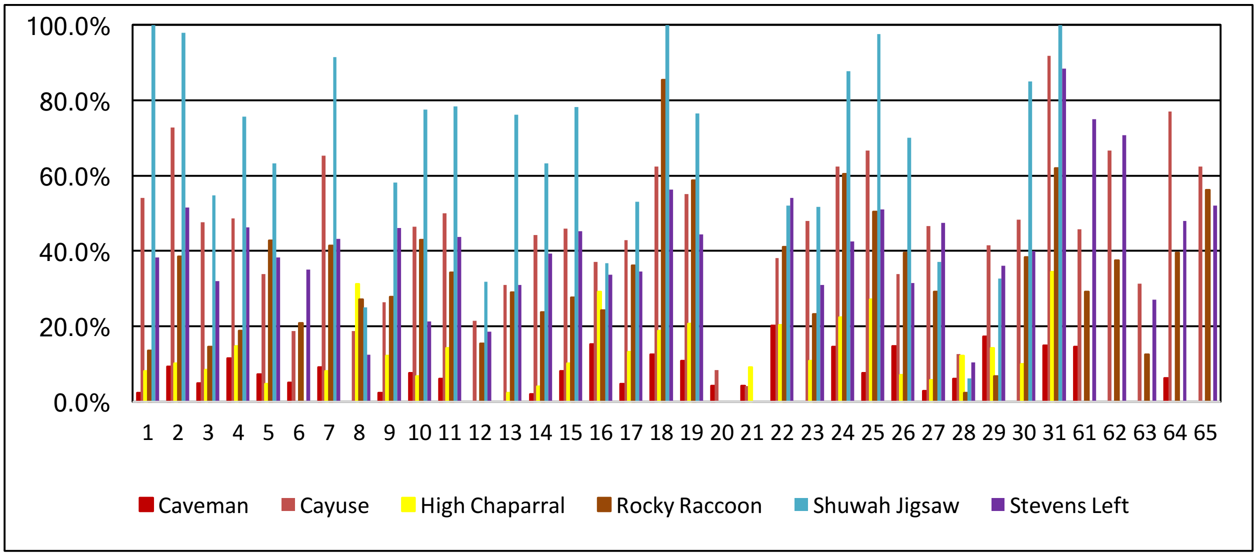

Figure 1. Average Percent of WPBR Infections (bole and branch) by Site and by Family.

ACKNOWLEDGMENTS

Funding for this project was provided by the US Forest Service and the WA DNR. Many people donated time to this study as well, including Glenn Kohler, Karen Ripley, Holly Kearns, Kristen Chadwick, Brian Morris, Brian Williams, Peter Hurd, John Keller, a host of WA DNR forestry staff, Angelia Kegley, Sally Long, Bob Danchock, and a host of Dorena Genetic Resource Center technicians for their support with the WPBR resistance WWP seedlot trials. This work would not be possible without the field and technical support all of our cooperators.

[*] THE EFFECTS OF SEED SOURCE AND PLANTING ENVIRONMENT ON DOUGLAS-FIR FOLIAGE DISEASES

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INTRODUCTION

The foliar pathogens *Phaeocryptopus gaeumannii,* the causal agent of Swiss Needle Cast (SNC), and *Rhabdocline* species*,* the causal agents of Rhabdocline Needle Cast, are two important pathogens specific to Douglas-fir (*Pseudotsuga menziesii).* These pathogens have been shown to disproportionately affect genetically maladapted seed sources, causing serious reductions in productivity. Understanding the variation in susceptibility to Swiss needle cast (SNC) and *Rhabdocline* Spp. (Rhabdocline) is a critical component to successful plantation management. This study is the first to thoroughly investigate the variation in tolerance/resistance of Westside Douglas-fir to Rhabdocline, and, through the inclusion of populations and test sites which span much of the range of conditions experienced by Westside Douglas-fir, expands on the currently limited knowledge of the variation in resistance/tolerance to SNC.

In this experiment, we examined every tree in the Douglas-fir Seed-Source Movement Trial (SSMT), a large scale common garden, reciprocal transplant study established by PNW Research Station in collaboration with private landowners. We examined the relationship between levels of resistance and/or tolerance to SNC and Rhabdocline, the climate of the seed source and the climate of the planting environment.

Our objectives were to:

1.) Assess the variation in resistance and/or tolerance to SNC and Rhabdocline as indicated by infection level and disease symptom expression.

2.) Utilize climate transfer distances between the seed source and test site to model this relationship and obtain estimated probabilities related to these transfer distances.

METHODS

The SSMT consists of nine planting sites, with 120 open pollinated Douglas-fir seed sources (families) representing 12 different geographic regions ranging from Northern California to Southern Washington, from high elevation to the coast. These seed sources were planted at nine different test sites located on three bands of latitude, one in southern Oregon, one in northern Oregon and one in southern Washington. All test trees present in the SSMT were assessed for disease severity and disease symptoms associated with SNC and Rhabdocline (8,960 trees in total). Infection severity ratings were estimated based on the presence

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of fruiting bodies of each fungal pathogen. *P. gaeumannii* severity was rated on both the north and south side of each tree on a secondary lateral branch on the fourth whorl from the top of the tree. Ratings were binary, 0 corresponding 0-33% of the stomata occluded, 2 corresponding to 33% or greater of the stomata occluded. Ratings for Rhabdocline were based on the same percentages as *P. gaeumannii*.

Crown density was used to assess symptoms of SNC and was rated with 0 corresponding to a sickly sparse crown lacking in needle retention, and a 2 corresponding to a full healthy crown. Although crown color and needle retention are also used to assess symptoms of disease, these attributes proved to be difficult to assess in 8 year-old trees and field assessment often was inconsistent. Using generalized linear mixed models and the probit link function, probabilities of moderate to severe disease symptoms and infection were calculated using differences between population source and test sites with respect to the climate variables May through September precipitation (MSP), continentality, and mean winter temperature (MWT). Models with the lowest AIC score were selected.

Photo 1. Assessing second year needles for *P. gaeumanni* psecdothecia density ratings.

RESULTS AND DISCUSSION

We hypothesized that:

1. There are differences in the levels of resistance/tolerance among populations planted at these test sites.

No patterns were observed in the infection levels of *P. gaeumannii*. However, there was variation in disease symptom expression (crown density) indicating a tolerance rather than resistance to *P. gaeumannii*. Most importantly, transfers of populations from low to high MSP, and/or cool to warm MWT increased the probabilities of moderate to severe Rhabdocline spp. infection and SNC disease symptoms. Transferring populations 337 mm in MSP (low to high) and/or greater than 7 C° in MWT (cool to warm) resulted in greater than 25% probabilities of SNC disease symptoms. Transfers greater than 251 mm or greater in MSP (low to high) and/or 9° C or greater in MWT (cool to warm) resulted in greater than 25% probabilities of moderate to severe Rhabdocline spp. infection.

2. These differences are a function of a difference in climate between the population source climate and the climate of the test site.

Populations of source climates conducive to foliar pathogens proved to be the most resistant/tolerant to Rhabdocline and SNC. Coastal seed sources exhibited the lowest probabilities of moderate to severe disease symptoms and Rhabdocline infection, while high elevation populations and inland populations from southern Oregon and Northern California exhibited the highest probabilities.

3. Populations from source climates most similar to that of the test site are the least susceptible to Rhabdocline and SNC.

Local seed sources consistently exhibited among the lowest probabilities of displaying disease symptoms indicating that local seed sources are currently well adapted to the disease pressure of their source climate.

4. Assisted migration of southern Douglas-fir provenances to the north will result in maladapted plantations.

Results from the current study indicate that populations from arid climates, those with high drought tolerance, are the most susceptible to SNC and Rhabdocline needle cast. These results urge caution in the transfer of drought tolerant populations of cool winters and dry summers to locations predicted to but not currently experiencing drought conditions, resulting in the transfer from low to high precipitation and/or low to high mean winter temperatures.

High elevation populations were also shown to be highly susceptible to Rhabdocline infection and disease symptoms associated with both Rhabdocline needle cast and SNC. Warmer winter temperatures at high elevations may lead to increased losses due to Rhabdocline and SNC in high elevation Douglas-fir stands. Transfer of less susceptible low elevation populations to these areas may offset losses due to increased pathogen presence in high elevation stands. However, other adaptive traits such as cold hardiness should be taken into account when making seed transfer decisions.

It is recommended that the climate transfer distances in this study, most importantly mean winter temperature and May through September precipitation, be taken into account when making reforestation and adaptive management decisions regarding seed transfer. Predictions of disease occurrence from this study indicate danger in moving Douglas-fir populations to regions that are significantly wetter or regions characterized by significantly warmer winter temperatures in anticipation of climate change.

Photo 2. Washington coast seed source with little to no Rhabdocline spp. infection (left) planted beside highly susceptible California Sierra seed source (right). Trees are the same age and were planted in the same year.

CONTRIBUTED POSTERS

*SOOTY-BARK CANKER (*ENCOELIA PRUINOSA*) DISEASE PROGRESSION

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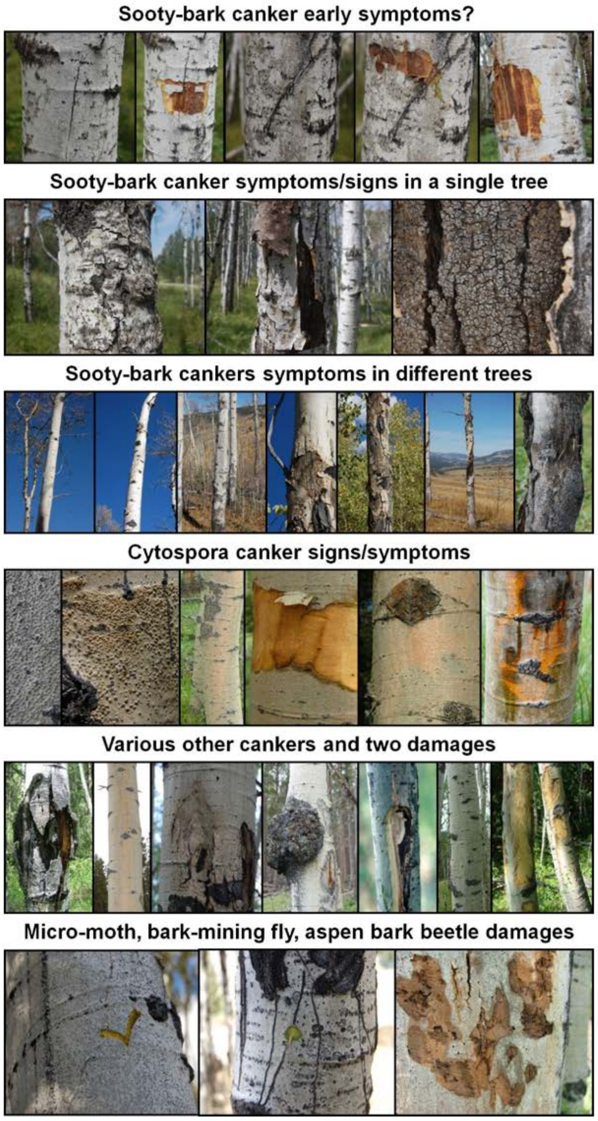
INTRODUCTION

Sooty-bark canker (*Encoelia pruinosa*) was reported to be the second most common damage agent in aspen (*Populus tremuloides*) in the Bighorn, Black Hills, and Shoshone National Forests (Blodgett *et al*. 2015). The report was based, in part, on canker disease symptoms that apparently have never been previously classified as a disease (Figure 1). Symptoms do not resemble any other known canker disease, or any common physical or insect damage in aspen (Figure 1). Trees with the common previously unclassified damage agent develop characteristic sooty-bark canker symptoms within 3 years.

Early sooty-bark canker symptoms are not well documented. Symptoms common in these National Forests are likely common in other forests. The study objectives are to: 1) document early sooty-bark canker symptoms, 2) determine canker expansion rates, and 3) discover how long it takes sooty-bark canker to kill aspen.


Sooty-bark canker early symptoms?

Sooty-bark canker symptoms/signs in a single tree

Sooty-bark cankers symptoms in different trees

Cytospora canker signs/symptoms

Various other cankers and two damages

Micro-moth, bark-mining fly, aspen bark beetle damages

Figure 1. Previously unclassified symptoms; typical sooty-bark canker symptoms and signs; Cytospora canker signs and symptoms; other common canker symptoms and physical damages; and common bark insect damages in aspen.

METHODS

Encoelia pruinosa apothecia (24 samples) and aspen bark (50 samples) were collected from three stands in each of the three forests in 2015. Small pieces of apothecia or phloem tissues from newly exposed diseased bark were transferred to water agar containing streptomycin sulfate (Figure 2).

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Figure 2. *Encoelia pruinosa* apothecia and bark samples were collected from aspen. Small pieces of apothecia or phloem tissues from newly exposed diseased bark were transferred to water agar. Dark brown colonies formed with light-gray aerial hyphae.

RESULTS

Isolations were successful (Table 1). Isolations from *E. pruinosa* apothecia produced dark brown colonies with light-gray aerial hyphae. The same colony form was common from bark isolations. The high percentage of "no growth" from bark isolations is likely due to excessively hot tools (scalpels/tweezers) used during phloem tissue transfers. If only isolations that generated a colony are used, bark isolations were positive 90% and negative 10% of the time. All negative colonies from bark were a *Cytospora* sp. Cytospora canker was the most common damage agent observed in the three Forests (Blodgett *et al*. 2015).

Table 1. Isolation results.

Isolation source: colony form	**Positive (%)**	**Negative (%)**	**No growth (%)**	**Number of attempts**
Encoelia pruinosa apothecia: dark brown	96	0	4	24
Bark: matching colony form of apothecia isolates	37	4	59	50

FUTURE PLANS

On June 6, 2016, trees were inoculated in the Black Hills National Forest and disease progression will be assessed for three growing seasons. Only isolates collected from the Black Hills were used. Trees were inoculated with an isolate form an *E. pruinosa* apothecia, a matching dark brown isolate from bark, and a *Cytospora* sp. isolate; water agar plugs were used for wounded controls. The study was replicated in two stands with eight inoculation treatment replications in each stand (64 total trees). Measurements will include canker expansion rates; and a photo-log will chronical disease progression. At the end of the study reisolations will be attempted, fulfilling Koch's postulates.

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*STUMPING OUT CLIMATE CHANGE: ECONOMIC FEASIBILITY OF STUMPING TO CONTROL ROOT DISEASES IN BRITISH COLUMBIA'S INTERIOR CEDAR-HEMLOCK FORESTS

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Stand stimulations were created using TASS growth and yield model and impact factors known for low, medium, and high Armillaria root disease volume impact for stands based on 1600 stems/ha and site index (SI) range from 15 to 35 m (age 50). Ranges for low to high costs and prices were stump removal cost 700-1000 \$/ha, planting costs 650-950 \$/m^3, timber prices 20-40 \$/m^3, carbon 5-25 \$/tCO^2, and interest rates 3-6%.

With low carbon values and average economic conditions, sites with productivity as low as SI 20 supports stumping on low disease impact sites (Figure 1). Under favourable economic conditions (high prices and low costs and low interest rates), then stumping is feasible on sites as low as SI 15 with low disease impact (not shown).

Stump removal to treat root disease and establish Douglas-fir on highly *productive* sites in the BC interior cedar-hemlock forests is economically feasible for certain economic and ecological conditions. Inclusion of live and dead biomass estimates for carbon stocks and carbon stock change and considering carbon prices improved the expected economic returns and extended the feasibility to a broader set of forest sites and economic conditions. Stumping holds promise to significantly increase standing timber inventories and carbon stocks and reduce risk of disease over a large area of interior British Columbia (and beyond).

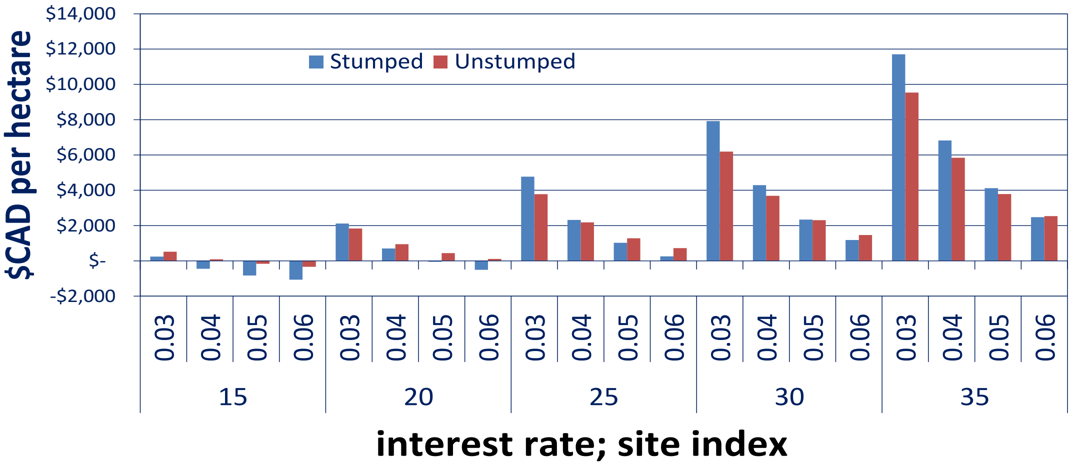

Figure 1. Results for low carbon price (\$15) and medium timber prices (\$30) and medium costs and low disease impact.

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[*]ENVIRONMENTAL EFFECTS ON ENDOPHYTE COMMUNITIES IN FOUR DOUGLAS-FIR PROGENY SITES: PRELIMINARY RESULTS

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INTRODUCTION

Douglas-fir provides countless social, economic, and ecological benefits in the Pacific Northwest (Spies et al. 1991). Minor defoliation has been previously linked to Swiss Needle Cast, associated with *Phaeocryptopus gaeumannii*. However, unprecedented defoliation has increased since the 1990s (Shaw et al 2011). Affected areas exceed 500,000 acres in Oregon (OFRI 2015). Recent symptoms are inconsistent with predicted effects of *P. gaeumannii* (Weiskittel et al 2006).

- The entire endophytic community is hypothesized to be relevant to disease ecology, although this has not been investigated to date.
- Probability of endophyte occurrence is hypothesized to be higher in cooler and wetter climates.
- Traditional culturing is hypothesized to be less effective than Next-Generation Sequencing.

More inclusive identification could lead to greater efficiency in forest management. It is vital to understand the complete etiology and ecological implications of disease in this important tree species.

OBJECTIVES

1. Quantify baseline inventories of fungal endophytes for Douglas-fir for each of four geographical locations, along gradients of site elevation, temperature, and mean annual precipitation, for Douglas-fir trees showing current symptoms of needle cast and for asymptomatic control trees.
2. Compare fungal communities found within local seed sources to those found within non-local seed sources.
3. Characterize fungal communities in association with *Phaeocryptopus gaeumannii* that may be additionally implicated in Douglas-fir needle-cast.
4. Determine if there are differences in identified fungal communities between methods, (1) traditional culturing or (2) high-throughput.

METHODS

Four study sites along a north/south gradient representing a matrix of warm/cold and wet/dry were chosen. The sites were planted with Douglas-fir as part of a Forest Service progeny study (Gould et al 2012). Sites range from low (240 m) to high (860 m) elevation, and low (616 mm/year) to high (2214 mm/year) mean annual precipitation.

Endophyte species will be determined via traditional plate culturing (Carroll & Carroll 1978) as well as high-throughput sequencing. The treatment structure consists of a study group (needles from non-local seed

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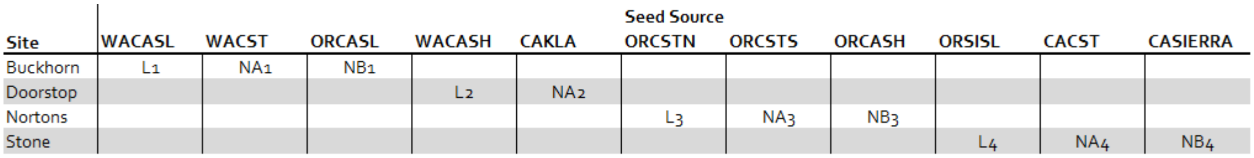
sources) and a control group (needles from local seed sources) from each progeny site. Local seed sources were chosen as the control due to the pervasive appearance of foliar disease at some sites. Coupled with the ambiguous definition of what symptomatic means with regard to Douglas-fir foliar disease, provenance was deemed a more appropriate indicator. The results will be described as a proportion of total endophytes by species. Statistical analysis will be conducted using ANOVA and linear regression.

EXPERIMENTAL DESIGN

Using a nested design, we were able to look at each of the seed sources from the original study, with 3 replications within sites (Table 1). This design was chosen due to limitations on both time and budget (Figure 1). The nested design allows for the most efficient use of resources, and will produce more powerful results. Additionally, the data from this project will be used to create a broader PhD study.

Table 1. Nested design of sample collection. L denotes local seed source, NA and NB non-local sources.



