

Collateral Damage: Fire and *Phytophthora ramorum* Interact to Increase Mortality in Coast Redwood¹

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Abstract

Invading species can alter ecosystems by impacting the frequency, severity, and consequences of endemic disturbance regimes (Mack and D'Antonio 1998). *Phytophthora ramorum*, the causal agent of the emergent disease sudden oak death (SOD), is an invasive pathogen causing widespread tree mortality in coastal forests of California and Oregon. In the absence of the pathogen, species composition in these forests is shaped by a number of biotic and abiotic factors, including wildfire. Large wildfires in California in 2008 provided an opportunity to test the interactions between *P. ramorum* and wildfire and their separate or joint impacts on forest composition. Here we ask whether the interacting effects of *P. ramorum* and wildfire on three dominant species in redwood forests were predictable from effects of either disturbance alone or whether there were synergies that occurred where both disturbances were present.

The 2008 Basin Complex and Chalk fires in Big Sur, California, burned more than 40 percent of the 280 forest monitoring plots established throughout the region in 2006-2007 (Metz et al. 2011). In 2009, we surveyed every stem that had been alive at plot establishment to determine mortality 1 year following the fire. In particular, we analyzed survival of tanoak (*Notholithocarpus densiflorus* (Hook. & Arn.) Manos, Cannon & S.H. Oh), California bay laurel (*Umbellularia californica* (Hook. & Arn.) Nutt.), and coast redwood (*Sequoia sempervirens* (D. Don) Endl.) in 61 redwood forest plots, half of which were infested with *P. ramorum*. These species differ in susceptibility to mortality from the pathogen and wildfire. Tanoak and bay laurel are both competent sporulating hosts for the pathogen and sensitive to wildfire, but only tanoak suffers lethal bole canker infections. Redwood may become infected with the pathogen, but is an epidemiologically unimportant host in the spread or impacts of the disease and is generally resistant to wildfire. To understand potential increases to fire-caused mortality caused by the pathogen, we analyzed stem survival in stands with and without the presence of *P. ramorum* using generalized linear mixed effects models with binomial errors and stem size (diameter at breast height, DBH) as a covariate. At the stand level, we compared the percentage of basal area that died between 2006-2007 and 2009 among plots in all combinations of burned/unburned and with/without SOD.

In the absence of fire, all three species had very little mortality between 2006-2007 and 2009, except for tanoak stems in pathogen-infested plots, as was expected from the asymmetric disease impacts that occur among hosts. All three species had increased mortality in burned plots, but mortality in tanoak and bay laurel was much higher than in redwood. Redwood mortality varied greatly by tree diameter: for stems >60 cm DBH there was negligible mortality, and below 10 cm DBH, there was > 80 percent mortality, regardless of pathogen presence. Surprisingly, mortality risk increased dramatically for redwood stems 20 to 80 cm DBH in infested, burned plots relative to uninfested plots. This increase in mortality was driven almost entirely by plots that were in an intermediate stage of disease progression where a mixture of standing and surface fuels occurred. For example, mortality of 40 cm DBH stems was over 65 percent in these stands compared to approximately 5 percent in uninfested stands.

At the stand level, loss of tanoak basal area was highest in plots that experienced both SOD and fire, but the amount appeared predictable from the additive amount of biomass lost to either disturbance alone. Loss of bay laurel basal area was not dependent on the disease status of a plot, but rather reflected the high fire-caused

¹ A version of this paper was presented at the Sudden Oak Death Fifth Science Symposium, June 19-22, 2012, Petaluma, California.

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mortality of this species. Overall, basal area loss of redwood was low because the largest diameter redwoods had very low mortality regardless of disease status in the stand. Nevertheless, twice as much basal area died in infested, burned plots relative to disease-free, burned plots, a result that was not predictable from the impacts of either disturbance on redwood alone.

Elevated fire-related redwood mortality in the presence of *P. ramorum* was not due to any direct effect of the pathogen on redwood, but rather the ways in which SOD influences fire severity through impacts on forest structure and fuel availability. This study demonstrates the important and surprising impact two interacting disturbances can have on a species that is otherwise resistant to the impacts of either disturbance alone.

Literature Cited

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