Stand Structure and Local Distribution of *Phytophthora ramorum* in Oregon Forests[1]

Ebba Peterson,[2] Molly Botts,[2] Everett Hansen[2]

Introduction

The *Phytophthora ramorum* eradication program in effect in Oregon has allowed for the rapid detection of new infection foci, typically before they develop within each stand and expand into adjacent sites. Yet despite gallant efforts, new locations that previously harbored no apparent infection have been identified each year since the original detection in 2001. Multiple factors may influence why and where each new infection occurs including, but not limited to, stand characteristics such as dominant understory and upper canopy vegetation, age and stem density (which influence microclimate variations within the stand), the distribution of host and non-host species, and the various possible dispersal mechanisms of the pathogen (Shaw 2004). Previous studies in California have found that landscape patterns of disease severity are poorly explained by variation at small scales (Condeso and Meentemeyer 2007); however detailed work on infestations at their origin, prior to local intensification, has not yet been performed. This study examined the stand and canopy characteristics and the local distribution of *P.ramorum* around the first trees detected, if not the first trees infected, in a remote location. We further set out to document and characterize a site with infestation that has developed to an extent previously unseen in Oregon.

Methods

The two sites of this study, site 2748 and North Bean Creek (NBC), were located within a mile of each other on land privately owned by South Coast Lumber Company near Brookings, OR. Both sites were composed of mixed Douglas fir (*Pseudotsuga menziesii*), alder (*Alnus rubra*), and tanoak (*Lithocarpus densiflorus*), and bordered fir plantations. The topography of the sites is similar; both are uphill from the nearest road and occupying east facing slopes with similar pitches (35-45 degrees), elevations (approximately 320-365 m above sea level), and locations relative to the top of their respective ridges. Both sites were first detected and confirmed positive for *P.ramorum* in summer 2007.

To assess the distribution of understory vegetation likely to contribute to the lateral spread of *P.ramorum*, notably *Rhododendron macrophyllum* and *Vaccinium ovatum*, a grid was established either around positive trees (site 2748; 30m by 40m) or through the area of worst infestation (NBC; 25m by 60m). For each $5m^2$ block within the grid presence or absence of foliar hosts was noted (*R.macrophyllum, V.ovatum, L.densiflorus* sprouts, and *Umbellularia californica* only). Symptomatic tissue

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[2] Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR 97331.
Corresponding author: petersoe@science.oregonstate.edu.

samples were taken from every block and *P.ramorum* presence was confirmed through culture on cornmeal, ampicillin, rifamycin, pimaricin (CARP) medium. Stand composition and canopy structure was assessed by running a belt transect (10m x 50m for NBC and 10m x 40m for site 2748) nested within the vegetation plot. For all tree species, tree height and length of crown were measured, as well as distance traveled along the length and width of the transect. Distances were later corrected for changes in elevation for depiction. Disease severity on tanoak was rated by estimating crown condition (percent browned to the nearest 10 percent), and recording presence or absence of symptoms associated with *P.ramorum* (bleeding, frass, symptomatic basal or stem sprouts). The stands were surveyed between July 25th and August 9th, 2007.

Results

Stems were denser at site 2748 though individual trees were much smaller, especially amongst tanoak (Table 1). Tanoak comprised a greater proportion of the upper canopy and total basal area in NBC (Table 1). In contrast, at site 2748 there was a marked stratification between the emergent Douglas fir, which were distributed throughout the transect, and the codominant tanoaks. While many of these stems were dominant, nearly all tanoak crowns were adjacent to taller Douglas fir crowns; a notable exception is the few known positive trees. At site 2748, of the 91 tanoaks measured there were only two symptomatic, brown-canopied trees and, directly adjacent to these, three bleeding stems. In contrast, within NBC 35 percent of the 78 tanoaks surveyed were bleeding, though 85 percent had some symptoms associated with *P.ramorum*, predominantly symptomatic, succulent basal sprouts.

Table 1ð Stand characteristics for the three tree species measured at North Bean Creek (NBC) and site 2748.

	No. live trees counted [a]		Tree density (stems/ha)		Total basal area (m^2/ha)		Mean tree height (m)	
Species	NBC	site 2748	NBC	site 2748	NBC	site 2748	NBC	site 2748
L.densiflorus	78	91	1520	2275	35.6	16.7	13.8	7.6
A.rubra	8	0	160	0	7.1	0	20.5	0
P.menziesii	3	23	60	575	5.7	19.1	24.0	14.8
Total for all species	89	114	1740	2850	48.4	35.8		

[a] NBC: 500m^2 plot, all trees greater than 7cm DBH; site 2748: 400m^2 plot, all trees greater than 5cm DBH

Both sites had a continuous understory of host vegetation (Table 2). *Umbellularia californica* was present only at NBC, though only as small understory saplings in four blocks. In previous studies in California recovery of the pathogen from attached leaves declined dramatically over the summer months (Fitchner and others 2007), however *P.ramorum* was readily recovered from the highly infested site in Oregon. *P.ramorum* was isolated from leaf tissue in all but two 5m^2 blocks within NBC (96

percent of 69 samples taken, Table 2). In contrast, at site 2748 despite extensive sampling within the grid *P.ramorum* was only recovered within 5m of bleeding trees (4 percent of 80 samples taken, Table 2).

Table 2ð Prevalence of host vegetation within the vegetation grid, number of samples taken, and proportion of samples positive for *P.ramorum* at site 2748 (2a; low incidence) and North Bean Creek (2b; high incidence).

	Proportion of blocks with species present [a]		# vegetation samples tested		Proportion positive samples	
Species	NBC	site 2748	NBC	site 2748	NBC	site 2748
L.densiflorus	1	1	55	26	0.98	0.08
R.macrophyllum	0.93	0.96	11	45	0.91	0.02
V.ovatum	0.9	1	1	9	0	0
U.californica	0.07	0	2	-	1	-
Total for all species:			69	80	0.96	0.04

[a] 500m^2 (NBC) or 400m^2 (site 2748) plot divided into 5m^2 blocks

Discussion

Our results are consistent with previous observations that the development of disease in Oregon is dependant upon the infection of mature tanoak. Site 2748 is a typical location: highly restricted, local infection centered around isolated trees whose disease developed from inoculum produced at an unknown source. While other studies have focused upon movement of infested soil to explain the original introduction of inoculum into remote areas (Davidson and others 2005), the location of this site is not consistent with movement by either people or vehicles. Other possibilities include movement by animals, either from below or above, or the aerial dispersal of inoculum. The crown exposure of the initially infected trees, as well as the lack of any observable infection on surrounding vegetation is suggestive of aerial dispersal. Further studies are needed to determine whether the observed pattern reflects the dispersal method of the pathogen or microclimate variation that favors initial establishment (or both).

It is likely not for the lack of host continuity or topographical differences that the severity of disease in either site differs so drastically, and which other factors may best explain this remain unclear. Nevertheless, this study highlights the potential for the diseases caused by *P.ramorum* to reach epidemic proportions in Oregon.

Literature Cited

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