	Seed Source										
Site	WACASL	WACST	ORCASL	WACASH	CAKLA	ORCSTN	ORCSTS	ORCASH	ORSISL	CACST	CASIERRA
Buckhorn	L1	NA1	NB1								
Doorstop				L2	NA2						
Nortons						L3	NA3	NB3			
Stone									L4	NA4	NB4

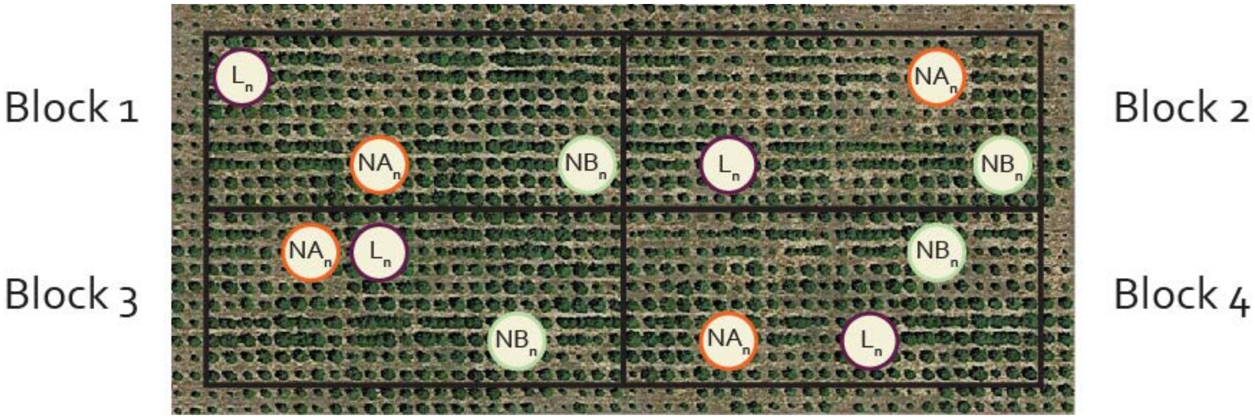


Figure 1. Example layout of sample collection. From each block at each site, one local seed source and two non-local sources were collected and examined.

PRELIMINARY RESULTS

Preliminary results suggest that the probability of occurrence at Buckhorn, a cool wet site was 2.6 times higher than Nortons, a warm, wet site ($p = 0.0001$). Probability of occurrence at Buckhorn was 2.4 times higher than Stone, a warm dry site ($p = 0.0001$). Probability of occurrence at Buckhorn was 1.7 times higher than Doorstop, a cool dry site, but these results were not significant ($p = 0.6$) (Figure 2).

Comparing endophyte occurrence of local to non-local seed sources, Nortons has the highest ratio, possibly influenced by the warm and wet conditions there. Local sources were more infected at Nortons by almost a 3 to 1 ratio (p = 0.04). The non-local sources were more infected at Stone, at a ratio of just over 14 to 1 (p = 0.0001) (Figure 3).

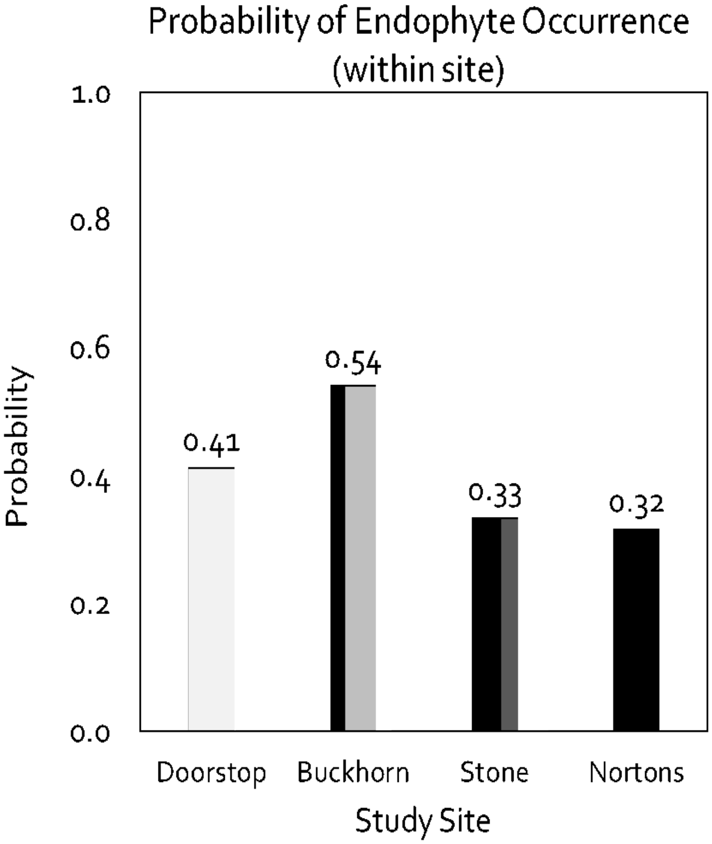


Figure 2. Probability of endophyte occurrence. Calculated within individual sites.

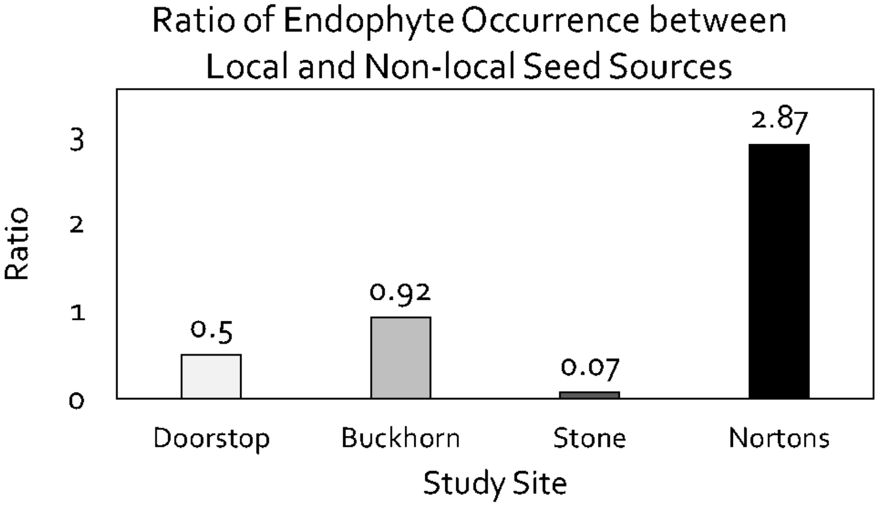
NEXT STEPS

Traditional plate culturing has recently been completed. DNA isolation is currently underway. Next-Gen Sequencing (high-throughput) and Sanger sequencing will proceed once DNA isolation and amplification is complete. Statistical analysis will be ongoing throughout the study.

Because many endophytes, both pathogenic and nonpathogenic, may not respond to traditional plate culturing (Carroll & Carroll 1978), differences between techniques may reveal greater speed and efficiency.

Future research on this subject will include more study sites (in collaboration with the Swiss Needle Cast Cooperative), including an east/west transect over the Cascade Mountains. An investigation into seed source and endophyte populations, and additional study of the biological interactions between pathogenic and non-pathogenic endophytes is also planned.

Figure 3. Ratio of endophyte occurrence between local and non-local seed sources at each site. Calculated within individual sites.



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*STATUS OF RESISTANCE SCREENING PROGRAM FOR FUSARIUM WILT IN *ACACIA KOA*

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ABSTRACT

Koa (*Acacia koa*) is a valuable tree species economically, ecologically, and culturally in Hawaii. A vascular wilt disease of koa, due to infection by the fungal pathogen *Fusarium oxysporum* f. sp. *koae* (FOXY), causes high rates of mortality in field plantings and threatens native koa forests in Hawaii. Landowners are reluctant to consider koa for reforestation and restoration in many areas due to the threat of FOXY. Producing seeds or propagules with genetic resistance to FOXY is vital to successful koa reforestation and restoration. *Fusarium sp*. isolates were collected and were morphologically and genetically identified as FOXY. Virulent FOXY isolates were used in seedling inoculation trials to evaluate resistance levels among koa families in greenhouse experiments. In addition, forty-one new FOXY isolates have been collected to be screened for pathogenicity for use in future seedling inoculation trials. Seedling survival in our most recent trials varied by family, ranging from 4% to 100%, with an overall average of 47%. The greenhouse screening method serves as a powerful tool to rapidly evaluate koa families prior to out-planting. However, the field trial data is needed to further validate the results and to monitor the durability of resistance over time. Three seedling field trials are planned to be established in 2016. These field trials are on-going and further are planned in priority eco-regions across Hawaii.

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*TOWARD A WEST-WIDE MODEL OF ARMILLARIA ROOT DISEASE: NEW SURVEYS NEEDED IN WESTERN OREGON, WESTERN WASHINGTON, AND ALASKA

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INTRODUCTION

Currently, Armillaria root disease causes large growth/volume losses (e.g., 16-55%) in areas of western North America (Filip and Goheen 1984; Cruickshank 2011; Lockman and Kearns 2016). Armillaria root disease is typically more severe in trees that are maladapted to climate-induced stress (Ayres and Lombardero 2000; Kliejunas et al. 2009; Sturrock 2011). Thus, it is likely that climate change will further exacerbate damage from Armillaria root disease, which can further predispose trees to beetle attack (e.g., Hertert et al. 1975; Tkacz and Schmitz 1986; Goheen and Hansen 1993).

Previously, DNA-based identification methods were used to identify *Armillaria solidipes* and other *Armillaria* species from surveys of the inland northwestern U.S.A., eastern Cascades of Oregon, Arizona, and Rocky Mountain zones (e.g., Blodgett et al. 2015; Burns et al. 2016; Hanna et al. 2007, 2009, 2012, 2014, 2016; Hoffman et al. 2014; Kim et al. 2010; Klopfenstein et al. 2012; McDonald et al. 2011; Nelson et al. 2013). Based on the precise locations of *A. solidipes*, bioclimatic modeling was used to predict the suitable climate space (the geographic area that is climatically suitable for a particular species' survival) or potential distribution of *A. solidipes* under contemporary and changing climates in the interior western U.S.A. (Figure 1). Although Armillaria root disease is commonly found in western Oregon, western Washington, and Alaska, DNA-based identification has been commonly applied to verify *Armillaria* species found in these regions.

Recently, a collaborative project was initiated to precisely identify *Armillaria* species found western Oregon, western Washington, and Alaska. This project will provide new and expanded predictions for potential distribution of *A. solidipes* across northwestern U.S.A. including Alaska, and expand predictions of the potential distribution of *A. solidipes* in the western North America under present and future climate scenarios (Figure 1). Currently, limited studies have identified *Armillaria* in western Washington and western Oregon (e.g., Banik et al. 1996; Volk et al. 1996). Furthermore, only limited information is available on *Armillaria* spp. in Alaska (e.g., Klopfenstein et al. 2009b; Shaw and Loopstra 1988), yet the state is experiencing very strong climate-change influences that could exacerbate Armillaria root disease.

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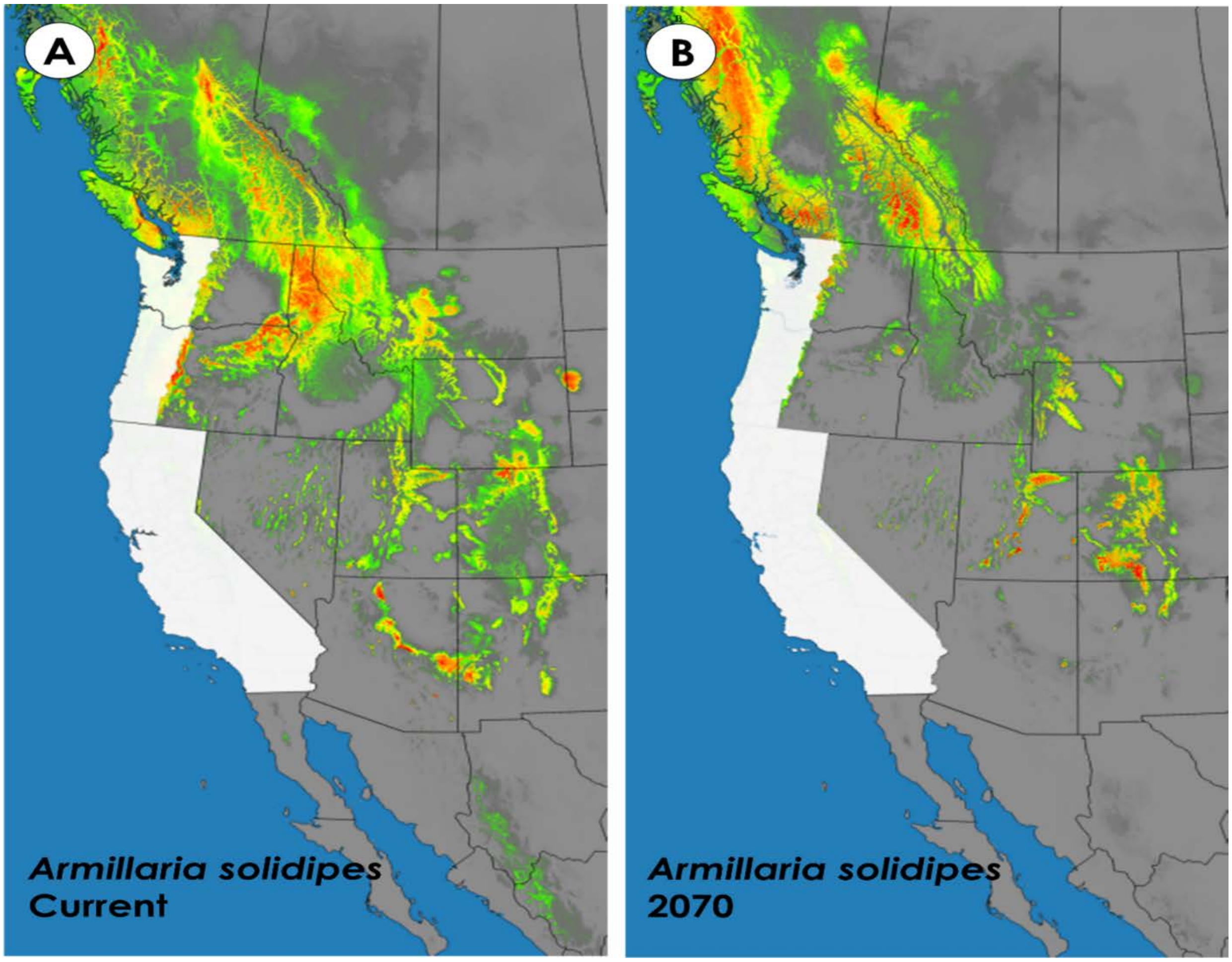

Figure 1. Maximum Entropy bioclimatic model of suitable climate space (potential distribution) for **(A)** predicted current *Armillaria solidipes* and **(B)** predicted for the year 2070 *Armillaria solidipes*. Darkest gray represents predicted suitable climate space, with light green, yellow, orange, and red indicating increased suitability, respectively.

OBJECTIVES

The objectives of this project are to (i) culture and identify *A. solidipes* and other *Armillaria* species from collections/surveys of under-represented areas in western Oregon, western Washington, and Alaska and (ii) integrate survey data from western Oregon, western Washington, and Alaska 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 present and future suitable climate space/potential distribution for *A. solidipes* in western North America. Any new *Armillaria* species/host combinations within OR, WA, and AK will also be documented.

Figure 2. *Armillaria* surveys. Armillaria root disease center (upper left); Excavating a root collar to survey for *Armillaria* (upper right); Armillaria fruiting bodies or basidioma (lower left); *Armillaria* rhizomorphs (lower center); and Armillaria mycelial fan (lower right).

New Surveys/Collections Needed in Western Oregon, Western Washington, and Alaska!

To supplement under-represented areas, additional *Armillaria* surveys/collections are needed in western Oregon, western Washington, and Alaska (Figures. 2, 3, and 4). We ask collaborators to contribute for surveys for *Armillaria* within these areas and send *Armillaria* samples (e.g., mycelial fans on live trees indicating disease activity or rhizomorphs), GPS-based location, and other host information to the USDA Forest Service, RMRS Forest Health Laboratory in Moscow, ID**.**

METHODS

- Coordinate and/or collaborate with supplemental surveys/collections of under-represented areas in western Oregon, western Washington, and Alaska.
- Conduct DNA-based diagnostics to identify *A. solidipes* and other *Armillaria* species: We will establish *Armillaria* isolates in culture, and use DNA sequencing (e.g., *tef-1a* gene) to identify isolates of *A. solidipes* and other *Armillaria* species from supplemental regions of OR, WA, and AK (Figure 2).
- Integrate *Armillaria* survey data into bioclimatic models to predict suitable climate space across Region 6 and western North America: A bioclimatic model, such as MaxEnt (Phillips et al. 2006), will be used to determine which climatic factors/predictive variables contribute to the occurrence of *A. solidipes* across the landscape (Klopfenstein et al. 2009a). In general, potential distribution of Armillaria root disease will be predicted for areas where the pathogen is climatically well-adapted, with increased risk associated with areas where the host is climatically maladapted.

Figure 3. *Armillaria* sample collection. GPS location (left), labeled collection bag for mycelial fans and/or infected wood (center); and labeled tubes for rhizomorphs (right).

EXPECTED OUTCOMES AND BENEFITS

This project will develop methods to monitor/predict potential disease risks under present and future climate scenarios across the western U.S.A., including Alaska. Predictions of the present and future distribution of Armillaria root disease pathogens can help guide forest managers to implement appropriate forest practices to manage Armillaria root disease pathogens according to current and future climates. Information from this project will be incorporated into prediction models for the western USA. This approach can also be adapted for other endemic and invasive forest diseases.

Figure 4. Map of proposed sample areas.

ACKNOWLEDGEMENTS

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[*]WHITEBARK PINE HEALTH OF SOUTHERN BRITISH COLUMBIA

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INTRODUCTION

Whitebark pine populations are in decline due to white pine blister rust, mountain pine beetle, seral replacement due to fire suppression, and climate change. Across BC, the levels of impacts are highly variable and the level of decline has been geographically described by others (e.g. Campbell and Antos 2000, Zeglen 2002). Identifying areas in greatest decline is important, regardless of cause, in order to prioritize recovery efforts and research. This project summarized health plots and transects established in 2015 and is not an exhaustive portrayal of health across BC.

METHODS

Permanent health plots were established in six regions of BC: Chilcotin, South Chilcotin, Lillooet, Manning Park, Okanagan, West Kootenay, East Kootenay, and Crown of the Continent. These plots were of two types, health transects (10m x 50m) (Tomback et al. 2005) and larger health plots (ca. 50m x 50m). In each plot, relevant data was collected regarding: blister rust infection, mountain pine beetle attack, tree sizes (DBH), and competing tree composition. Diameters for each tree were converted to basal area (BA).

Two complementary approaches to analysis were taken. The first, and most common approach, looked at infection as a percentage of stems. In this approach, all trees in the sample are equal in contributing to the level of infection present. The second approach looked at the BA of each infected tree, this approach can be used to identify what size of trees are infected and link directly to cone production and other attributes associated with tree size.

The difference between the percent stems and BA approach is illustrated in Figure 1. In this example, 50% of the stems are healthy but less than 5% of basal area is healthy. Although half of the trees are healthy, most of the ecological function has been lost from the stand through the loss of the large mature tree.

RESULTS AND DISCUSSION

Although the differences between % of stems and BA can be minimal on some plots, it is most important to consider the two approaches together. At 14 of the 38 plots analyzed, % of Stems and BA analyses were within 5% of each other (Figure 2, Table 1); at these sites infection was well distributed among size classes. Most of these sites represented the extremes of the surveys with the majority being very healthy or very infected. At six sites, the difference between %stems and BA was greater than 30%, all where the BA approach yielded poorer health than % of stems. At these sites, larger trees are being lost with probable impacts to regeneration and wildlife.

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[*] In: Goodrich, B. & P. Palacios (Comps). Proceedings of the 64th Annual Western International Forest Disease Work Conference, 2016 May 9-13, Sitka, AK

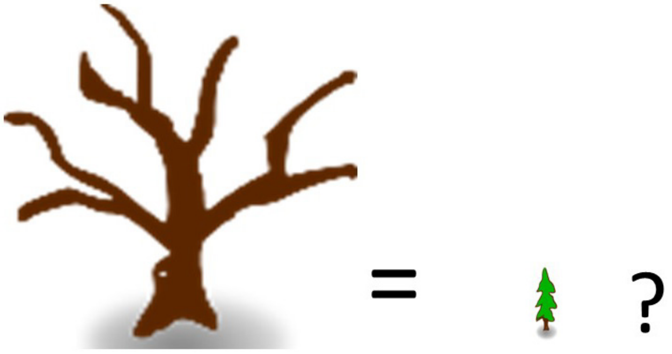


Figure 1. Comparison of healthy stems and Basal Area approaches.

As an example, consider the Downton site where 72% of stems were healthy, but only 29% of basal area was healthy; at this site most of the larger and ecologically contributing trees are infected illustrating that the stem-only approach portrayed a healthier ecosystem than is actually present.

Further, consider that by including BA in the analysis, cone production thresholds can be monitored to identify when potential ecological tipping points may be approaching. Barringer et al. 2012 identified that basal area of 2.0 m^2/ha was required to meet cone production requirements to support nutcracker visitation. Nutcrackers are the primary dispersal agent responsible for whitebark pine reproduction. At present only Red Mountain and Bluejoint in the West Kootenay are below this threshold, but an additional eight sites may fall below this threshold if observed infection manifests into mortality in the near future.

