Survival of *Phytophthora ramorum* Following Wildfires in the Sudden Oak Death-Impacted Forests of the Big Sur Region[1]

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Introduction

The summer of 2008 brought the first wildfires to occur in known *Phytophthora ramorum*-infested forests in California, with the largest individual fire burning in the Big Sur region of the central coast (Monterey County) (Metz et al. 2011). More than 100,000 ha in Big Sur were ultimately burned that summer, providing a natural experiment to examine the feedbacks between a destructive, invasive forest pathogen and wildfire. Big Sur is one of the most botanically and ecologically diverse areas in California, and its forests were among the earliest infested and most impacted by sudden oak death (SOD) in the state (Mascheretti et al. 2008, Meentemeyer et al. 2008). In 2006 and 2007, we established a network of 280 long-term forest plots in Big Sur to study the feedbacks between *P. ramorum*, its various hosts, and the physical environment (Haas et al. 2011, Metz et al. 2011). This plot network provided important pre-fire data on pathogen distribution, tree mortality, and host density levels, and a post-fire survey of burn severity indicators quantified forest impacts immediately post-fire in a subset of the plot network.

The pre- and post-fire data from the Big Sur plot network allowed for a rare opportunity to study the interactions between *P. ramorum* and wildfire. Metz et al. (2011) found that, while burn severity was not greater in *P. ramorum*-infested areas compared to uninfested areas despite greater fuel loads, the stage of the disease invasion impacted burn severity in different forest strata. In this study, we examined the direct and indirect impacts of wildfire on the persistence of *P. ramorum* across the burned landscape of Big Sur (Beh et al. 2012). Specifically, we addressed three questions: (1) Did the 2008 wildfires eradicate *P. ramorum* from areas known to have been infested prior to the fires? (2) If the wildfires did not eradicate the pathogen, under what conditions was *P. ramorum* able to persist in forest stands despite fire? (3) What are the likely reservoirs for pathogen persistence and re-invasion?

Methods and Materials

To accomplish the research objectives of this study, we completed intensive *P. ramorum* surveys in 2009 and 2010—1 and 2 years post-fire, respectively—within 63 plots in the Big Sur network that were known to contain *P. ramorum*-infected trees at the time of plot establishment. Of these plots, 45 were located within the areas burned in the wildfires of 2008 and 18 were outside of the fire perimeters; the plots in each burn status group were evenly divided between redwood-tanoak and mixed-evergreen forest types. Our surveys consisted of sampling *P. ramorum*-symptomatic vegetation in the plots, nearly all of which was collected from California bay laurel (*Umbellularia californica* (Hook. & Arn.) Nutt.) and tanoak (*Notholithocarpus densiflorus* (Hook. & Arn.) Manos, Cannon & S.H. Oh). Because these *P. ramorum* host species sprout prolifically following injury or fire, many of the samples collected from burned plots originated from post-fire regenerative growth, including leaves and twigs from basal and epicormic sprouts. All plant materials collected during the surveys were processed using standardized isolation techniques for culturing *P. ramorum* (Davidson

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et al. 2003). Following the determination of *P. ramorum* presence in each plot, we examined the conditions under which *P. ramorum* persisted on the Big Sur landscape: we used over 20 plot-based variables consisting of burn status, habitat type, pre-fire host abundance, pre-fire disease prevalence, and post-fire host mortality measurements as predictors in the analyses of *P. ramorum* recovery following the wildfires.

Results

The Big Sur wildfires of 2008 suppressed, but failed to eradicate, *P. ramorum* from areas of the landscape that were previously infested with the invasive forest pathogen. We were able to recover the pathogen 1 and 2 years following the fires in burned plots of both forest types, and in some cases, with no difference in frequency than in unburned plots. However, *P. ramorum* recovery 1 year after the wildfires tended to take place in plots with the lowest burn severities, while pathogen recovery 2 years post-fire occurred in plots with greater burn severities and was largely influenced by high levels of pre-fire disease prevalence and low levels of post-fire bay laurel mortality. In plots from which *P. ramorum* was not recovered even 2 years post-fire, burn severities and levels of post-fire bay laurel mortality tended to be high. In sum, multiple interacting biotic and abiotic factors were responsible for the persistence or lack thereof of *P. ramorum* in burned, previously infested plots (Beh et al. 2012).

Discussion

Our results indicate that while wildfire is not a panacea for the control of *P. ramorum*, it may at least temporarily reduce the abundance of the pathogen. Destruction and mortality of hosts of *P. ramorum*, especially bay laurel, was likely the most significant impact of the wildfires on the pathogen's survival, as there is little chance that *P. ramorum* would be able to subsist in dead hosts, regardless of whether the pathogen could have survived the high temperatures produced in the fires. Our findings that the recovery of *P. ramorum* in burned plots was positively correlated with the number of bay laurels expressing symptoms of *P. ramorum*-infection prior to the fires further highlights the importance of this sporulating host to the establishment, spread, and persistence of the pathogen. Patchy burn patterns, typical of mixed-severity fires, which left green, *P. ramorum*-infected bay laurels amidst the charred landscape, may have allowed these trees to serve as inoculum reservoirs that could infest newly sprouting vegetation (Perry et al. 2011). One unexpected result from this study was that two other *Phytophthora* spp., *P. pseudosyringae* and *P. nemorosa*, were frequently isolated from new vegetative growth in burned plots that were not known to contain these pathogens prior to the fires. Continued and ongoing surveys in Big Sur will provide additional information on *P. ramorum* re-establishment following fires, host mortality trends, and the effects of competing invasive *Phytophthora* species in the post-fire landscape.

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