Comparison of the Recovery of *Phytophthora ramorum* From Tanoak and California Bay Laurel, and the Potential Recovery of Inoculum in Fog[1]

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Introduction

Oregon's sudden oak death (SOD) eradication program has focused its efforts upon the aggressive treatment of tanoak (*Notholithocarpus densiflorus* (Hook. & Arn.) Manos, Cannon & S.H. Oh) over all other host species in its efforts to control the spread of *Phytophthora ramorum*. Despite its known importance to the epidemiology of SOD as described in California, bay laurel (*Umbellularia californica* (Hook. & Arn.) Nutt.) has been retained at some eradicated sites due to apparent lack of infection. Some of these trees have since been identified as harboring *P. ramorum*. Along with the retention of California bay laurel at some recently identified SOD sites, these circumstances have allowed us to compare rates of infection and sporulation of *P. ramorum* from tanoak and California bay laurel in Oregon. In this study, we compared incidence of *P. ramorum* infection between tanoak and California bay laurel located within one forest stand identified as positive for SOD in 2011; additionally, we compared rates of inoculum capture with open, baited buckets set underneath either host. While the collection of inoculum in baited buckets has proven to be a useful measure of detection during periods with rain, we also sought to assess the feasibility of monitoring sporulation and spore movement in precipitation resulting from fog.

Methods

Recovery From Foliage and Baited Buckets

The recovery of *P. ramorum* from foliage was assessed at an extensively infested and untreated SOD site in which both California bay laurel and tanoak were present. Between May and September 2011 we sampled 20 to 25 symptomatic tanoak sprouts from random trees at 2-week intervals. One lesion per sprout was plated in *Phytophthora*-selective media. On the last collection period, we also gathered symptomatic California bay laurel leaves in the understory of infected tanoak to determine the extent by which *Phytophthora* spp. were infecting California bay laurel within this stand.

The recovery of *P. ramorum* from rain splash was assessed by placing bait leaves of rhododendron and tanoak in plastic bags secured in screened, 4 L buckets set in SOD-positive areas. Baits have been recovered and plated in *Phytophthora*-selective media every 2 weeks since the buckets were first deployed. To monitor sporulation from California bay laurel, buckets were placed under bay laurel trees retained at multiple SOD-positive sites; sporulation from tanoak was assessed for all baits placed underneath untreated, infected tanoaks.

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[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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Recovery From Fog Traps

Traps designed to monitor fog quantity (Schemenauer and Cereceda 1994) were adapted to monitor potential spore movement in blowing fog: three 1.5 m by 1.5 m traps were constructed using a pvc frame stretched with tan-colored, 70 percent polymer shade cloth. The bottom of the shade cloth was contained in a round 12.7 cm diameter trough. The trough was connected via 30.5 cm irrigation tubing to a closed, translucent bucket baited with rhododendron and tanoak leaves. Each screen was suspended in the opening between two Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) or alder (*Alnus* sp.) trees approximately 10 to 20 m above the ground and 15 to 25 m away from the nearest live tanoak canopy within drainages known to contain SOD. The bait leaves were processed as done for the bucket traps every 2 weeks between 16 July 2011 and 8 March 2012.

Results

Recovery From Foliage and Baited Buckets

Recovery of *P. ramorum* from emergent and aged tanoak sprouts was consistently high throughout the summer months, exceeding 90 percent for all collection dates (fig. 1). Infection by *P. ramorum* could account for only 43 percent of the lesions found on California bay laurel at this site (fig. 1). Other *Phytophthora* spp. were found infecting California bay laurel. If these species are infecting tanoak at this study location, their relative frequency is too low to be detected with our sample size (fig. 1).

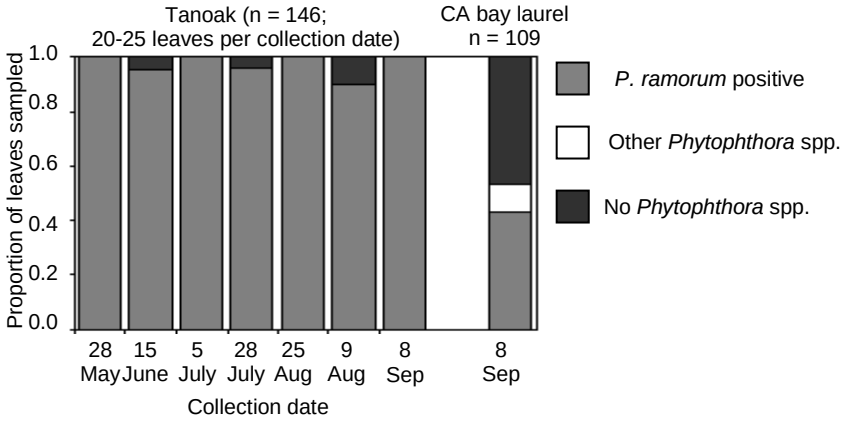

Figure 1—Recovery of *Phytophthora ramorum* or other *Phytophthora* species from symptomatic tanoak sprouts (collected between 28 May and 8 September 2011) or California bay laurel leaves (collected 8 September 2011). All samples were collected from a single untreated sudden oak death site first identified in spring 2011.