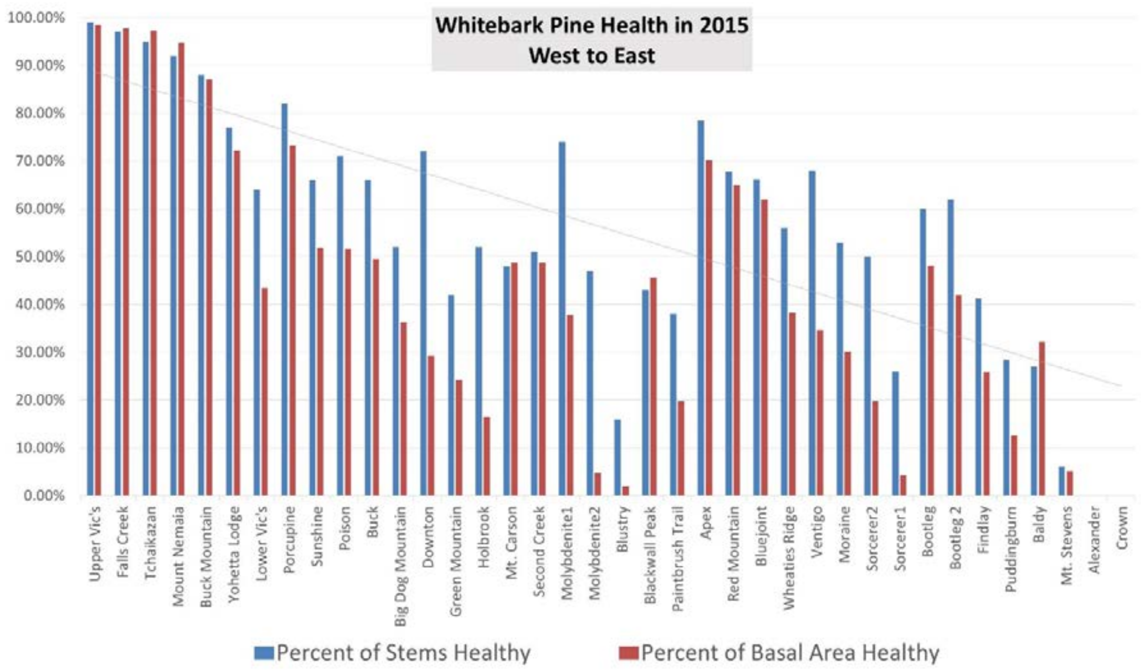


Figure 2. Summary of whitebark pine health in 2015 in terms of percent of stems and basal area.

When evaluating stand health, basal area should be included in summaries as the percent infection alone does not convey the full story of stand health. By including basal area changes in absolute values and percentage, managers can better identify what ecological ramifications may be present.

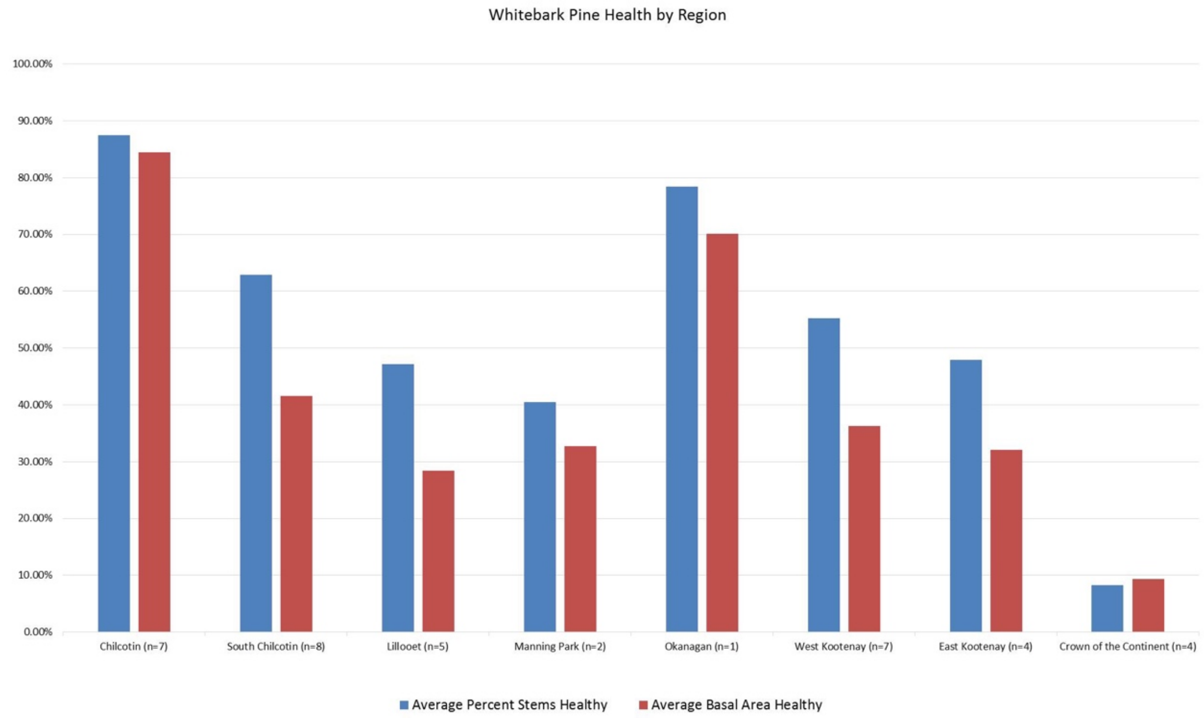


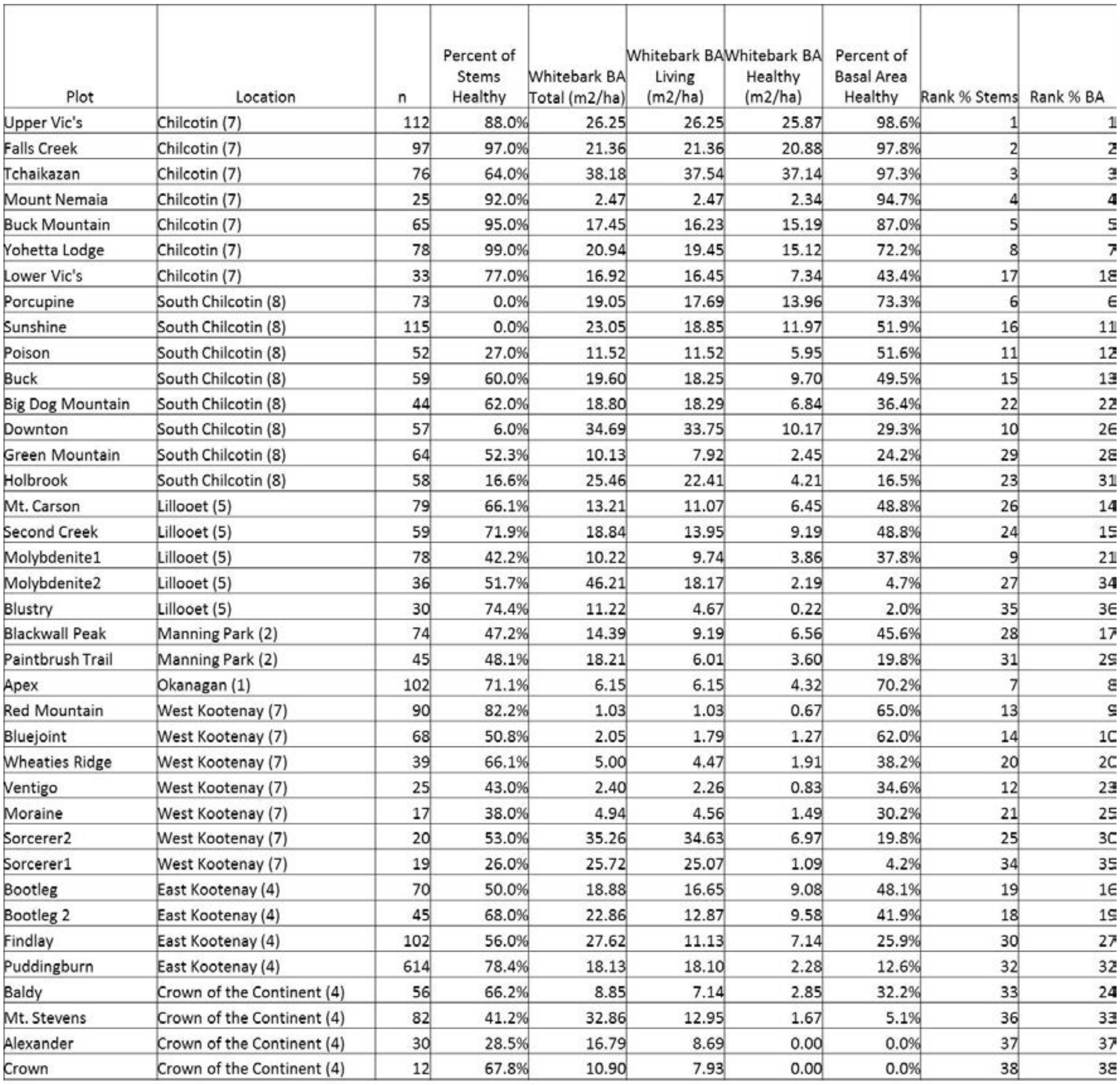
Figure 3. Regional summary of whitebark pine health from a % stems and % BA perspective across southern BC.

The health of Whitebark pine generally declines moving eastward (Figure 2). Four of the 38 plots were considered to be within the Crown of the Continent: Baldy, Mt. Stevens, Alexander, and Crown. These were some of the most infected stands surveyed, being respectively ranked 33rd, 36th, 37th and 38th in terms of health from a % stems perspective and 24th, 33rd, 37th and 38th from a BA perspective (Table 1). Collectively, this area was the unhealthiest of all regions in the province with less than 10% of the trees healthy from both a % stems and basal area perspective (Figure 3). This health trend echoes previous findings. Zeglen (2002) found the unhealthiest stands to be in the Southern Rockies (includes Crown of the Continent Ecosystem). Campbell and Antos (2000) observed infection rates greater than 61% in all plots. Smith and others (2008) found the Crown area to be comparatively less healthy than northerly Divide stands averaging 44-78% of trees infected.

While all sites were very unhealthy, at Alexander and Mt. Stevens mortality was exceedingly high, killing over 50% of BA in the plots (even greater outside of the Mt. Stevens plot) (Table 1, Figure 4). These high mortality rates indicate a dire need for restoration in the region. The high infection rates present an opportunity to for cone collections from parent trees that are already under high selection pressure for rust resistance.

Figure 4. Dead Whitebark Pine forest outside of sample plot on Mount Stevens.

Table 1. Summary of whitebark pine and basal area in 2015.



Plot	Location	n	Percent of Stems Healthy	Whitebark BA Total (m2/ha)	Whitebark BA Living (m2/ha)	Whitebark BA Healthy (m2/ha)	Percent of Basal Area Healthy	Rank % Stems	Rank % BA
Upper Vic's	Chilcotin (7)	112	88.0%	26.25	26.25	25.87	98.6%	1	1
Falls Creek	Chilcotin (7)	97	97.0%	21.36	21.36	20.88	97.8%	2	2
Tchaikazan	Chilcotin (7)	76	64.0%	38.18	37.54	37.14	97.3%	3	3
Mount Nemaia	Chilcotin (7)	25	92.0%	2.47	2.47	2.34	94.7%	4	4
Buck Mountain	Chilcotin (7)	65	95.0%	17.45	16.23	15.19	87.0%	5	5
Yohetta Lodge	Chilcotin (7)	78	99.0%	20.94	19.45	15.12	72.2%	8	7
Lower Vic's	Chilcotin (7)	33	77.0%	16.92	16.45	7.34	43.4%	17	18
Porcupine	South Chilcotin (8)	73	0.0%	19.05	17.69	13.96	73.3%	6	6
Sunshine	South Chilcotin (8)	115	0.0%	23.05	18.85	11.97	51.9%	16	11
Poison	South Chilcotin (8)	52	27.0%	11.52	11.52	5.95	51.6%	11	12
Buck	South Chilcotin (8)	59	60.0%	19.60	18.25	9.70	49.5%	15	13
Big Dog Mountain	South Chilcotin (8)	44	62.0%	18.80	18.29	6.84	36.4%	22	22
Downton	South Chilcotin (8)	57	6.0%	34.69	33.75	10.17	29.3%	10	26
Green Mountain	South Chilcotin (8)	64	52.3%	10.13	7.92	2.45	24.2%	29	28
Holbrook	South Chilcotin (8)	58	16.6%	25.46	22.41	4.21	16.5%	23	31
Mt. Carson	Lillooet (5)	79	66.1%	13.21	11.07	6.45	48.8%	26	14
Second Creek	Lillooet (5)	59	71.9%	18.84	13.95	9.19	48.8%	24	15
Molybdenite1	Lillooet (5)	78	42.2%	10.22	9.74	3.86	37.8%	9	21
Molybdenite2	Lillooet (5)	36	51.7%	46.21	18.17	2.19	4.7%	27	34
Blustry	Lillooet (5)	30	74.4%	11.22	4.67	0.22	2.0%	35	36
Blackwall Peak	Manning Park (2)	74	47.2%	14.39	9.19	6.56	45.6%	28	17
Paintbrush Trail	Manning Park (2)	45	48.1%	18.21	6.01	3.60	19.8%	31	29
Apex	Okanagan (1)	102	71.1%	6.15	6.15	4.32	70.2%	7	8
Red Mountain	West Kootenay (7)	90	82.2%	1.03	1.03	0.67	65.0%	13	9
Bluejoint	West Kootenay (7)	68	50.8%	2.05	1.79	1.27	62.0%	14	10
Wheaties Ridge	West Kootenay (7)	39	66.1%	5.00	4.47	1.91	38.2%	20	20
Ventigo	West Kootenay (7)	25	43.0%	2.40	2.26	0.83	34.6%	12	23
Moraine	West Kootenay (7)	17	38.0%	4.94	4.56	1.49	30.2%	21	25
Sorcerer2	West Kootenay (7)	20	53.0%	35.26	34.63	6.97	19.8%	25	30
Sorcerer1	West Kootenay (7)	19	26.0%	25.72	25.07	1.09	4.2%	34	35
Bootleg	East Kootenay (4)	70	50.0%	18.88	16.65	9.08	48.1%	19	16
Bootleg 2	East Kootenay (4)	45	68.0%	22.86	12.87	9.58	41.9%	18	19
Findlay	East Kootenay (4)	102	56.0%	27.62	11.13	7.14	25.9%	30	27
Puddingburn	East Kootenay (4)	614	78.4%	18.13	18.10	2.28	12.6%	32	32
Baldy	Crown of the Continent (4)	56	66.2%	8.85	7.14	2.85	32.2%	33	24
Mt. Stevens	Crown of the Continent (4)	82	41.2%	32.86	12.95	1.67	5.1%	36	33
Alexander	Crown of the Continent (4)	30	28.5%	16.79	8.69	0.00	0.0%	37	37
Crown	Crown of the Continent (4)	12	67.8%	10.90	7.93	0.00	0.0%	38	38

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*MICROSATELLITE MARKERS FOR ASSESSMENT OF GENETIC VARIATION IN POPULATIONS OF *ENDOCRONARTIUM HARKNESSII*

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INTRODUCTION

Endocronartium harknessii (J.P. Moore) Y. Hirats. (= *Peridermium harknessii* J.P. Moore) causes western gall rust (WGR), a disease affecting several hard pines across North America (CABI/EPPO 2007). WGR is characterized by the formation of globular galls on branches or stems of infected trees. The galls are perennial and especially obvious in spring when they become covered with bright, yellow-orange spores of the rust fungus (Figure 1). WGR reduces growth, devalues the wood and ultimately results in partial or complete tree death through girdling or breakage at the gall. The disease is of particular concern for sustainable forest management in western Canada where lodgepole pine (*Pinus contorta* Dougl. ex. Loud var. latifolia Engelm) and jack pine (*Pinus banksiana* Lamb.), two highly susceptible host species, are prevalent.

Genetic variation in resistance to *E. harknessii* has been identified in lodgepole and jack pines that could inform selection and breeding for resistance to this disease (Yang et al. 1997, White et al. 2000). There is also evidence that resistance to WGR may be influenced by the pathogen's geographic origin and therefore its unique genetic makeup (Walla et al. 1997, Yang et al. 1999). However, there are still many gaps in our knowledge of the genetic variability and population structure of *E. harknessii* in Canada.

Previous studies looking at the genetic diversity of *E. harknessii* have been limited by the efficiency of the markers (isozymes, restriction fragment length polymorphisms and random amplified polymorphic DNAs) used in these studies (e.g. Vogler et al. 1991, Li et al. 2001). The aim of the present study was to develop microsatellite (DNA tandem sequence repeats) markers for *E. harknessii* and use them to characterize the genetic diversity and population structure of this pathogen across Canada.

Figure 1. Signs of Western Gall Rust on branch and stem of mature pine trees.

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MATERIALS AND METHODS

Twenty three microsatellite markers (including di-, tri- and tetra-nucleotide motifs) were identified from the draft genome sequence of *E. harknessii*, isolate PhW48OC (GCA_000500795). Each marker was selected from a unique assembly scaffold and included a perfect tandem sequence repeat, with a minimum of 9, 8 and 6 units for di-, tri- and tetra-nucleotide motifs respectively. Primers were designed, with expected fragment sizes ranging between 75 and 325 bp to allow for multiplex fragment analyses.

Eighteen markers were evaluated in two multiplex assays on a test population collection of 176 single-gall isolates of *E. harknessii* collected from sites in British Columbia (BC), Alberta (AB), Northwest Territories (NWT), Saskatchewan (SK), Manitoba (MB) and Ontario (ON), Canada (Figure 2). Isolates were genotyped using the nested PCR method developed by Schuelke (2000), with M13 universal primer labelled with FAM, NED, PET and VIC fluorescent dyes.

Microsatellite loci summary statistics, gene and genotypic diversity and linkage disequilibrium were evaluated using functions implemented in the R package 'poppr' (Kamvar et al. 2014). Population structure was investigated using the programme STRUCTURE (Pritchard et al. 2000).

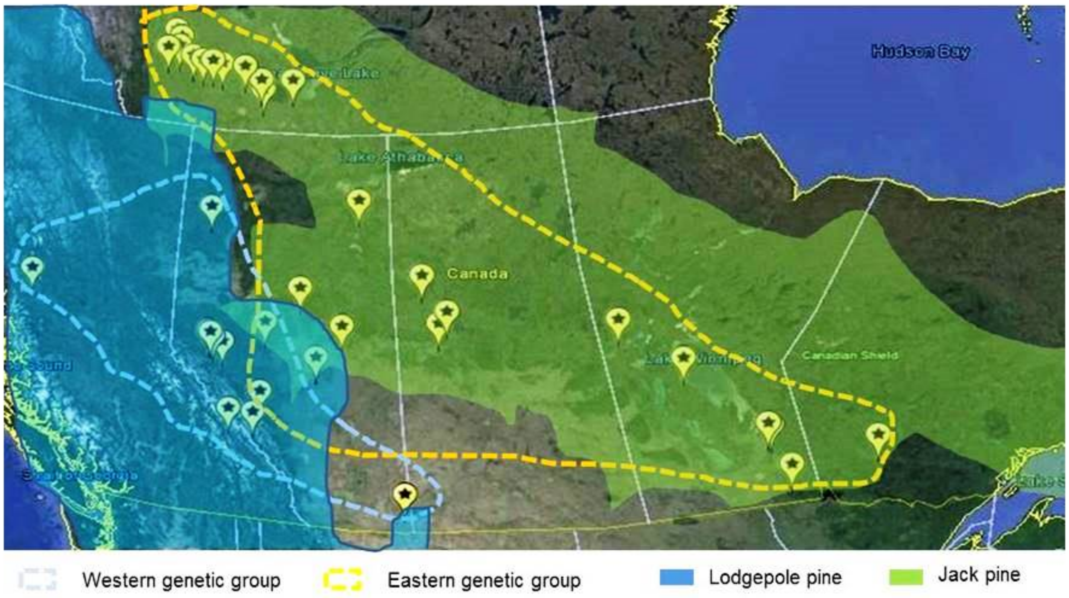

Figure 2. Sample distribution and distribution of the genetic groups identified against the background of the ranges of lodgepole and jack pines.

RESULTS

The 18 microsatellite markers evaluated amplified 2 to 8 alleles per locus (average = 4.7, total = 75) (Table 1). Gene diversity ranged from 0.40 to 0.80 for both the Simpson's (1-D) and Nei's (Hexp) indices, while evenness in allele distribution was generally high, ranging from 0.59 to 0.98 (Table 1).

A total of 84 multilocus genotypes (MLGs) were recovered, including 65 that were detected as singletons. The two most prevalent genotypes were detected in more than one province: the first (21/176) in MB and

ON, and the second (20/176) in AB, NWT and SK. Genotype accumulation curve indicated that 90% of the genotypes could be detected with 15 to 16 markers (Figure 3).

Genetic clustering analyses depicted a population structure split between a western and eastern genetic groups (Figure 4). The geographic distribution of the two groups in the investigated population appeared to be superimposed with the distribution ranges of lodgepole and jack pines respectively, showing a narrow overlapping area in AB (Figure 2). However, no recombinants were detected and no allele was shared between groups.

Analyses of linkage disequilibrium in the entire population (rbarD = 0.403, *p* = 0.001) as well as in each western (rbarD = 0.0598, *p* = 0.001) and eastern (rbarD = 0.334, *p* = 0.001) genetic group considered separately supported exclusive clonal reproduction in *E. harknessii*.

