

Ecology of *Phytophthora nemorosa* and *Phytophthora pseudosyringae* in Mixed-Evergreen Forests¹

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Abstract

Recent research has shown that *Phytophthora ramorum* is a major threat to California's coast live oak (*Quercus agrifolia*) dominated, mixed-evergreen forests (Rizzo and Garbelotto 2003). However, the role that diseases caused by other *Phytophthora* species play in the ecology of these forest communities is less evident. Surveys in mixed-evergreen forests have revealed two additional *Phytophthora* species, *P. nemorosa* and *P. pseudosyringae*. In these forests, *P. nemorosa*, *P. pseudosyringae* and *P. ramorum* are all aerial, canker-causing pathogens with overlapping host and geographic ranges. Although all three pathogens seem to share a similar ecological niche, *P. nemorosa* and *P. pseudosyringae* are not associated with landscape level tree mortality. Additionally, the geographic distribution of *P. nemorosa* and *P. pseudosyringae* extends beyond the known distribution of *P. ramorum*. This study was initiated to learn more about the role of *P. nemorosa* and *P. pseudosyringae* in the ecology of mixed-evergreen forests and to gain an understanding of the dynamics of these forests prior to *P. ramorum* invasion. In this paper we address the incidence and mortality levels associated with *P. nemorosa* and *P. pseudosyringae* and describe biotic and abiotic variables associated with pathogen presence.

One hundred 500-m² circular plots were established in coast live oak and bay laurel (*Umbellularia californica*) dominated, mixed-evergreen forests outside of the known geographic distribution of *P. ramorum*. Plots were randomly distributed at each of eight sites including: Big Creek Reserve (BCR), Santa Lucia Preserve (SLP), and Hastings Reserve (HR) in Monterey Co.; Las Trampas Regional Wilderness (LTRW) and Briones Regional Park (BRP) in Contra Costa Co.; Redwood Regional Park (RRP) in Contra Costa and Alameda Cos.; and Angel Island State Park (AISP) and Point Reyes National Seashore (PRNS) in Marin Co. At each plot, data were collected on tree species, diameter, crown position, health and pests. Cover class of all woody and herbaceous species was recorded, as well as slope, aspect, elevation, distance to trail and waterway, and number of seedlings. Calculated and derived variables included basal area, importance value, diversity and various climate descriptors. Symptoms (e.g., leaf lesions, stem cankers) of *Phytophthora* infection were recorded. Samples of symptomatic tissues were returned to the laboratory for isolation and identification of the pathogen(s).

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A total of 3463 woody plants were surveyed, including 1219 coast live oak and 1408 bay laurel. *P. pseudosyringae* was a commonly isolated pathogen in these forests; it was recovered at six of the eight sites (BCR, SLP, LTRW, BRP, RRP and AISP). The pathogen was isolated from 118 bay laurel trees in 40 of the 100 plots; disease incidence on bay laurel in these plots averaged 26.9 percent. Cankers caused by *P. pseudosyringae* were found on eight coast live oaks in seven plots (a 1.7 percent infection level in plots with *P. pseudosyringae* present). Three of the plots with *P. pseudosyringae* infected coast live oaks did not have infected bay laurel trees. *P. pseudosyringae* was never found infecting tanoak (*Lithocarpus densiflorus*). *P. nemorosa* was recovered at four of the eight sites (BCR, RRP, AISP and PRNS) and found on bay laurel in 22 plots; disease incidence on bay laurel in these plots averaged 59.1 percent. *P. nemorosa* was isolated twice from tanoak twigs and never from coast live oak. *P. ramorum* was recovered in nine of the 100 plots. These appeared to be new infection sites; there was an average cumulative oak mortality of 7.7 percent in these plots, while the other 91 plots had an average of 6.7 percent. Of the 100 plots, 11 plots had more than one *Phytophthora* species present and eight of these plots had more than one *Phytophthora* on the same tree.

The mean cumulative mortality of coast live oak in all 100 plots was 6.8 percent. To assess whether *P. pseudosyringae* was causing high levels of unidentified mortality in the plots, the mean cumulative mortality in the 43 plots with *P. pseudosyringae* infection on any host (8.9 percent) was compared to the mean cumulative mortality in the 57 plots with no infection (5.1 percent). These two means were not significantly different (Wilcoxon rank sum test, $n=100$, $P=0.06$). The low incidence and mortality of coast live oak and tanoak attributed to both *P. pseudosyringae* and *P. nemorosa* suggests that although these are common foliar pathogens of mixed-evergreen forests, at this time they are causing low levels of change and are essentially background mortality agents.

Multiple logistic regression was used to determine the environmental, compositional and structural variables that contribute to the likelihood of disease presence in a plot. *P. pseudosyringae* presence in a plot was found to be positively correlated with increased slope ($P=0.003$) and increased bay laurel basal area per ha ($P=0.013$) and negatively correlated with woody species diversity of the plot ($P<0.0001$) and average annual precipitation ($P=0.0019$). *P. nemorosa* presence in a plot was positively correlated with bay laurel basal area per ha ($P=0.006$) and annual average precipitation ($P=0.003$) and negatively correlated with elevation of the plot ($P<0.0001$).

The observed positive density dependence between both *P. nemorosa* and *P. pseudosyringae* and bay laurel is presumably a result of the increasing target for airborne inoculum with increasing bay laurel basal area. A similar positive association with bay laurel has been observed with *P. ramorum* (Kelly and Meentemeyer 2002, Swiecki and Bernhardt 2002, Murphy and Rizzo, this volume). Although numerous plant species were sampled in this study, bay laurel was overwhelmingly found to be the dominant foliar host of both *P. nemorosa* and *P. pseudosyringae*. As is the case with *P. ramorum* (Davidson and others., this volume), bay laurel could be the driver of *P. nemorosa* and *P. pseudosyringae* spread and survival in coastal forests by acting as the major reservoir and supplier of inoculum.

P. pseudosyringae occurrence in a plot was also strongly associated with lower diversity forests. The plots in which *P. pseudosyringae* was most commonly found were a somewhat reduced phase of the

mixed-evergreen forest in which coast live oak and bay laurel were dominant and other species, such as madrone (*Arbutus menziesii*), toyon (*Heteromeles arbutifolia*), big leaf maple (*Acer macrophyllum*) and tanoak, were uncommon. These other species, on which *P. pseudosyringae* infection was never found, may act as a barrier to the movement of spores. If this is the case, then the less bay laurel's presence is diluted by other species in the forest, or the less diverse the forest is, then the higher the likelihood of disease presence. Because of its wide host range the opposite may be true for *P. ramorum*; more diverse forests may increase the likelihood of disease occurrence (Rizzo and Garbelotto 2003).

The logistic models indicated that *P. nemorosa* was associated with higher annual average precipitation and lower elevation plots, while *P. pseudosyringae* was associated with lower annual average precipitation plots. The current broad-scale distribution of *P. nemorosa* and *P. pseudosyringae* support these results; *P. nemorosa* is more commonly found in the more mesic near-coast forests while *P. pseudosyringae* is predominantly recovered in more inland areas that receive less rain (Jensen and others., this volume).

These plots are part of a larger network established to evaluate the effects of disease on various coastal California forest types. Further research and analysis based on the combined information from all plots will help to strengthen our overall understanding of the role of native and exotic pathogens in forest communities.

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