Table 1. Microsatellite marker summary statistics.

Locus	allele	1-D	Hexp	Evenness	Repeat type	Allele size range	Multiplex set / fluorescent dye
EH02	8.00	0.72	0.73	0.73	di	288–312	1/FAM
EH04	9.00	0.79	0.80	0.86	di	284–302	1/PET
EH05	5.00	0.68	0.69	0.90	di	308–316	1/VIC
EH07	5.00	0.74	0.75	0.92	tetra	333–357	1/NED
EH09	3.00	0.58	0.59	0.84	di	209–217	1/VIC
EH10	3.00	0.53	0.54	0.89	di	206–214	2/FAM
EH11	5.00	0.72	0.72	0.88	di	207–217	1/NED
EH15	3.00	0.61	0.61	0.91	tetra	200–224	2/NED
EH19	4.00	0.46	0.46	0.79	di	140–149	1/NED
EH20	3.00	0.48	0.49	0.92	di	143–147	2/PET
EH26	2.00	0.40	0.40	0.82	di	298–300	2/FAM
EH27	7.00	0.58	0.59	0.59	tri	292–355	2/NED
EH32	2.00	0.49	0.49	0.98	tetra	346–350	2/PET
EH34	3.00	0.49	0.49	0.90	di	208–212	1/FAM
EH37	3.00	0.62	0.62	0.92	tri	207–222	2/VIC
EH44	2.00	0.49	0.49	0.97	tri	141–144	1/PET
EH45	3.00	0.62	0.63	0.92	tri	123–144	2/VIC
EH46	5.00	0.63	0.63	0.85	tri	101–119	2/FAM
Mean	4.17	0.59	0.59	0.87			

allele = Number of observed alleles
1-D = Simpson index
Hexp = Nei's 1978 gene diversity

CONCLUSIONS

After evaluation on a test population of 176 isolates, 18 of the 23 microsatellite markers developed in this study proved to be polymorphic, reproducible and to amplify readily under standard PCR conditions. Therefore, these markers provide a useful tool for investigating genetic variation in *E. harknessii*.

A genetic structure including two discrete groups that share no allele at any of the investigated loci suggests that *E. harknessii* may have evolved in two distinct diversification centers, isolated from one another for an extended period of time, allowing for the accumulation of multiple private mutations. The apparent superimposition of the pathogen spatial structure and the distribution range of lodgepole and jack pines is consistent with the high differentiation of the pathogen between the two hosts highlighted by Li et al. (2001), using random amplified polymorphic DNAs.

The observed exclusive clonal reproduction suggests that any sexual recombination in *E. harknessii* happens mostly through self-fertilization.

Further studies will focus on exploring the relationship between host-pathogen interaction and spatial genetic structure and identifying the putative centers and drivers of genetic diversification of *E. harknessii*.

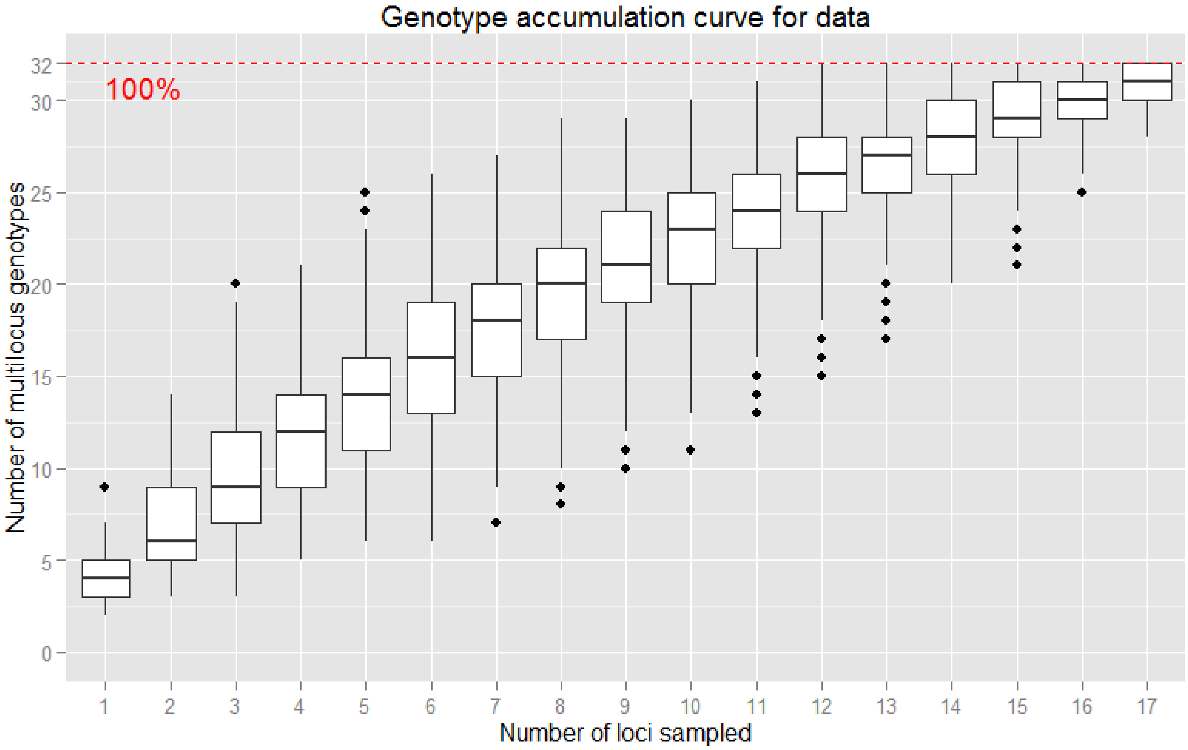

Figure 3. Multilocus genotype accumulation curve.

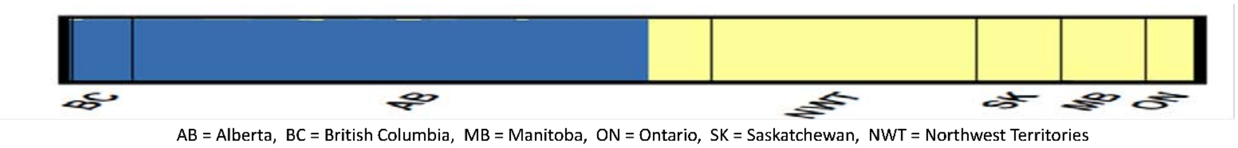

Figure 4. Population structure of *E. harknessii* in western Canada showing two discrete genetic clusters.

ACKNOWLEDGEMENTS

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*PHYTOPHTHORA RAMORUM DETECTION AND MONITORING IN WESTERN WASHINGTON WATERWAYS, 2015

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INTRODUCTION

Phytophthora ramorum (*Pr*), an exotic plant pathogen, is the causal agent of Sudden Oak Death (SOD), ramorum leaf blight and ramorum dieback. The pathogen can move aerially through landscapes with wind and wind-driven rain, such as in the forests of Oregon and California. The pathogen can also be moved long distances in nursery stock. Western Washington is at risk for *Pr* caused diseases and *Pr* spread due to hosts in the natural environment, suitable climatic conditions (moist weather and mild temperatures), the presence of plant nurseries with *Pr* infected host stock and nursery associated water runoff. To date, the pathogen has only been detected in locations that are either at or near plant nurseries and in one botanical garden (*) in western Washington and not in general forests.

*Botanical garden found with positive plants

A Kitsap county botanical garden was found to have a *Pr*-positive *Pieris* plant in April, and several more positive plants were found during subsequent delimitation surveys in October. However, all 224 samples collected around the perimeter of the botanical garden and in the adjacent native woodland were negative for *Pr*. Washington State Department of Agriculture and WSU staff continue to work with Federal regulatory officials to ensure the pathogen is being managed effectively. A community-based, stream monitoring project on the northern Olympic Peninsula, under the auspices of WSU, did not detect *Pr* in any of the waterways sampled.

2015 METHODS AND RESULTS

With funding provided by the USDA National *Pr* Early Detection Survey of Forests has been ongoing since 2003 (Figure 1). In 2015, ten Washington waterways in six counties (Clallam, King, Kitsap, Lewis, Mason, and Thurston) were surveyed for the pathogen using a rhododendron leaf filled baiting bag method. Two Washington waterways in Kitsap and Thurston counties were found positive for *Pr*. Both waterways have been positive in previous years' surveys and are downstream from previously positive nurseries. In June, streamside surveys were conducted along the waterways in Kitsap and Thurston counties. There are no indications that the pathogen is leaving the waterways as all vegetation samples collected in the woodlands bordering the two waterways were negative for *Pr*.

REGULATORY UPDATES

Phytophthora ramorum, the causal agent of Sudden Oak Death (SOD), ramorum leaf blight and ramorum dieback has been detected in nurseries and waterways in western Washington. Nevertheless, on April 3, the

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Animal and Plant Health Inspection Service (APHIS) deregulated all regulated areas in Washington, except for those nurseries that are under compliance agreements with APHIS due to regulatory samples testing positive for *Pr*, which will remain regulated establishments. The basis for the revision is that the majority of nurseries in regulated areas have not tested positive in years or have never tested positive and the absence of *Pr* in the natural environment causing SOD, leaf blight or dieback.

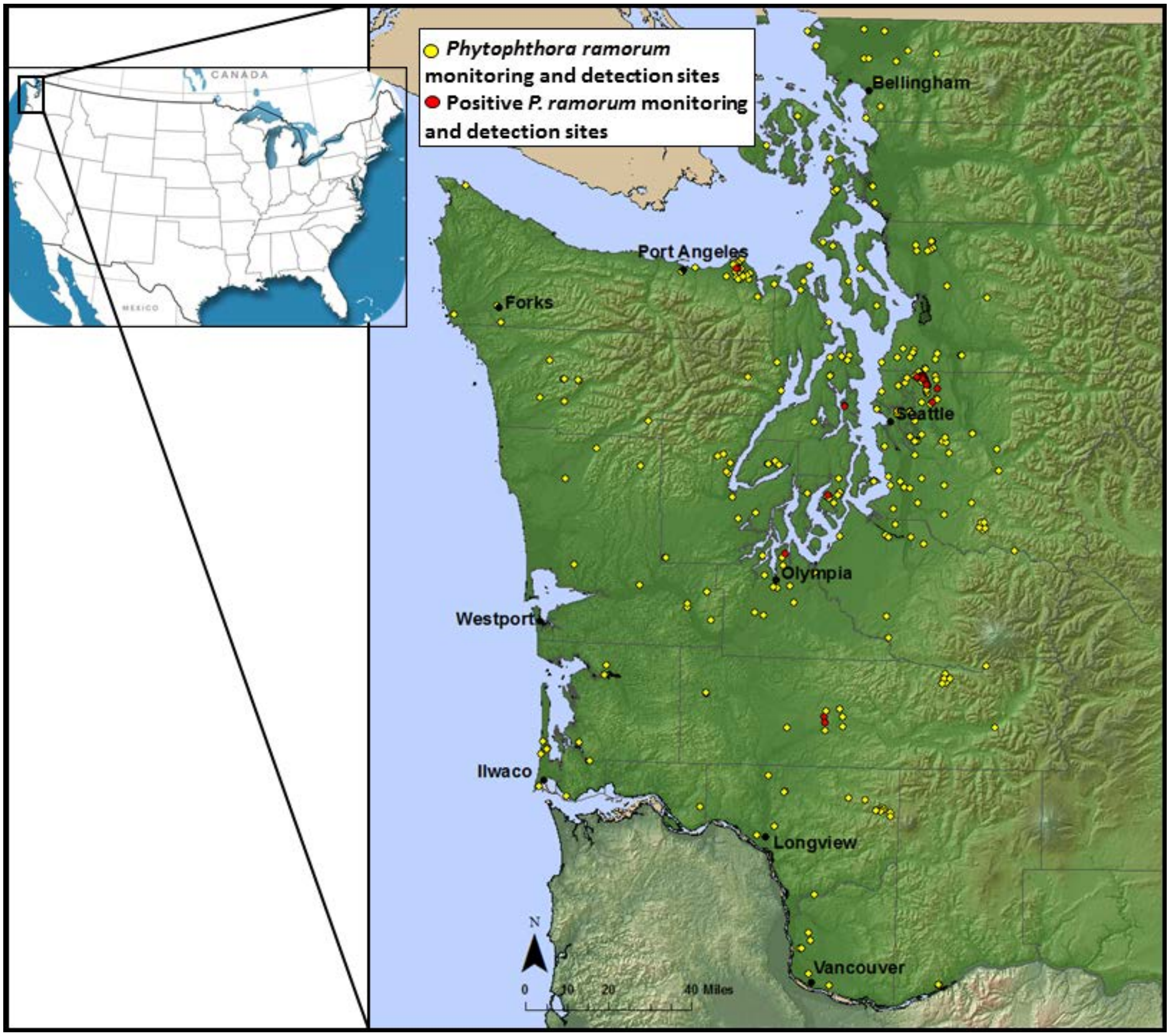

Figure 1. WA DNR *Phytophthora ramorum* (Pr) monitoring, detection and survey sites, 2003-2015. Map by A. Ramsey, Washington DNR.

*ESTABLISHING AND MONITORING BLISTER RUST RESISTANCE, PATHOGEN VIRULENCE, AND GENETIC ADAPTABILITY OF WESTERN WHITE PINE IN WASHINGTON

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ABSTRACT

Western white pine (WWP, *Pinus monticola* Dougl.) is a wide-ranging forest tree species of high economic and ecological value. However, due to several factors, including the inadvertent introduction of the non-native fungal pathogen *Cronartium ribicola* Fisch. (cause of white pine blister rust (WPBR) disease) around 1910, there has been extreme levels of mortality in many natural populations of WWP, and a greater reluctance to use this species in reforestation and restoration. Fortunately, some genetic variation in resistance exists in within WWP.

The development of genetically resistant populations of WWP is well under way (Sniezko *et al.* 2014), but field trials are needed to test the resistance in a range of environments. The Washington Department of Natural Resources (WA DNR) and the U.S. Forest Service's (USFS) Dorena Genetic Resource Center (Dorena GRC) have partnered to undertake a series of field trials to evaluate WWP.

Trials such as the RV20 test series planted in winter planted in 2014/2015 in western Oregon (1 site) and eastern Washington (6 sites), complementing another test series planted in 2006/2007 in western Washington (6 sites, RV11 Test Series) (Ramsey *et al.* 2014), will provide key information on the efficacy of rust resistance over time, as well as the adaptability of different seed sources of WWP in a changing climate.

These trials include both the most advanced seed orchard lots currently available, as well as seedlings from parents spanning the full range of resistance types currently known for WWP. The parent trees for this trial originate from Oregon, Washington, Idaho and British Columbia and are part of the three programs to develop blister rust resistance located in Oregon, Idaho and British Columbia. A subset of these seedlots were also planted in field trials in British Columbia in winter 2014. This series of trials will provide information on genetic resistance to white pine blister rust, on adaptability of seedlots from different geographic sources in these locations, and serve as sentinel plantings to monitor impacts of pathogens and insects or impacts from abiotic events associated with a changing climate.

Nine years after planting the western Washington trials, the level of blister rust infection varies dramatically among the five sites assessed in 2015, from 6.9 % to 61.9%. The high susceptible seed checklot showed 15.0%, 91.8%, 34.4%, 100.0% and 88.4% rust infection at the five sites. Sites in western Washington vary dramatically in their apparent rust hazard, according to our data, and different management strategies (level of resistance, pruning, spacing, etc.) may be utilized across the region. Continued monitoring and

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assessment of these sites will provide landowners key information on the potential level of success of utilizing WWP in their reforesting and restoration plantings.

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[*]DWARF MISTLETOE SANITATION TRIAL

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INTRODUCTION

Sanitation spacing or removal of all regen over a specified height is a commonly prescribed treatment for reducing the spread of lodgepole pine dwarf mistletoe (Figures 1-2). The objective of this trial is to measure the spread and impact of lodgepole pine dwarf mistletoe under 3 sanitation (knockdown) treatments (0.3m, 1m, and 2m) and a no treatment (control).

Figure 1. Female lodgepole pine dwarf mistletoe plants.

Figure 2. Male lodgepole pine dwarf mistletoe plants.

METHODS

Site Location

The block is located southwest of Williams Lake, B.C. (Figure 3) in the dry cool Douglas-fir biogeoclimatic subzone. The block was a forests for Tomorrow Innovative Timber Sale License harvested under the direction of BC Timber Sales. The block was harvested in 2013. Mountain pine beetle had killed most of the lodgepole pine over story prior to harvest. Most of the mountain pine beetle mortality occurred between 2004 and 2007.

Block Layout

60m x 60m blocks were laid out in a 3 x 6 grid (Figure 4). Six of the grid blocks were excluded from the trial because they had very little tall advanced regeneration following logging. The remaining 12 blocks were randomly assigned to each of the four treatments (3 replicates per treatment). For the 3 sanitation treatments, 17.85m radius plots were established within each block and the height, distance and bearing from plot center, and Hawksworth dwarf mistletoe rating were recorded for each tree in the plot over the

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knockdown height for that block (Table 1). This information provides a record of what was present in each plot prior to the sanitation treatment being carried out. The sanitation treatments were carried out in the fall of 2014. A 0.3 m knockdown was used in blocks where no treatment was assigned.

Table 1. Pre and post planting stocking and damaged trees.

Rep	Treatment	Post treatment Stocking Prior to Plant in spring 2015	Planted and still alive in Aug 2015	Stocking after plant	damaged trees	damaged trees
		(stems/ha)	(stems/ha)	(stems/ha)	(stems/ha)	(%)
1	0.3 m	2420	1460	3880	460	11.9
2	0.3 m	1440	1340	2780	200	7.2
3	0.3 m	1540	1120	2660	280	10.5
mean	0.3 m	1800	1307	3107	313	9.9
1	1 m	1780	1000	2780	680	24.5
2	1 m	380	1560	1940	100	5.2
3	1 m	2960	1520	4480	600	13.4
mean	1 m	1707	1360	3067	460	14.3
1	2 m	5080	1980	7060	540	7.6
2	2 m	540	1280	1820	200	11
3	2 m	2100	1400	3500	720	20.6
mean	2 m	2573	1553	4127	487	13.1
1	no sanitation	4420	1440	5860	920	15.7
2	no sanitation	7140	1360	8500	900	10.6
3	no sanitation	2080	1620	3700	700	18.9
mean	no sanitation	4547	1473	6020	840	15.1

Post Treatment Assessments

The same plots used in the pre-assessments were used. Each plot was subdivided into 12 sections based on bearing (30 degree increments starting from 0). All dwarf mistletoes trees within 12.62 (0.05 ha plot size) of the plot center were tagged and the distance from plot center, plot section, dbh, height, status (planted or regen), and Hawksworth Dwarf Mistletoe and Elytroderma severity rating were recorded for each tree. Data was also collected on trees with dwarf mistletoe plants between 12.62 and 17.85 m from the plot center. For those infected trees outside the inner plot, the actual bearing from plot center was recorded so that they could be relocated without tagging the trees.

PRELIMINARY RESULTS

Planting density was similar in all treatments. Tables 1 and 2 show a trend towards increased stocking, damage, height, and dwarf mistletoe when taller sanitation heights are used. The 1 m treatment had a lower mean stocking level prior to planting than the 0.3 m treatment due to very low stocking in one of the 1m replicates. This trial will be re-measured periodically to see how long infected residuals remain over topping and to study the effect of sanitation height on any long term growth impacts from lodgepole pine dwarf mistletoe.

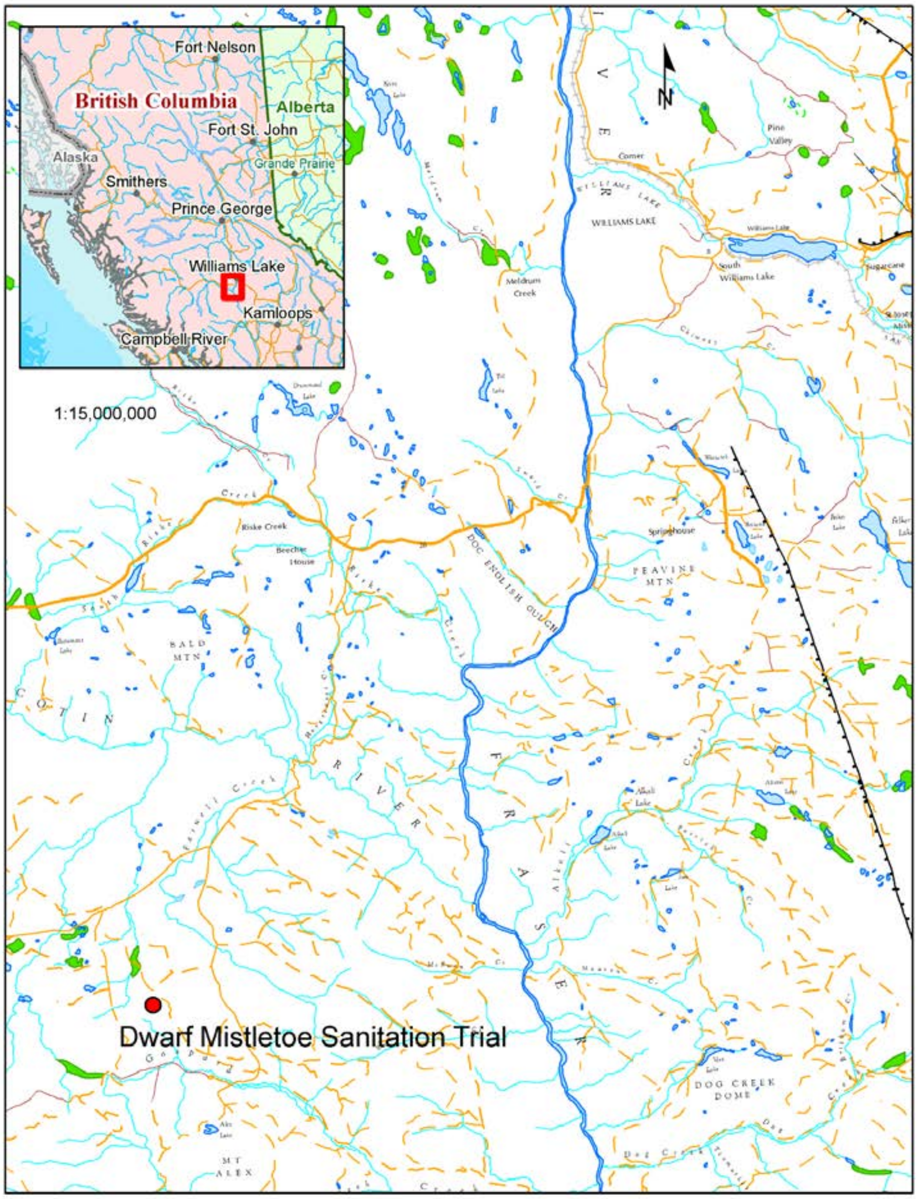
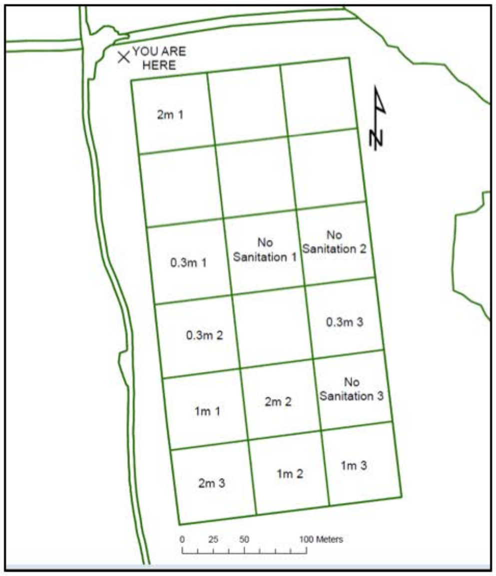


Figure 3. Location of trial.



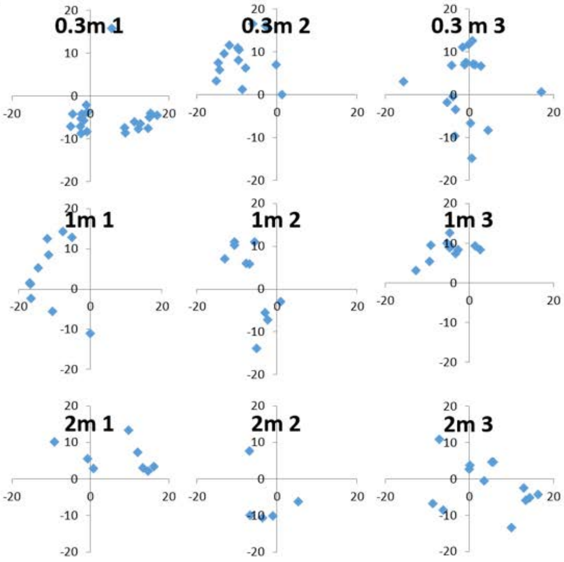
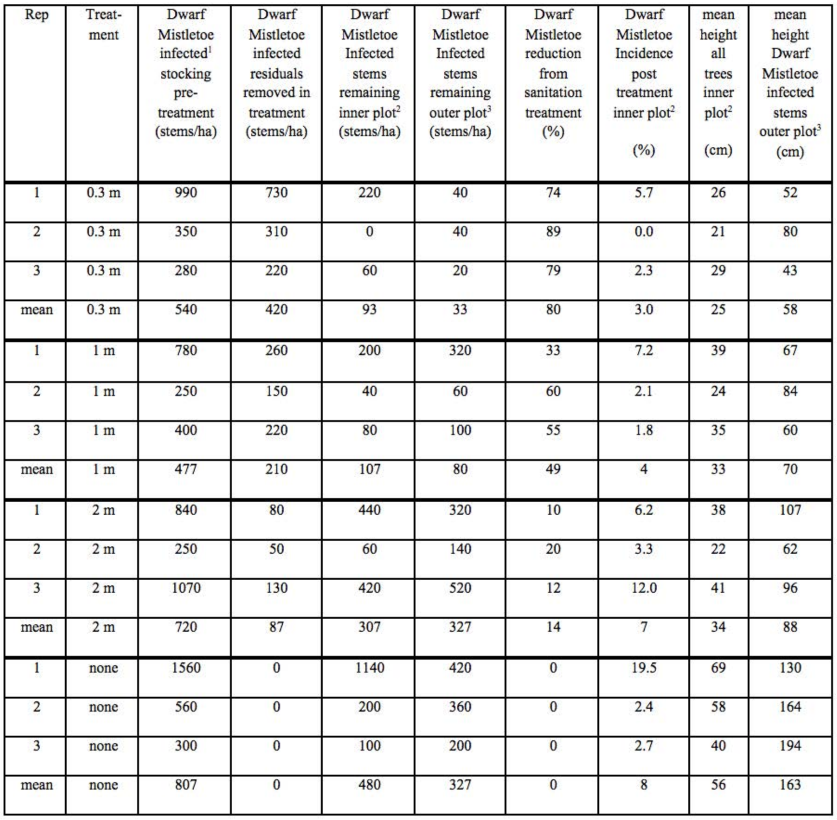


Figure 4. Map of trial area.

Figure 5. Distribution of Dwarf Mistletoe infected residuals over 2m tall prior to sanitation.

Table 2. Dwarf mistletoe levels pre and post sanitation and post planting mean tree heights.



Rep	Treat-ment	Dwarf Mistletoe infected[1] stocking pre-treatment (stems/ha)	Dwarf Mistletoe infected residuals removed in treatment (stems/ha)	Dwarf Mistletoe Infected stems remaining inner plot[2] (stems/ha)	Dwarf Mistletoe Infected stems remaining outer plot[3] (stems/ha)	Dwarf Mistletoe reduction from sanitation treatment (%)	Dwarf Mistletoe Incidence post treatment inner plot[2] (%)	mean height all trees inner plot[2] (cm)	mean height Dwarf Mistletoe infected stems outer plot[3] (cm)
1	0.3 m	990	730	220	40	74	5.7	26	52
2	0.3 m	350	310	0	40	89	0.0	21	80
3	0.3 m	280	220	60	20	79	2.3	29	43
mean	0.3 m	540	420	93	33	80	3.0	25	58
1	1 m	780	260	200	320	33	7.2	39	67
2	1 m	250	150	40	60	60	2.1	24	84
3	1 m	400	220	80	100	55	1.8	35	60
mean	1 m	477	210	107	80	49	4	33	70
1	2 m	840	80	440	320	10	6.2	38	107
2	2 m	250	50	60	140	20	3.3	22	62
3	2 m	1070	130	420	520	12	12.0	41	96
mean	2 m	720	87	307	327	14	7	34	88
1	none	1560	0	1140	420	0	19.5	69	130
2	none	560	0	200	360	0	2.4	58	164
3	none	300	0	100	200	0	2.7	40	194
mean	none	807	0	480	327	0	8	56	163

[1] only trees with dwarf mistletoe shoots were considered infected

[2] inner plot was 12.62m radius (0.05ha)

[3] outer plot was 17.85m radius plot with 12.62 m radius donut hole in the center (net area 0.05 ha). Only DMP residuals measured in outer plot.

*USING DIGITAL PHOTOGRAPHY AND LIDAR HEIGHT CLASS DATA TO IDENTIFY ROOT ROT CENTERS AT GAVIN LAKE

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Root rot centers were identified in the Gavin Lake UBC Research Forest using imagery and Lidar height class data (Figure 1) as well as information provided by the Research Forest. Twenty-three root rot polygons were identified from imagery and 15 were identified from Lidar height class data. These areas were then visited on the ground and root rot centers that were encountered were traversed and mapped and given a root rot severity rating. The centers were given an overall severity rating of between 0 and 10, where 0 represents no canopy loss and 10 represents 100% canopy loss.

A total of 42 root rot centers were identified on the ground (this represents about 2% of the area of the research forest). Seventy-one percent of the centers were laminated root rot and 29% were Armillaria centers but because the laminated root rot centers were about a third of the size of Armillaria centers (2.0 ha vs. 6.4 ha) the percentage of area infected by each root rot was similar. In a few instances Laminated and Armillaria polygons were adjacent to each other but they rarely overlapped. The lowest Armillaria severity rating was 3 and the lowest Laminated root rot severity rating was 7. This reflects the fact that a couple of the Armillaria centers had only scattered mortality. These Armillaria centers were much more difficult to map than centers with high severity ratings and were not detected from imagery. Both Armillaria and Laminated root rot showed a strong preference for south and southwest facing slopes. Eighty –four percent of root rot centers were south or southwest facing. Only 7% of root rot centers had north, northeast or east aspects. Most of the root rot centers (93%) were in the SBSdw1 and the remainder (7%) were in the ICHmk3. This probably reflects the fact that much of the ICHmk3 at Gavin Lake (roughly half the area) has a northeastern aspect.

Just over half (57%) of the ground proofed root rot centers overlapped with areas that were pre-identified from ortho photos or Lidar, 39% were not detected prior to ground truthing, and 5% were previously identified by the research forest but were not detected from ortho photo or Lidar height class data. Some of the ortho and Lidar identified root rot areas were much larger than the ground proofed areas that they overlapped with. Some of the most common causes for misidentification based on ortho photos and Lidar were deciduous patches, mountain pine beetle impacted areas, and partial harvest areas.

Inventory data was collected from inventory polygons that overlapped with root rot polygons. Live volume, crown class, age class, height class, percentage of Douglas-fir leading polygons, and polygons with a deciduous component in the inventory label were compared for inventory polygons with less than 50% of the area occupied by root rot and inventory polygons with more than 50% of the area occupied by root rot. Unfortunately, due to the small size of the average root rot center (3.1 ha) relative to the average inventory polygon size (17.4 ha) there were very few polygons with >50% root rot (7 Armillaria inventory polygons and 4 laminated inventory polygons out of a total of 100 overlapping inventory polygons) which made comparisons difficult. As expected, inventory polygons with more than 50% root rot showed lower volumes (but only small reductions in crown, age, and height class) than inventory polygons with less than 50% of

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the area occupied by root rot. Root rot polygons were predominantly Douglas-fir leading as expected (77%) but the percentage of root rot polygons with a deciduous component was somewhat lower than expected. Only 55% of root rot polygons with more than 50% of the area in root rot had a deciduous component in their inventory label.

LANDSCAPE LEVEL MAPPING OF ROOT DISEASE IN THE CARIBOO REGION

For the last two years, detailed helicopter mapping of laminated and Armillaria root rot centers has been conducted in the Cariboo Region. It started in 2014 when Richard Reich conducted aerial mapping of young spruce and Douglas-fir leading stands in the Cariboo Interior Cedar Hemlock Zone using methods he previously developed in the Robson Valley and Clearwater Forest Districts. In the fall of that year, a test flight was done over mature stands and follow up ground surveys confirmed the presence of root rot in the mature stands (Figure 2).

In 2015, the mapping was done in conjunction with detailed helicopter surveys for Douglas-fir beetle (Figure 3). Waypoints for root rot centers were collected during the bark beetle flights and then the root rot centers were traversed from a helicopter during a follow up flight. Based on limited ground truthing, the results look promising In the future it should be possible to skip the waypoint collections stage and go directly to the traversing stage. This work requires people trained to pick up root rot from the air that have a strong stomach when it comes to flying.

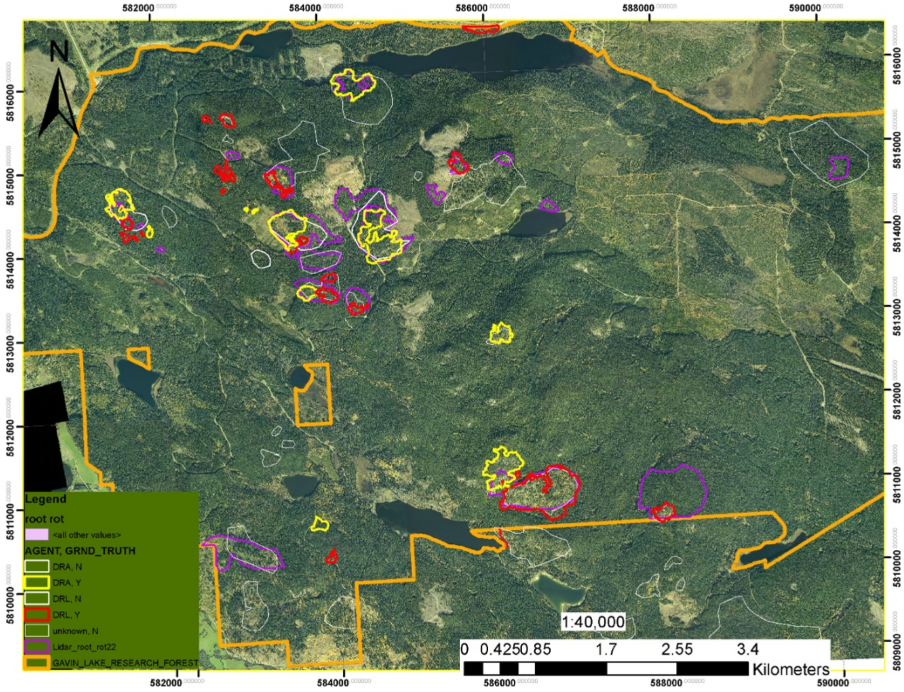

Figure 1. UBC Gavin Lake Research Forest Ortho photo showing predicted root rot locations based on ortho photos (white), lidar height class data (purple), and actual ground proofed laminated (red) and Armillarai (yellow) root rot centers.

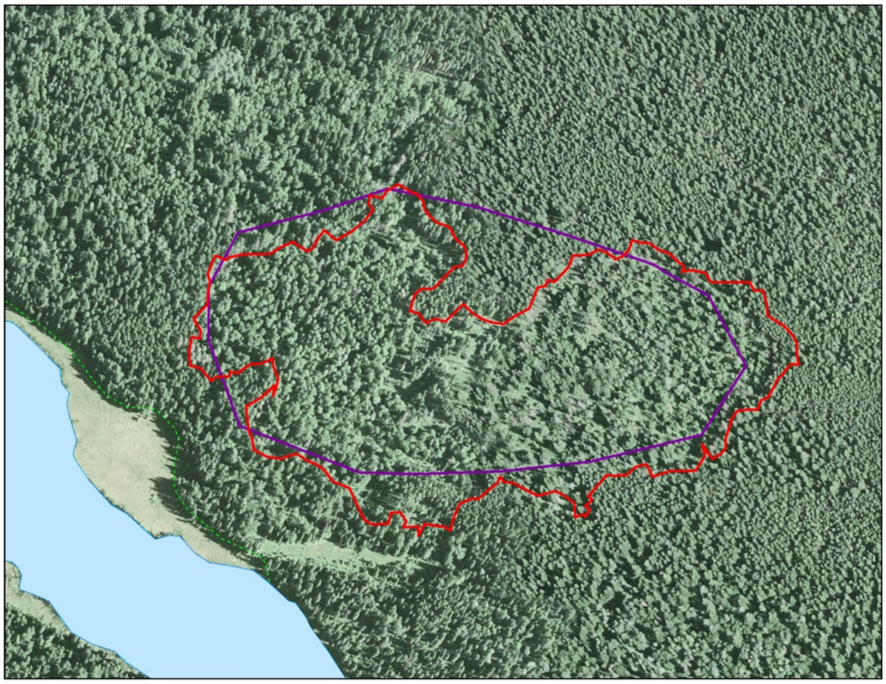

Figure 2. Digital photograph showing helicopter mapped (blue) and ground truthed (red) laminated root rot center.

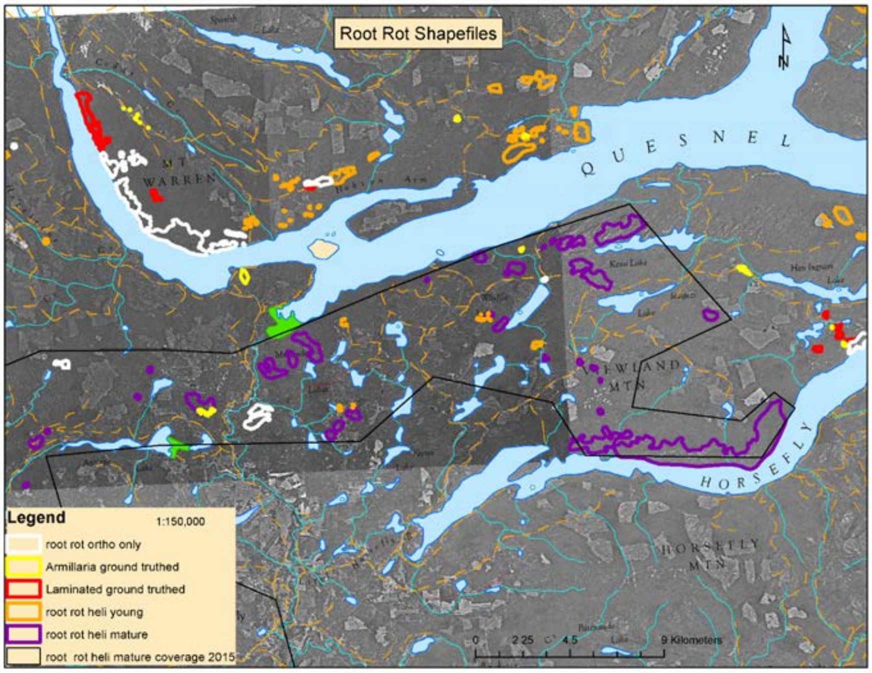

Figure 3. Landscape level root rot polygons based on ground proofed locations (red and yellow), heli mapped locations in young and old stands (orange and purple) and ortho photo mapped locations (white).

*PROGENY TESTING OF LODGEPOLE PINE TO IDENTIFY VARIATION IN RESISTANCE TO ELYTRODERMA NEEDLE CAST

David Rusch[1]

[1]BC Ministry of Forests Lands and Natural Resource Operations

INTRODUCTION

Elytroderma is a common foliage disease in western North America that causes needle cast and systemic infection and stunting of lodgepole pine and ponderosa pine (Figure 1). It also reduces wood quality by causing large upturned branches and abnormal growth rings. It can also occasionally kill trees with severe stunting in the upper crown. The southern Cariboo of BC has a number of lodgepole pine stands with severe stunting and growth loss caused by repeated needle outbreaks in the mid to late nineties. The effects of Elytroderma in some of these stands has been exacerbated by thinning programs conducted during the nineties and the mountain pine beetle epidemic that spilled over into young lodgepole pine stands and resulted in the death of several of the larger trees.

Figure 1. Elytroderma needle cast fruiting bodies on lodgepole pine needles.

A silviculture site prep trial set up in 1988, in the dry cool Interior Douglas-fir (IDFdk4) subzone showed visible (Figure 2) and significant differences in the susceptibility of different lodgepole pine provenances (one bare root and one container stock) to stunting caused by Elytroderma needle cast. Height measurements and measures of stunting caused by Elytroderma showed there were significant differences in disease severity and height between the two provenances. Natural regeneration on the site had similar levels of disease severity and height impacts as the container stock. The bare root stock was from the dry warm sub boreal spruce subzone (SBSdw1) from an elevation of 950m and the container stock was from the very dry cool montane spruce subzone (MSxk) at an elevation of 1225m. The sub boreal spruce zone has an annual precipitation of 585 mm compared to 433mm for the IDFdk4. There are no measurements of annual rainfall in the MSxk but it is a very dry subzone. Other blocks in the area that were planted with stock from the SBS also show anecdotal evidence of improved growth and reduced Elytroderma impacts compared to natural stands of the same age.

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There is some evidence that elevation may play a role in needle cast diseases with trees from higher elevation sites showing greater susceptibility to lodgepole pine needle casts than trees from lower elevations (Carlson et al. 2000). Differences in resistance to foliar diseases have also been linked to growth in wetter provenances in the case of cedar blight (Russell et al. 2007).

Figure 2. Google Photo showing the bareroot pine (dark patches), container pine (lighter) and Douglas-fir (very light). Each row in each block has a Fdi or Pli container and bareroot treatment.

METHODS

A progeny trial is currently being set up in three biogeoclimatic (BEC) subzones in the Cariboo that are high hazard for Elytroderma Needle Cast. The trial will compare the resistance of 94 families from a variety of elevations and BEC zones. Each site is divided into 10 blocks and 5 trees from each family were randomly located within each block (Figure 3). Some of the families (74) are from the Big Bar B+ Family Trial, 5 are control class A seedlots, and the rest (19) are from open pollinated seed from parent trees previously rated for susceptibility to Elytroderma Needle cast by Richard Reich (Wallis et al. 2010).

TRIAL OBJECTIVES

1) Identify families with resistance to Elytroderma needle cast. If significant family differences in resistance to Elytroderma needle cast are identified they could be potentially used in a breeding program. If resistant stock was developed it could help mitigate the future risk from Elytroderma needle cast. Alternatively, it might be possible to use existing seed sources known to have higher levels of Elytroderma resistance to mitigate future risk from the disease.
2) Study whether BEC or elevation of seed provenances is related to resistance to Elytroderma.
3) Compare relative resistance of parent trees previously rated for Elytroderma resistance by with trees grown from openly pollinated offspring.

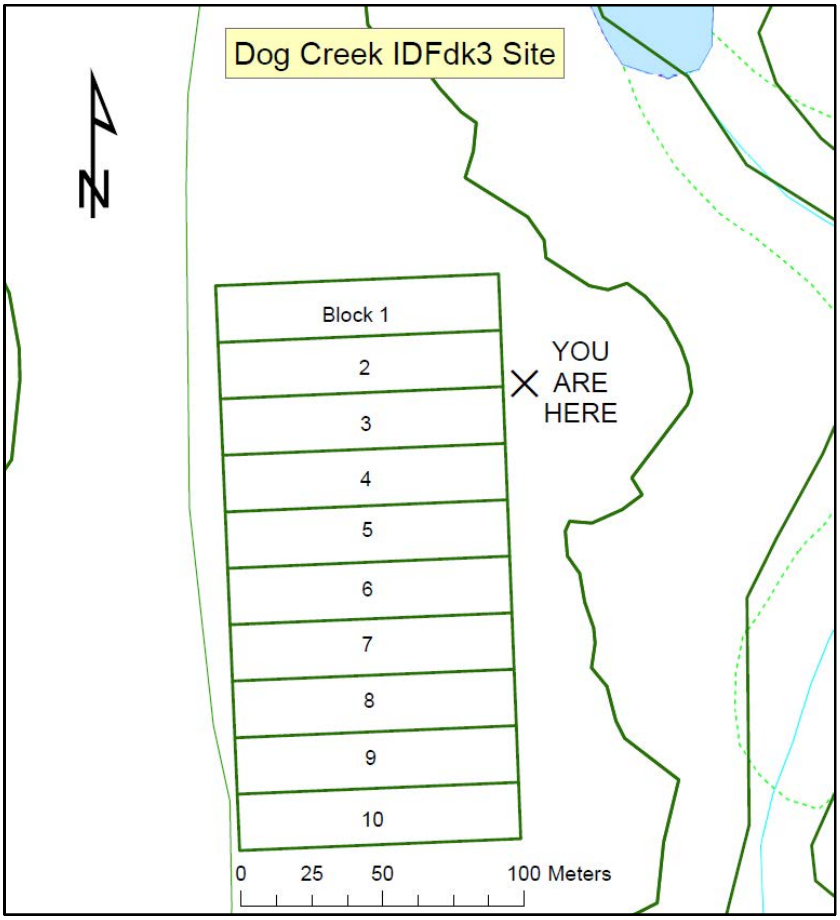

Figure 3. Dog Creek Block Layout.

ACKNOWLEDGEMENTS

I would like to thank Vicky Berger, NIch Ukrainitz, Teresa Newsome, Richard Reich, Rita Wilson, and Harry Kope for their help in setting up the trial as well as Tolko and BC Timber Sales for supplying trial sites.

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*PHYLOGENETIC AND POPULATION ANALYSES OF THE INVASIVE BROWN ROOT-ROT PATHOGEN (*PHELLINUS NOXIUS*) HIGHLIGHT THE EXISTENCE OF AT LEAST TWO DISTINCT POPULATIONS

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INTRODUCTION

Phellinus noxius (Corner) G. H. Cunn is a vastly destructive, fast-growing pathogen that affects a wide range of woody hosts in pan-tropical areas, including Asia, Australia, Africa, and Oceania (Ann *et al*. 2002). This invasive pathogen causes brown root-rot disease on cacao, coffee, and rubber, as well as diverse fruit, nut, ornamental, and other native/exotic trees, and little host specificity is known to occur (Sahashi *et al*. 2010). Symptoms of *P. noxius* infection can include reduced tree growth, defoliation, and branch dieback; however, *P. noxius* can also survive as a saprophyte by colonizing the heart wood and other organic matter. Brown root-rot disease can develop over several years, or in some cases, *P. noxius* infection can cause tree mortality within a year. Understanding the genetic diversity and evolutional history of *P. noxius* populations worldwide well help assess the evolutionary origins, worldwide movement, and potential ecological differences within *P. noxius*, which will contribute to the development of management strategies. Our objective was to understand the genetic diversity and evolutional history of *P. noxius* populations worldwide to assess the evolutionary origins, worldwide movement, and potential ecological differences within populations of *P. noxius*.

METHODS

Isolates and DNA Sequencing

A total of 147 isolates were included from Japan, Taiwan, Australia, China (Hong Kong), Malaysia, and the Pacific islands of American Samoa, Saipan, Guam, Palau, Yap, Pohnpei, and Kosrae were sequenced at four loci including internal transcribed spacer (ITS), large subunit (LSU-rDNA), translation elongation factor-1 alpha (*tef1*), and RNA polymerase subunit II (*RPB2*) (Table 1).

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Statistical Analyses

Genotype sequences were phased into haplotypes for each locus and DnaSP v.5 (Rozas *et al*. 2003) was used to estimate the number of unique haplotypes, pairwise nucleotide diversity (π), and the number of segregating sites for each locus. Haplotype networks were constructed for each locus by statistical parsimony with the program TCS v1.21 using a 92% similarity cutoff (Clement *et al*. 2000). Phylogenies were inferred for collapsed haplotypes for each locus with Bayesian inference using MrBayes v3.0 (Huelsenbeck *et al*. 2001). DT-ModSel (Minin *et al*. 2003) was used to estimate the best-fit, nucleotide-substitution models for each dataset. Bayesian inference was performed with parameter settings suggested by the best-fit, nucleotide-substitution models. The Markov chain Monte Carlo (MCMC) search was run with four chains for 3,000,000 generations generating 30,001 trees; the first 6,000 trees were discarded as "burnin" of the chains.

Table 1. Number and location (Country/ Island) of isolates used in this study.

Country / Island	Number of isolates
American Samoa	30
Australia	25
China	21
Guam	15
Japan	10
Kosrae	2
Malaysia	15
Palau	8
Pohnpei	7
Saipan	12
Taiwan	2
Yap	2

Table 2. Total number of sites, haplotypes, sequence diversity, segregating sites and nucleotide diversity for each lous.

Locus	N [a]	# of hap [b]	Seg. sites [c]	π [d]	H*d*[e]
LSU	880	20	11	0.002	0.837
ITS	639	78	83	0.013	0.924
RBP2	861	86	103	0.014	0.983
tef1	1077	60	83	0.008	0.923

[a] Total number of bps; [b] Number of unique haplotypes; [c] Number of segregating sites; [d] Nucleotide diversity; [e] Haplotype diversity

RESULTS

On the basis of these preliminary analyses, the most diverse locus was the *RBP2* with a nucleotide diversity (π) of 0.014 and a haplotype diversity (H*d*) of 0. 983 (Table 2). The least diversity locus was the LSU region with $\pi = 0.002$ and a haplotype diversity of 0.837 (Table 2). The LSU Bayesian phylogeny highlighted a general grouping of *P. noxius* sequences, while showing that the genus *Phellinus* is polyphyletic, indicating that further research is needed to clarify *Phellinus* taxonomy (Figure 1).

The *tef1* locus showed the most phylogenetic signal of the four loci (Figure 2). The Bayesian phylogeny showed two distinct clades of *P. noxius* that separated sequences by general geographic regions. All sequenced isolates from Malaysia (15) and Taiwan (2) grouped with high posterior probably into an eastern Asia/American Samoa clade, which also contained some isolates from Japan, China (Hong Kong), and American Samoa. Separate from the eastern Asia/American Samoa clade, isolates from Australia, Guam, Saipan, Palau, Yap, Pohnpei, and Kosrae grouped in a distinct eastern Asia/Oceania/Pacific islands clade that also contained some isolates from Japan and China (Hong Kong). Isolates from Australia formed a distinct monophyletic subclade (PP = 0.92) within but distinct in the eastern Asia/Oceania/Pacific island clade. Interestingly, isolates from American Samoa formed a distinct, monophyletic subclade (PP = 0.86) within the eastern Asia/American Samoa clade.

Haplotype networks of the *RBP2* and ITS also highlighted the existence of these two major phylogenetic groups based on each *P. noxius* sequences (data not shown). However, signals of admixture or migration were observed where isolates from the eastern Asia/American Samoa and eastern Asia/Oceania/Pacific islands regions share haplotypes. However, in both networks, isolates from American Samoa formed a distinct group. These American Samoa isolates do not share *RPB2* haplotypes; however, one ITS haplotype is shared with an isolate from Australia.

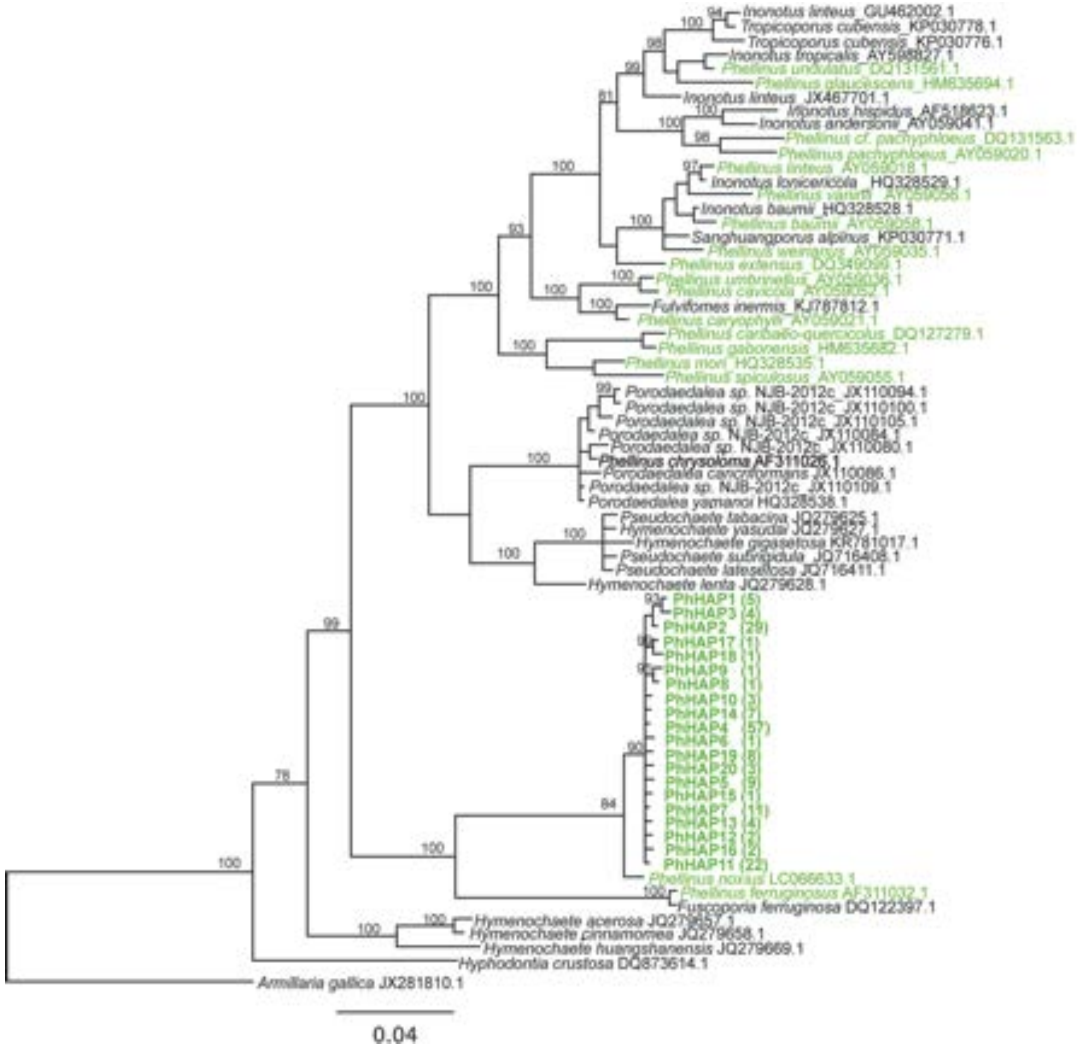

Figure 1. Bayesian phylogeny of the large subunit (LSU; 25S) of rDNA. Node support as posterior probability is labeled above each node. Isolates from this study are labeled as PhHAP. note: these isolates are grouped together in these analyses.

DISCUSSION

From these preliminary sequencing and phylogenetic analyses, we have evidence to suggest the existence of at least two genetic distinct populations of *P. noxius* from eastern Asia/American Samoa (Japan, Taiwan, China, Malaysia, and American Samoa) and eastern Asia/Oceania/Pacific islands (Australia, Guam, Saipan, Palau, Yap, Pohnpei, Kosrae, China, and Japan). However, our data suggests that admixture or migration of genotypes across these two populations is likely to have occurred, which can be compared to regional population structure that has been previously studied in Japan (Akiba *et al.* 2015) and Taiwan (Chung *et al.* 2015). In addition, the results suggest that isolates from American Samoa are genetically distinct, and at the *tef1* locus, group with isolates from the eastern Asia/American Samoa clade. Future analyses will include sequencing data generated by Illumina sequencing of double-digest reduced representation libraries, which will allow high-resolution analyses. Continued analyses will assess regional population structure, gene flow among populations, diversity in recently observed populations, and potential suitable climate space for specific genotypes.

Continued studies of the genetic diversity and population structure of *P. noxius* is essential to understand the pathways of dispersal for this destructive, invasive pathogen. Furthermore, understanding of *P. noxius* populations will contribute to management strategies by better characterizing host range, suitable climate space, and potential/existing hybridization among *P. noxius* populations, which will allow informed predictions of geographic regions that are at risk of invasion.

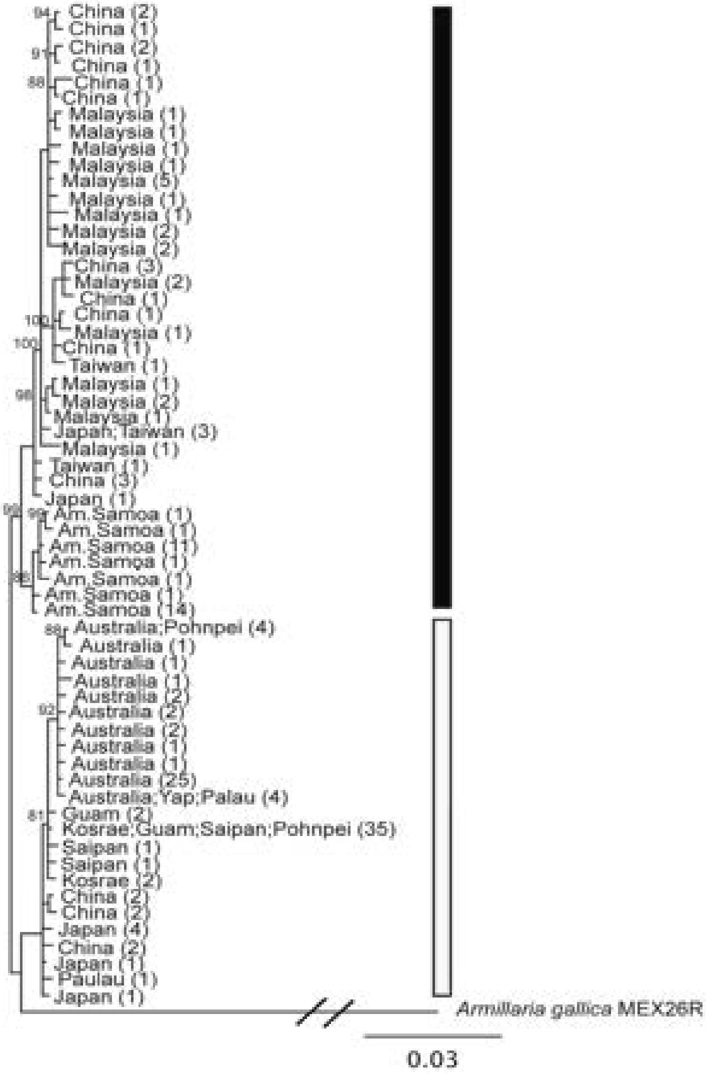

Figure 2. Bayesian phylogeny of the translation elongation factor 1-alpha (tef1) with Armillaria gallica used as the outgroup. Note: support as posterior probability is labeled above each node. Isolates are labeled by their country of origin. There are two major clades, the eastern Asia/American Samoa clade (black) and the eastern Asia/Oceania/Pacific islands clade (white). Isolates from American Samoa form a distinct subclade within the eastern Asia/American Samoa clade.

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COMMITTEE MEETING REPORTS

2016 TWIG AND FOLIAR DISEASE MEETING

Committee Chair: Harry Kope

SHORT PRESENTATIONS

Harry Kope

Septoria leaf blight

- In 2007 the first confirmation and report of *Mycosphaerella populorum* (also known as *Septoria musiva*) in British Columbia was published (Pacific Northwest Fungi, 2; 1-7).
- The disease infects both leaves and stems of hybrid and native poplar trees.
- Since 2008 surveys have been conducted in the Fraser River Valley collecting leaf samples from both hybrid poplar and *Populus trichocarpa* trees.
- In conjunction with the University of British Columbia, a test has been developed to distinguish between native *Mycosphaerella* spp (that do not cause stem cankers) from the canker causing *M. populorum*.
- Infected native P trichocarpa have been found in the Fraser Valley, but at very low levels.
- Although the poplar industry is threatened by this disease the greater threat is to the native poplar species that provide biodiversity and benefits to riparian areas.
- Control of the disease can be managed though fungicide sprays if the trees are small enough and through the selection of less susceptible hybrids.
- Tests are underway in British Columbia to determine whether pre-sterilizing hybrid poplar cuttings (in fungicide) can be a viable method for producing clean planting stock.

Robin Mulvey and Terry Shaw

Sirococcus

- A 1981 publication by Terry Shaw *et al*. (Research Note PNW-387) followed the development of Sirococcus shoot blight on western hemlock following commercial thinning.
- Although shoot blight was present on trees that remained, *Sirococcus* caused little damage to the surviving trees. The recommendation was that thinning can proceed.
- It was recognised that the disease is common and it needs to be monitored and managed.
- More recently, Robin Mulvey has noticed an elevated incidence of Sirococcus shoot blight on hemlock.
- Especially seen on landscape trees (mountain hemlock).
- And there also appears to be a correlation between cold air drainage with higher disease incidence.
- Management suggestions include collecting and using seed from areas where disease pressure is high.

Lori Winton

Gemmamyces

- Buds on spruce species in Southcentral Alaska were noted to be covered with black pseudothecia. Buds may die or twist, causing altered branching patterns.
- The affected tree species were ornamental Colorado blue spruce (*P. pungens*) on the Kenai peninsula.
- Small outbreaks in Sitka spruce (*P. sitchensis*) and white spruce (*P. glauca*) have also been found in native forests on the Kenai Peninsula and the Anchorage area.
- The causal agent was determined to be *Gemmamyces piceae*.

- Coincidentally, an outbreak of *G. piceae* on *P. pungens* was reported in the Czech republic on Colorado blue spruce in 2009 (published in 2016 - http://onlinelibrary.wiley.com/doi/10.1111/ppa.12513/pdf)

ROUND ROBIN

Swiss needle cast

- Stefan Zeglen invited Danny Norlander from Oregon Department of Forestry to assess an aerial detection survey method for determining occurrence and incidence of Swiss needle cast (SNC) in the coastal forests of British Columbia.
- The conventional method of aerial detection survey mapping of SNC has the ability to immediately apply expert knowledge across a broad area and the survey results require minimal post-processing to create maps of disease extent and severity.
- Although forest cover diversity is greater in British Columbia than in coastal Oregon and Washington, it was felt that an aerial detection method could be used.
- Work on this method will continue.

Dothistroma

- Alex Woods said that *Dothistroma* needle blight has flared up again in Northwest British Columbia and has reached levels not seen for the past decade or more.
- The extent of red needles in the Lower Nass River area suggests that the trees had recovered enough to have needles in much of the crown, but these needles have subsequently been heavily attacked.
- There appears to be a relationship between *Dothistroma* outbreaks and El Nino's as presented by Alex at a previous WIFDWC meeting.

2016 ROOT DISEASE COMMITTEE MEETING

Committee Chair: Blakey Lockman

SHORT PRESENTATIONS

Holly Kearns - status of National Root Disease Paper- it's DONE!! It is being published as a GTR through Rocky Mountain Research Station, and hard copies should be available soon.

Amy Ramsey - presented tools being used by Washington DNR for mapping root diseases as a continuation of yesterday's panel on same subject.

- WA Forest Health Protection trying to get foresters to record what they're seeing out in the woods.
- WA DNR using ArcGIS online which can be used on any platform.
- Create an online account, pick a basemap, and then can create specific maps for what you need.
- Drop down menus can be associated with site, tree, disease factors, etc…
- Identify boundary for area of interest- take GPS points and load them into ArcGIS.
- Can easily map root disease areas using GIS points by buffering waypoints, then analyzing and merging polygons developed from these buffered waypoints.
- Can load information on forest management unit, such as a timber sale map.
- Contact WA DNR for more information.

Lori Winton - presented tools being used in Alaska for mapping root diseases as a continuation of yesterday's panel on same subject.

- Lori has had problems with using downloaded maps when out of cell service.
- Setting up a collector application can be very time consuming, so she's now using an application called Survey 1-2-3.
- She uses an iPad, and used it in the winter, with some problems with the external battery.
- To collect data, she brings up a pre-configured spreadsheet.
- Question regarding file types. Lori believes you can download the information as any file type, such as CSV, excel, geodatabase, etc.
- Question: are files compatible with other devices, such as what FIA is using? Lori thinks FIA is using Trimble, but you'd have to get their data and import it into your system.
- Survey 1-2-3 has data summaries, maps, dates of surveys, etc… many statistics are available.
- Question: what is the storage capacity and speed? It is assumed it's not taking up as much space because you aren't uploading a lot of spatial data.
- Lori shared some minor issues as a user, including to remember to always push the compass button in the collector application!
- Short discussion:
    - Blakey- Region One is trying to get data into FSVeg system.
    - Lori- at the national level, they should standardize data collection and archiving.

Dave Shaw - discussed some historical laminated root rot plots and drumming interest in remeasuring the plots.

- Blyn plots- plots established in 1926 by WH Meyer, located in NE area of Olympic Peninsula. 0.75 acre plots, trees 42 years of age in 1926.
- Plots resurrected by the Permanent Study Plot program, a partnership between the H.J. Andrews Long-Term Ecological Research program and the USFS, PNW Research Station, Corvallis.
- Highlights from remeasurements:
    - No large gaps, laminated root rot appears to be killing trees throughout infection areas, but so far, not all DF.
    - Accelerating succession- shifting species dominance to cedar.
    - Alternative pathway for old-growth development?
- Will Littke- growth and yield projections always in disease-free stands so this data was probably dropped. Dave- relevance of these plots to management is probably limited, but they are very relevant with describing successional pathways in old-growth.
- Dave looking for interested parties to help with the next remeasurement, planned for 2017. (It was suggested he send out an email to WIFDWC mailing list to see if anyone wants to volunteer to come help.)

ROUND ROBIN

Helen Maffei - working on long-term plots with Armillaria in mixed conifers. They were set up with Greg Filip in the early 1990's- this will be a 5-year remeasurement, and will then do a 20-year write-up. Trees go from non-infected to infected to mortality.

Blakey Lockman - FHP Report of one set of Sue Hagle's permanent root disease plots in R1 was completed: . Blakey recently cleaned up another set of these plots and hopes to get a summary report next winter. This will be 2 sets completed out of XX sets of plots.

James Jacobs - working on a Ganoderma diversity study.

- Montana, Idaho, Oregon, and Washington samples have provided some interesting results.
- Samples need to include species, host, disease presence, and should be a conk with some wood attached.
- Store: freezer or dried down. Freezer with overnight shipping is the best.
- Need samples from Equador, Minnesota, and other places….

Michael Murray - working on stump removal being done in BC for control of Armillaria root disease. Is it worth it to stump? Need to model growth and yield after stump removal. If anyone has data, please send.

Pete Angwin - at Happy Camp- Klamath NF- finished round of remeasurement of blackstain on DF. PCT in areas with plots. Added more plots to network with thinned and unthinned.

2016 HAZARD TREE COMMITTEE MEETING

Committee Chair: Kristen Chadwick

Meeting notes: Betsy Goodrich and Kristen Chadwick

Kristen Chadwick brought the meeting to order. The group said thank you to the former chair Pete Angwin for nine years of leadership with the Western Hazard Tree Committee. Pete was present for the meeting.

The Western Hazard Tree Committee hosts a workshop every three years jointly with arborists. The next workshop is in Bend, OR October 18-20th 2016 at the DoubleTree in downtown Bend. The agenda is coming together. There are three Program Chairs; Bill Jones from the Ashville field office, John Guyon, and Paul Reese with Oregon State University. Helen Maffei and Brent Oblinger are the local arrangements coordinators. Jessie Glaeser is the secretary and will be compiling the proceedings. This year registration is being handled by Oregon State University Conference Services as well as some of the local arrangements logistics.

Lori Winton gave a special presentation demonstrating the app they had developed for an iPad that included forms they have developed for hazard tree data, how to spatially mark the location and how the data is stored. It works in conjunction with ArcGIS online and the app runs on an android and iPad. Using survey 1-2-3 is easy and you don't have to download a basemap. The app is designed from the R10 book and is still in development. It features drop down menus, auto fill options, calculated failure potential, and calculates the sound rind thickness.

Lori's presentation led to a discussion about the development of databases and data collection methods that are spatially related. Kelly Burns mentioned that they had one set up on a website for Trimble units, yet no one uses Trimble GPS units any more. Although Brent Oblinger was not present R6 mentioned the database development that he had for the Deschutes that was specific to Trimble units. Kelly mentioned that Jim Worrel had a database where data could be uploaded easily and it had data summaries that were easy to do. Overall it was noted that each region had a need to develop some type of long term data collection unit and things were moving along so data collection and retrieval is becoming easier.

James Jacobs asked if we could find time on the agenda in the Bend meeting to get the FS people together to talk about standardizing the data platform and apps so we can all collaborate. It was agreed that we could all get to Bend early and have an afternoon discussion on Monday.

Pete Angwin discussed the Forest Service's AgLearn hazard tree training. There is an online training in the FS AgLearn system that was developed by the Missoula Technology Development Center. The same group is putting together a danger tree awareness guide. Kristen Chadwick, Pete Angwin, and Bill Jones are helping with the editing. The timeline for completion is unknown but the group is working on having a useful guide for all field going employees nationwide. We may be sending out a request for photos for the guide.

Forest Service Regions 1 and 4 are working on a standardized Hazard Tree guide led by John Guyon and includes Paul Zambino, Christy Cleaver, and Angel Saavadra. The group is working on the field guide, developing appropriate forms, and standardized powerpoints for trainings. They have used manuals from R5 and R6.

Jim Blodgett mentioned that Region 2 will also have a new field guide and is asking for comments from students.

The meeting was cut short to accommodate the afternoon field trip.

CLIMATE CHANGE COMMITTEE MEETING

Committee Chair: Alex Woods

Meeting Notes: Christy Cleaver, Paul Zambino, Alex Woods.

As pathologists we know the role of the environment in the disease triangle. That concept is based on the interactions between environment along with the host and the pathogen and how those interactions between all three dictate the extent and severity of disease. So, if we recognize how much the environment has already changed we should expect to see changes in disease behaviour. We need to be skeptical about attributing too much to climate change (CC) but at the same time we should recognize the importance of a changing environment on diseases. Many agreed that we have to be careful about blaming CC for changes too quickly.

The difference between weather and climate was discussed. Extreme variation in weather from one year to the next and the effect that can have on hosts and pathogens is significant and is probably responsible for many of the unusual disease occurrences we are seeing and those year to year differences are due to weather not climate change. For example, last spring in SE AK was very warm and dry and there was a higher incidence of a weak pathogen resulting in canker in alder. Parts of SE AK saw only one day of rain last May and experienced high temperatures. It was not expected that the canker would be back again this year. So this was an example of an unusual weather event and not climate change. But, wider variations and increased frequency of extremes in weather is consistent with projections of the effects of global climate change. We are likely to see greater extremes and so should expect to see more of the unexpected. The CA weather extremes alone could not be considered climate change and it is impossible to predict such events using probabilities.

Alder die off in the Rocky Mountains of CO has been attributed to the PDO but climate change could make the conditions that caused the die off to be more permanent. The question was asked “how many documented changes in disease behaviour do we have? It came down to basically the yellow cedar decline story and the Dothistroma story in NW BC. It was suggested that if we wait to have the perfect example it will be too late to do anything about it. It might help if we speak to the trends we are observing and pose the question “Is this a signature of climate change?” We still have to look at other climate forcing factors like the PDO and ENSO and see if the observed changes are not consistent with those factors. Why is it important to attribute strange forest disease events to climate change?

We should accept that under climate change we have increased uncertainty about how all of the systems we thought we understood will behave. In the most general sense with higher CO2 concentrations in the atmosphere more heat is trapped and there is more energy in the whole system. So even if a disease outbreak can be linked to another forcing factor like PDO or ENSO the frequency and behaviors of those other forcing factors is being influenced by more energy in the system. There has been a documented link between climate change and more frequent extreme ENSO events.

One of the first disease groups to be affected by climate change will be the foliar diseases and already that appears to be playing out. An increase in precipitation coupled with warmer temperatures will favour many foliar diseases. Warmer temperatures in the absence of increased rain will lead to host stress and a different group or groups of pathogens like bark cankers and root diseases.

Some are still worried about making any statements about how a changing climate may affect forests and forest diseases because if the GCMs predict overall drier conditions and instead increased summer precipitation occurs causing increased foliar diseases the public will think the pathologists lack credibility. It is our role as scientists, however, to be as honest as we can about what we believe is happening and to try to uncover the underlying causes. Do we need or want to attribute or associate changes in forest disease behaviour with climate change? In short, yes. If we can show compelling evidence of climate change influences on forests and forest diseases we can add our collective voices to the growing body of evidence of the fundamental changes to our environment. With that message we can advocate for the need to make the fundamental changes necessary to reduce the emission of GHGs so that we can start to combat the root cause of climate change. We can also try to influence forest management decisions so that the losses from diseases are minimized and so that forests can fix as much C as possible as sustainable forest management is one of the few proactive mitigation options available to combat climate change.

One of the most fundamental forest management decisions is that of which species to plant. In BC assisted migration of tree species is being practiced with western larch moved as much as 3° latitude N in part due to the extent of losses in lodgepole pine regeneration from rusts and other forest health factors. Assisted migration adds to the species options and increases biodiversity and the forests ability to continue to fix C. But those species will still have to be capable to coping with cold events and frosts that challenge trees when they are no longer on site. The subject of assisted migration was clearly a hot button issue with many at the meeting. People are worried about moving disease along with species to new environments. It was stated that trees are long-lived and in many areas they may have out-lived their adaptation to where they are growing.

T. Shaw mentioned that some Forest Plans are being challenged because they are not incorporating the effects of climate change into management. The question of which areas can forest management have an influence on is germane. In intensively managed stands on shorter rotations (40 years) a species decision can be made and then lived with for that period but possibly changed in the following rotation. Such decisions are not as easy to make with longer rotations because you are stuck with a species like lodgepole pine for 80 years. In protected areas there is very little that can be done. There are other management adaptations that can be used including higher planting densities

It was suggested that we should have a panel on assisted migration at an upcoming WIFDWC and have the panel in a debate style format. It was also suggested that a panel on other adaptive management approaches in forest management to cope with climate change in forest management would be a good subject.

The discussion came back to forest pathology and the attribution of causes to new and different disease behaviours. It was generally agreed that with CC we can expect to see more diseases but that we should be careful when attributing disease events to CC specifically. The interactions are complex. Concerns were raised about undermining our credibility by diluting solid disease/climate change stories with other rare event stories. We need multiple defensible events to get managers buy in that climate change is having an impact on forest diseases. If these damaging events are not properly accounted for then the productivity of the forest may be over-estimated. A few people were surprised at the hesitancy of many of the pathologists present to be willing to associate changes in climate with changes in disease behaviour. The question was asked “how many of you think weird things are happening with diseases in forests?”

ROUND ROBIN

Michael Murray: In the Canadian Kootenays they have had very wet springs which have increased the incidence of many foliar diseases. In the same area birch decline has resulted from a combination of unusual weather events (extreme drought and heat in 1998) and build-up of weak pathogens. Armillaria root disease has also increased in incidence as a result of hot dry years. Dothistroma needle blight was seen on ponderosa pine for the first time last summer. BC's Chief Forester has asked for documented evidence of the impacts of last year's drought.

Blakey Lockman: Do we wait for a major outbreak of some new disease or do we try to influence management now?

Kathy Lewis: We should go beyond our role as forest pathologists and advocate for the need to address the root causes of climate change and the need to change our collective behaviours. We need to go political.

Kristen Chadwick: The Swiss Needle Cast Co-op quantified the economic losses associated with that disease in order to change management.

Jared LeBoldus: Looked at black-stain root disease with foresters and the foresters said the damage was unusual and probably due to climate change so there was nothing you could do about it.

Alan Kanaskie: Forester's attitude is if it is climate change causing the damage it is not their problem because they are going to be gone before things get really bad.

Terry Shaw: The timing of green-up is related to the severity of some diseases.

Amy Gagnon: There are lots of examples in entomology and the interactions between drought, fires and insects.

Out of the entire discussion in general there seemed to be more reluctance on the part of the Americans in the discussion to associate possible changes in disease behaviour with climate change while the Canadians seemed more comfortable with this. David Price suggested that because Canadians are further north and the changes are supposed to be greater in the north that Canadians have more clear examples in their faces.

WIFDWC
WIFL
Save Whitebark Pine

DWARF MISTLETOE COMMITTEE MEETING

Committee Chair: Dave Shaw

Upcoming meeting in Ashland, Oregon: IUFRO 7.02.11, *Parasitic flowering plants in forests*, Conference: Mistletoes: Pathogens, Keystone Resources, and Medicinal Wonder. July 18th-21st, 2016 (see meeting update at end of minutes).

Discussion on taxonomy of Arceuthobium and Phorodendron (reduces number of Arcuethobium spp. from 46 to ~22 or 23, see previous meeting notes for details). Name changes have the potential to be confusing to those managing dwarf mistletoes. For example, *A. campylopodum* on western larch – managers, etc. will have to interpret literature based on the host under new taxonomic changes. Update on the letter written by WIFDWC group – there will be editors notes saying the name changes aren't full accepted.

New publication: Mathiasen and Kenaley 2016. The Classification of California Viscaceae: An Alternative Perspective. Madroño, 63(1):8-33.
DOI: http://dx.doi.org/10.3120/0024-9637-63.1.8

ROUND ROBIN

Blakey Lockman – Really need to take closer looks at western larch with DM infection. Example: western larch with severe DMT found on Lolo NF outside Missoula – found heavily decayed roots with possible tomentosus (sent to Jessi Glasser for ID). Suppressed understory larch with dying roots and butt rot. Symptoms included some resinosis on small trees, some roots had lesions below-ground but mostly crown symptoms.

A discussion followed on whether the larch will die fairly quickly (~10 years) with heavy mistletoe. Some discussion on whether it is accurate to advise that larch with heavy DMT (DMR = 5/6) would not infect understory trees (Hadfield and Schmidt 2009 publication says those trees will die soon and/or lose branches/brooms, but Bob Mathiasen has a publication on infection of understory larch by o/s trees, 1998 West.J. Appl. For. 13(2):41-46).

Josh Bronson - report on rate of intensification and spread of DFDM in SW Oregon is now out (SWOFIDSC-16-10, April 2016).

James Jacobs – A new publication on the DM "knee-high rule" (intensive DM management on reservation in NM) – provide info on incidence of latent infections after overstory removal. Still observing stump sprouts 11 years later (more common in SW). Asked if there was interest from the group if they held a workshop on PIPO DM management on the Mescalero Reservation in NM (a silviculture plus meeting).

Helen Maffei – pushing to finish up permanent plot studies (pruning DF DMT in campgrounds and growth responses, 15 year results). Publication out soon.

Some discussion about western hemlock DMT and relationship to bird habitat in western PNW. Murrelets are thought to use platforms behind brooms on swollen branches (or may only need a large branch?) They also use moss mats, there are some researchers in Oregon studying murrelets. It was also noted that not all large, swollen appearing hemlock branches are infected with DMT.

Report on the IUFRO 7.02.11, *Parasitic flowering plants in forests*, Conference: Mistletoes: Pathogens, Keystone Resources, and Medicinal Wonder. July 18th-21st, 2016. Ashland, Oregon, USA.

The IUFRO technical group, 7.02.11, Parasitic flowering plants in forests, held a conference in Ashland, Oregon, USA: Mistletoes: Pathogens, Keystone Resources, and Medicinal Wonder. July 18th-21st, 2016. The Klamath-Siskiyou region of Southern Oregon and Northern California is widely known for botanical diversity, including expansive regions of serpentine bedrock with endemic species of trees and other vegetation. The mistletoes are no exception, with Viscaceous mistletoes numbering 11 taxa (species, subspecies, forms) of *Arceuthobium,* and 4 taxa (species) of *Phoradendron* in the region. For this reason we held two full day field trips led by Robert Mathiasen and David Shaw, one to Crater Lake National Park, a high elevations site, and another to the serpentine region SE of Grants Pass, Oregon. The meeting featured keynote addresses from David Watson (Australia), "Of mistletoes and mechanisms: advances in understanding their ecological role and ecosystem function" and Cynthia Ross-Friedman (Canada), "The Little Bang Theory: Explosive Seed Discharge in Dwarf Mistletoe". Other talks from world renowned mistletoe experts such as Gerhard Glatzel, Clyde Calvin, Carol Wilson, Vanessa Ashworth, Robert Mathiasen, Shawn Kanaley, Barry Logan and Gregorio Ceccantini covered a wide breadth of topics. Graduate students that addressed the conference were from USA, Canada, Brazil, and Germany. A special section of the journal Botany (formerly Canadian Journal of Botany) is forthcoming in 2017, and may have 12 papers included.

Figure 1. Field trip to serpentine soils, with Jeffrey pine (*Pinus jeffryii*) infected by *Arceuthobium campylopodum*, knobcone pine (*P. attenuata*) infected with *A. siskiyouense*, and incense cedar (*Libocedrus decurrens*) infected by *Phoradendron libocedri*.

Figure 2. Specimens were collected for demonstration by Robert Mathiasen, such as this endemic species to the area.

NURSERY COMMITTEE MEETING NOTES

Committee Chair: Anna Leon

The 2016 WIFDWC Nursery Committee Meeting followed a roundtable format with informal presentations and discussions on a number of nursery related issues. A central focus for many of the attendees was the constant presence of methyl bromide in our discussions both as a difficult problem to surmount and as one of the only funding sources for nursery research. Representatives from region nurseries discussed relevant local issues and all expressed concern about the lack of funding for nursery operations and the limited role that nurseries have taken over the past several years. Concern continues to be expressed regarding the movement of plants and procurement of plants from unknown sources, the latter having been met with new mandates that plants be sourced from federal nurseries by the Forest Service.

The following are a summary of roundtable items discussed by meeting participants:
Anna Leon – Overview of Allyl Isothiocyanate (AITC/Dominus) trial at Weyerhaeuser and the Washington Department of Natural Resources Webster Nursery. AITC is being tested with and without chloropicrin against a methyl bromide operational control at both facilities and also against chloropicrin alone and bare fallow at Webster. Early results show no difference in seedling morphology or soil and seedling pathogen loads. More detailed results will be presented at the 2017 nursery committee meeting.

John Browning – Overview of a solarization trial led by Jennifer Parke at Oregon State University. Jennifer has had success greatly reducing *Phytophthora* and weed levels in raised bed solarization plots using anti-condensation film. She is now expanding her work to also look at rates of *Pythium, Fusarium,* and weed reduction in collaboration with Weyerhaeuser and other nurseries. There was some discussion about the target temperatures and concern about how deep the solarization will be effective.

Jim Blodgett – Gave an update on the status of the nursery and handed out the "2016 Nebraska National Forest Nursery" update. The nursery is growing shrubs and other landscape plants to increase funds because the nursery is self-supportive. This led to a conversation on the fading nursery industry. Many federal nurseries are not growing at the same level they used to.
This year a major hailstorm resulted in greenhouse damage at the Nebraska National Forest Nursery. *Phomopsis* was a problem on junipers for a few years, but eventually went away on its own. Paul Zambino also saw *Phomopsis* on larch plantations, but has not yet found any in the nursery. However, this may be an indication that *Phomopsis* is on the rise.

Josh Bronson – There are no disease issues on the bareroot stock at the J Herbert Stone Nursery due to good sanitation practices. They are having problems with dieback of *Clarkia*, (a restoration forb) occurring 100 feet from the row end. The OSU plant clinic found *Phytophthora* at the root crown, but Josh couldn't find it with an ELISA test. The seed manager also found *Fusarium* in some seed lots before it became a widespread problem. Hot water is currently used for seed treatment.

Jane Stewart found *Fusarium commune* on sugar pine.

Gerry Adams – Discussed the political climate of nursery research in which we must work on methyl bromide alternatives to receive funding. Efficient Basamid application could be the answer with good machinery, however the methyl bromide situation raised the price of Basamid. It's difficult to work within the political funding climate and where legal issues prevent research from progressing or information from being disseminated. Funding tends to go towards mitigating current infections (primarily with regard to SOD), and not towards protecting uninfected areas. Also there were recently pines in the upper peninsula of Michigan removed that were raining *Diplodia* down on young trees. Molecular assays were done that determined that red and Scots pine seedlings had endophytic *Diplodia* infections. Mugo pine, Scots pine, and other species are planted as windbreaks around the nurseries. This is a common practice in which excess stock are used as windbreaks, however this often leads to susceptible species and stocks being planted in vulnerable areas.

Jerry Wieland – Having methyl bromide money has helped grow his program because he uses the leftover funds for other basic pathology work such as *Pythium* identification, pathogenicity trials, biocontrol trials, and population genetics. However, it's worth noting that the biocontrol research has not lead to any potential treatments as they are not consistent and often fail in the field, potentially due to the diversity of pathogens. The population genetics study has shown that pathogens are being moved between nurseries and that there are some fungicide resistant types. However, the lack of funding for research makes nurseries a troubling place to work for early career scientists.

Paul Zambino – The Coeur D'Alene nursery had a willow and poplar borer outbreak and the trees have Valsa cankers associated with the borers. It's likely that the water regime was not kept up with to prevent stress to the trees. Last year there were *Fusarium* problems on western whitebark pine.

Josh Bronson – There has been a recent mandate from the forest service that everything needs to be grown by Stone and other forest service nurseries rather than outside nurseries. This mandate is in response to foresters ordering from online sources of unknown quality in the past. However, there is concern that this mandate may not cover all seed that is grown.

OTHER REPORTS

STUDENT AWARDS COMMITTEE REPORT

Betsy Goodrich, Dave Shaw, Harry Kope and Alex Woods

The Student Travel Award Committee again was busy in the months leading up to WIFDWC. The timing of the meeting in May caught us a bit off-guard as we weren't used to reviewing applications in March. The chance to visit Alaska was irresistible so there was a great contingent of graduate students at WIFDWC this year. We reviewed seven excellent applications and in the end gave out travel awards totaling $1704.

Congratulations once again to the following students:

Mikhail Yatsov, **Brandon Alveshere**, **Patrick Bennett**, **Dixie Daniels**, **Kelsey L Dunnell**, **Yung-Hsiang (Sky) Lan**, and **Katie McKeever**

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 $1,062.00,similar to the year earlier. In addition, there were 46 regular WIFDWC member registrations which added $690.00 to the student travel account which now has a balance of $2,160.00.

Jared LeBoldus has now joined the committee, and Alex Woods has cycled off. Thanks to Alex for his time on this committee and to Jared for stepping forward.

BUSINESS MEETING MINUTES, 64TH WIFDWC

Secretary (acting): Betsy Goodrich

The WIFDWC business meeting was called to order by the Conference Chair Paul Hennon at 9:20 AM on Friday, May 13th, 2016. There were 40 people in attendance.

OLD BUSINESS

A motion to adopt the 2015 business meeting minutes without revision was made by Ellen Goheen (then seconded). Motion passed.

Holly Kearns reported a summary of the Treasurer's report, including that there were 60 registrants for this meeting. She also reported approximately $16,000 from regular member registrants and $900 raised at the silent auction will go to the Student Awards Committee. There is still approximately $7,056 available in the international travel fund (discussed in new business) and $7,766 in the hazard tree workshop fund. A complete report will be included in the Proceedings.

Stefan Zeglen confirmed that the 2017 WIFDWC meeting will be held on Vancouver Island. There is no date set and he would like to poll the group. There is a conflict with the IUFRO 25th anniversary the week of Sept 23, 2017. It was suggested to hold the meeting in spring, but Stefan mentioned he would rather not have the meeting in the spring. A discussion on the merits of holding the meeting in September vs. October was held (September = travel restrictions and October = a new fiscal year for US government employees). A straw poll showed that the majority of attendees would prefer the meeting in October over September. The Chair chose to table the conversation on specific dates for now, no specific date was set but decided that the meeting would be held in October 2017.

NEW BUSINESS

The chair thanked the meeting organizers and local arrangements for the Sitka meeting.

The group discussed proposals for meeting locations in 2018. It was decided that there had been several meetings on the coast in recent years and it should be moved inland in 2018 and Regions 1 and 3 were next on the list to host. Jane Stewart said Colorado would be interested in hosting, possibly Estes Park. Mike McWilliams proposed a motion that the 2018 WIFDWC be held in Colorado (seconded, passed).

Robin Mulvey suggested trying to decide on season of meetings and the possibility of alternating fall and spring meetings. Kristen Chadwick suggested that the bylaws address the season and Ellen Goheen suggested the bylaws stated it was up to the host (*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"). Holly Kearns mentioned that it was a financial challenge to have two meetings in one fiscal year for government employees.

The slate of candidates for the 2017 meeting executives was reported as: Conference Chair (Harry Kope), Program Chair (Dave Shaw), Secretary (Christy Cleaver, nominated by Jane Stewart, seconded, passed), Interim Program Chair (Sarah Navarro), Treasurer (Holly Kearns), Local Arrangements (Stefan Zegler).

Ellen Goheen made a motion to close and accept nominations (seconded). Motion passed. Sarah Navarro presented two ideas brought forward to her regarding the 2017 meeting: 1) panel on forest health and forest economics and 2) a panel that focuses on the social science aspects of forest health.

Brief reports were then given from the standing committees.

Anna Leon reported on the nursery pathology committee meeting. There were conversations on the status of various nurseries and an active conversation on the use of methyl bromide. She will write up and include details in the proceedings.

Blakey Lockman reported on the root disease meeting. 40 people were in attendance at the lunch meeting. The National Root Disease white paper has been published. There were continuous discussions on mapping root disease, both Lori Winton and Amy Ramsey discussed and demonstrated technology available for mapping root disease in Alaska and Washington, respectively. Dave Shaw discussed long-term laminated root rot plot re-measurement efforts in western Washington. More info will be provided and emailed by Dave, he was encouraged to solicit help for re-measurements from the group. Blakey will submit a written report on the meeting.

Kristen Chadwick reported on the hazard-tree committee meeting. She thanked Pete Angwin for his tenure as the chair of the committee. An upcoming Hazard Tree Workshop is partially WIFDWC sponsored and will be held in Bend in October 2016. The workshop will be 1.5 days indoors, 1.5 days outdoors on field trips. The registration will open on the website in June. Lori Winton presented on using a hazard-tree data collection template on an iPad at the meeting. There was discussion to get USFS group together the Monday before the workshop in October to standardize the data collection and technology.

Dave Shaw reported on the dwarf mistletoe meeting. It was a good meeting, a lot of rekindled interest in larch dwarf mistletoe (see new publication by Jackson et al. 2016). There still doesn’t seem to be an agreement among individuals working on dwarf mistletoes about taxonomic clumping and splitting. The IUFRO parasitic flowering plants subgroup is hosting a meeting on mistletoes in Ashland, Oregon on July 18-21, 2016.

Harry Kope reported on the Foliage and Twig Disease committee meeting. It was a well-attended meeting. Septoria blight was discussed, Terry Shaw and Robin Mulvey discussed Sirococcus on hemlock, Lori Winton discussed and showed excellent photos of black spruce buds (Gemmamyces spp.), Dave Shaw discussed Swiss Needle Cast and Alex Woods presented information on Dothistroma in British Columbia.

Alex Wood reported on the climate change meeting. It was a very good meeting that was well attended with lively discussions; Alex thanked Christy Cleaver for taking notes. Issues discussed included panel subjects for future meetings, having assisted migration discussions in a debate format, and what can we do to help forests adapt to a changing climate? Kathy Lewis called for people to think more actively and lead by example. Alex will discuss ideas with next year’s program chair.

The outstanding achievement award committee contains members that cycle out every three years and there are personnel changes this year. Kathy Lewis will rotate off the committee. Current members included Ellen Goheen as the lead (2015), Jared LeBoldus (joined for 2016 meeting) and Anna Leon (joining for 2017 meeting). Jared LeBoldus is a professor and Canadian, fulfilling the need to have academic and international representation on the committee. It was asked whether the international representation had to be stationed in their country of representation – it was decided to check the letter and intent. Paul Hennon mentioned that there were no nominations this year and that many WIFDWC members have not won the OAA, even though you may assume they have. He encouraged members to check the list of previous awardees and nominate exceptional candidates this year.

Alex Woods reported on the student awards committee update. Current members are Alex Woods, Harry Kope, Dave Shaw and Betsy Goodrich. Dave Shaw nominated Jared LeBoldus to replace Alex Woods on the committee (he will cycle off), he accepted. The awards committee gave funds to seven students this year to attend the meeting. It is important to adhere to deadlines for student award applications in future meetings as the awards may affect their ability to attend and meet early registration deadlines.

Paul Hennon initiated a discussion on the WIFDWC website. Robin Mulvey explained that this year they found out the FHTET webmaster/contact had a temporary position cut and that FHTET cannot support the website anymore. The local meeting committee wanted to use Region 10 people but FHTET said they cannot do that. So they contracted with a person out of Albuquerque – Barry Lilly – who did an excellent job helping with the website this year. However, this poses a challenge when the meeting is not hosted by USFS. Robin Mulvey also mentioned that having the website associated with a federal server poses logistics that include 508 accessibility compliance, which makes it very difficult to get older proceedings onto the website. It was brought up that it is time to look at private options for a website. Danny Norlander suggested that as an organization we could host our own website as it is fairly inexpensive (~$200/year), it could be fairly basic and you do not need a consultant. Holly Kearns mentioned that the forest insect group, WFIWC, have their own website and it was agreed that having a website separated from FHTET was a good option. The option of Oregon State U. hosting the website was brought up by Mike McWilliams, and Kristen Chadwick shared that she is working with OSU on the logistics and website for the Hazard-tree workshop this year. Stefan Zeglen made a motion to vote that Danny Norlander investigates and invests in options in conjunction with the 2017 planning committee for hosting WIFDWC 2017 website on a non-federal option (seconded, passed). Holly Kearns said there was money available in the budget for this option. The vote passes unanimously.

Paul Hennon initiated another general conversation on seasonality of WIFDWC meetings. Mike McWilliams stated that the advantage of September was that it was early enough for academics to attend. Blakey Lockman recalled that the original idea for alternating between Sept and October was that it would favor both academics and federal employees. Holly Kearns pointed out that the bylaws state a preference for late summer but ultimately dates are chosen by the Executive Committee. Jane Stewart mentioned that a heavy fall course load made October meetings almost impossible. Paul Hennon concluded that the group would keep having discussions on this topic but no conclusions were made today. The 2017 meeting had already been decided on October 2017.

The topic of international funds was initiated by Paul Hennon. The discussion was opened to help clarify the intent of these funds with the group. Holly Kearns mentioned that the original grant obtained by Phil Cannon was for $20,000 to bring 3 visitors from Mexico and 1 visitor from Guam. They only spent ~$10,000 of the funds, so half the funds are left and there has been little direction with how to use them. There is no direction to return funds. Funds could have been used to help fund invited speaker travel from New Zealand and England at the 2016 meeting, but neither speaker sent airfare receipts/requests for reimbursements. Dave Shaw mentioned that Phil Cannon's intent was to encourage pathologists from

Mexico to attend the meetings to build relationships, and that we should stay consistent with his original intent. Terry Shaw made a motion that 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. The motion was seconded by Kristen Chadwick and passed.

Paul Hennon then initiated a conversation on meetings management guidance. Robin Mulvey mentioned that you need a letter on the meeting stating the rational and an approximate number of attendees which then has to go up the chain of approvers after submitting the package. This is a lot of pressure for the planning committee. Robin suggested that a subcommittee be put together with the duties of defining the meeting rationale and meeting management information needed. Ellen Goheen mentioned that a subcommittee of FS employees was the best option for the next meeting because it shouldn't be up to Canadians to work on meetings management paperwork for FS employees. Three people volunteered to form the subgroup to put together the rational: Josh Bronson, Blakey Lockman and Robin Mulvey. Blakey Lockman mentioned that it is important to involve Bruce Moltzan in the meeting rationale and Paul Hennon mentioned that support from the R10 Regional Forester helped for this meeting.

Blakey Lockman then wanted to take a moment to thank the planning committee for an excellent meeting in Sitka. Robin Mulvey thanked Steve Swenson, Liz Graham and Melinda for local arrangements support.

At the close of the new business, a motion was made to end the business meeting and the motion was passed. The business meeting ended by 10:15 AM on Friday, May 13th.

TREASURER'S REPORT, 64TH WIFDWC

Submitted by Holly Kearns

The 64th annual WIFDWC in Sitka, Alaska had 66 attendees including 46 regular members, 7 graduate students, 5 retirees, 1 single day attendee, and 7 guests. The following is a summary of transactions for the WIFDWC accounts from 11/30/2015 through 12/31/2016. The WIFDWC Federal Tax Identification Number is available upon request**.**

	Income / Expense	Balance	Total Account
All WIFDWC Accounts balance 11/30/15			**$44,963.05**
WIFDWC Meeting Account balance 11/30/15		$27,427.47	
Total registration	17,612.13		
Hotel meeting rooms, meals & breaks	-6,993.63		
Welcome social	-308.33		
Banquet	-3,027.62		
Field trip transportation	-3,200.00		
Field trip supplies and snacks	-305.38		
Souvenirs	-540.00		
Office supplies	-237.61		
Invited speaker expenses	-1,000.00		
Regular member registration fees to STA Fund	-690.00		
Other Account Activity			
2015 Proceedings (printing and formatting)	-4,055.65		
2015 Proceedings (postage)	-621.20		
WIFDWC Meeting Account balance 12/31/16		**$24,060.18**	
Hazard Tree Committee Account balance 11/30/15		$7,666.94	
Invited speaker expenses	-3,873.26		
Field trip supplies and snacks	-283.70		
Hazard Tree Committee Account balance 12/31/16		**$3,509.98**	
Student Travel Award Fund balance 11/30/15		$2,112.00	
2016 Student Travel Awards	-1,704.00		
2016 Silent auction proceeds	1,062.00		
2016 Regular member registration fees (46 @ $15)	690.00		
Student Travel Award Fund balance 12/31/16		**$2,160.00**	
International Sponsorship Fund balance 11/30/15		$7,756.64	
No activity			
International Sponsorship Fund balance 12/31/16		**$7,756.64**	
All WIFDWC Accounts balance 12/31/16			**$37,486.80**

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		

Year	Recipient	Meeting	Comments
2009	Bill Jacobi	Durango, CO	In recognition of his 30-plus years as an educator, researcher, organizer, advocate and practitioner of forest pathology.
	Bob Edmonds		In recognition of his 40-plus years as an educator, researcher, organizer, advocate and practitioner of forest pathology and ecology.
2010	Paul Hennon	Valemount, BC	For sustained, significant contributions to our knowledge and understanding of forest disease dynamics and ecology.
2011	Susan Frankel	Leavenworth, WA	For leadership in the science and practice of forest pathology and for critical contributions to the management of Sudden Oak Death.
	Ellen Goheen		For leadership in the science and practice of forest pathology and for critical contributions to the management of Sudden Oak Death.
2012	John Schwandt	Lake Tahoe, CA	For the energy, enthusiasm, and integrity which he has invested in the professions of forest pathology and forest management.
2013	Don Goheen	Waterton Lakes, AB	In honor of your 35 years of dedicated service to forest pathology as a researcher, leader and mentor of others.
2014	Terry Shaw III	Cedar City, UT	In recognition of broad western U.S. and international experiences, and dedicated mentoring and storytelling.
	Willis R. Littke		In recognition of a valuable industry perspective, support for WIFDWC Nursery Committee, international experience, mentoring and storytelling.
2015	Brian Geils	Newport, OR	In recognition of a creative scientist with a broad range of interests, a high level of enthusiasm and curiosity, and a great guy to be with in the field.
2016	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

STANDING COMMITTEES AND CHAIRS, 1994—2016

Committee	Chairperson	Term
Hazard Trees	J. Pronos	1994—2005
	P. Angwin K. Chadwick	2006—2015 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—present
Disease Control[a]	B. James	1995—2002
Nursery Pathology	B. James	2002—2005
	K. Mallams	2007—2010
	W. Littke A. Leon	2011—2014 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 September 25, 2015.

Article I

Objectives

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

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

Article 2

Membership

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

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

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

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

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

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

Article 3

Officers

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

Duties of the Conference Chairperson

At each WIFDWC, the Conference Chairperson will run the general and business meetings. The Conference Chairperson will appoint an interim Program Chairperson at the start of each WIFDWC to gather suggestions and opinions to guide the conference in the planning of next year's conference. The Conference Chairperson will also appoint three members to serve as the "railroad committee" to nominate candidates for next year's Conference Chairperson and Secretary (and every fifth year, Treasurer, Historian and Web Coordinator). The Conference Chairperson may appoint members to assist in conducting the affairs of the Conference including, but not limited, to Local Arrangements representative(s) and Program Chairperson. The Conference Chairperson may also appoint ad hoc committees and their chairpersons as deemed necessary to assist in carrying out the mission of WIFDWC.

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

Duties of the Secretary

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

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

Duties of the Treasurer

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

Duties of the Program Chairperson

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

Duties of the Historian

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

Duties of the Web Coordinator

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

Compensation

Officers will not be compensated for their services.

Non-liability of Officers

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

Article 4

Decision Making Process________

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

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

Article 5

Finances________________________

Expenditures

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

Contracts

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

Gifts

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

Fiscal year

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

Article 6

Bylaws_________________________

Amendments

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

Article 7

Meetings________________________

Frequency

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

Date

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

Registration

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

Article 8
Committees____________________

There shall be two types of committees, namely

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

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

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

The following are WIFDWC standing committees:

- Executive Committee
  - ○ Composed of the elected Conference Chairperson, Secretary, Treasurer, Historian and Web Coordinator.
  - ○ The Conference Chairperson may appoint a Program Chair, Local Arrangements representative(s) and other persons as necessary to carry out the business of the next WIFDWC meeting.
  - ○ The Executive Committee may invite non-member speakers to the annual meeting and pay their travel expenses from conference registration fees.
- Awards Committee
  - ○ Composed of three members with the longest serving member designated as chair.
  - ○ Committee will be comprised of a representative from each of the following – a university employee, a public agency employee, and one member at large. At least one member should be from Canada.
  - ○ The chair's term will be completed at the end of the annual business meeting and a new junior member will be appointed by the Conference Chairperson. The most senior serving member will assume the chair for the next year.
  - ○ The chair will provide a report of activities at the annual business meeting.
  - ○ Responsible for accepting and evaluating nominations and determining recipients of the WIFDWC Outstanding Achievement Award as outlined in Article 10.
- Student Scholarship Committee
  - ○ Composed of four members with the longest serving member designated as chair.
  - ○ The chair will provide a report of activities at the annual business meeting.
  - ○ The committee will be comprised of at least one representative from a university.
  - ○ Replacement of committee members will be by election at the annual business meeting.
  - ○ The committee is responsible for fundraising to finance any awards given by the committee.
  - ○ The committee is responsible for determining and advertising the award application criteria, receiving and evaluating applications and determining recipients of the WIFDWC Student Travel Awards as outlined in Article 10.
- Hazard Trees Committee,
- Dwarf Mistletoe Committee,
- Root Disease Committee,
- Rust Committee,
- ~~Disease Control Committee~~ [disbanded 2002],
- Nursery Pathology Committee [approved 2002],
- Foliage and Twig Diseases Committee [established 2007, approved 2009],
- Climate Change Committee [established 2007, approved 2010].

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

Article 9
Proceedings____________________

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

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

Article 10

Awards________________________

Outstanding Achievement Award

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

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

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

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

Student Travel Awards

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

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

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

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

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

WIDFDWC 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.


PICNIC AREA
CLOSED
10 P.M. TO 6 A.M.
User Responsibilites at this site
35
SITE CLOSED Until further Notice
Safety hazards exist

PAST ANNUAL MEETING LOCATIONS AND OFFICERS, 1953—2016

#	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	Couer 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	HarrisonHotSpring 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—2016 (cont.)

Annual	Year	Location	Chair-person	Secretary	Treasurer	Program Chair	Local Arrangements	Historian	Web Coordinator
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—2016 (cont.)

Annual	Year	Location	Chair-person	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

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.

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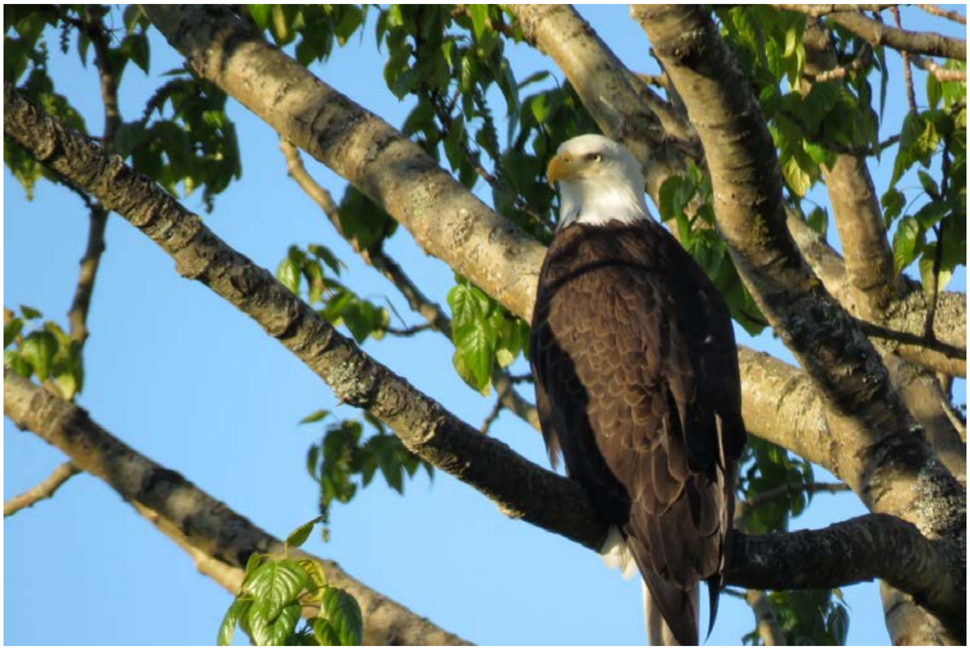

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