The proportion of *P. ramorum* -positive buckets ranged from 0 to 0.89 and was positively correlated to the amount of precipitation over the collection period (Pearson's r = 0.49) (fig 2a). The proportion of *P. ramorum*-positive buckets placed underneath California bay laurel ranged from 0 to 0.42, never exceeding 0.5, even during spring rains (fig. 2a). A greater diversity of *Phytophthora* spp. were recovered from buckets placed underneath California bay laurel; in contrast to previous observations in Oregon, we recovered no other *Phytophthora* spp. from buckets underneath tanoak within this study period and locations (fig. 2b).

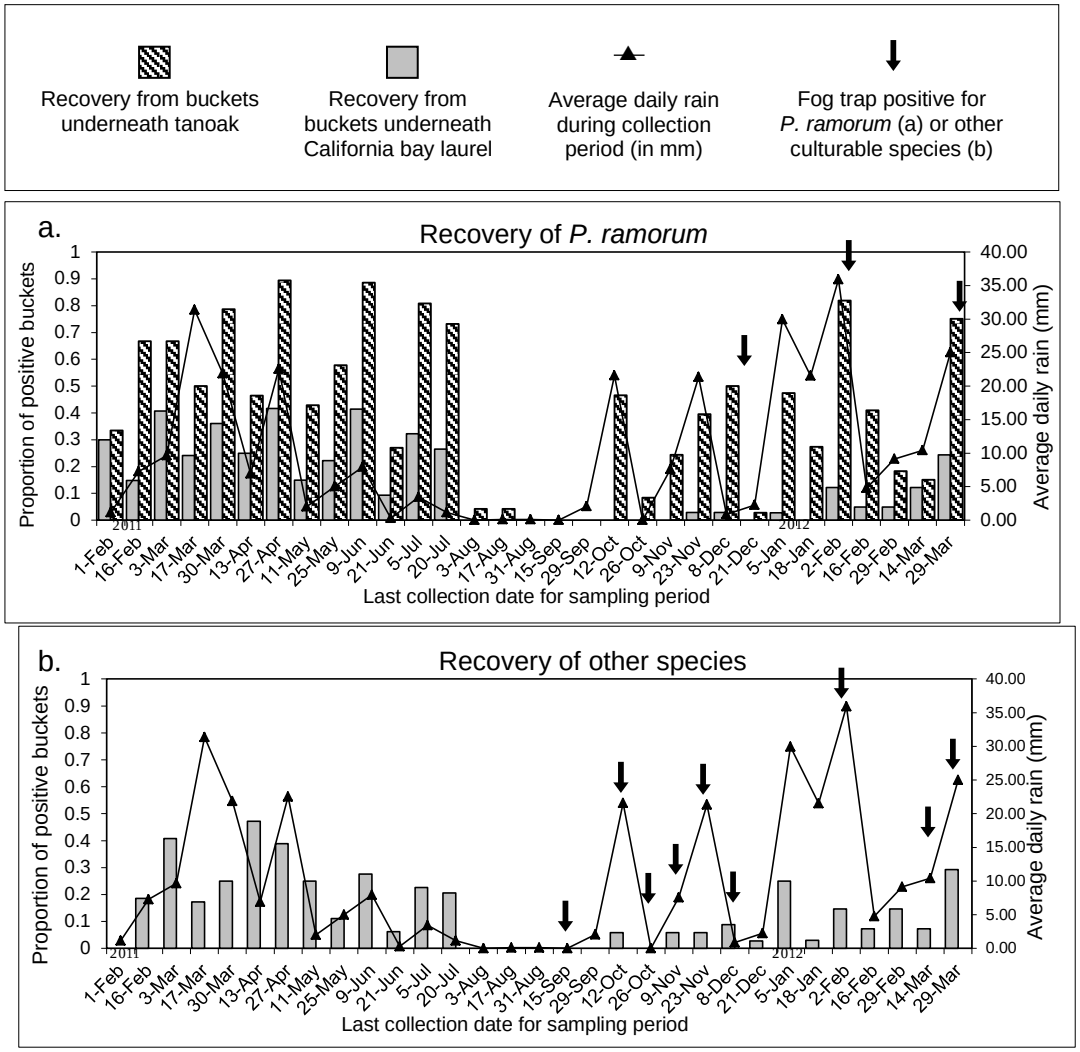

Figure 2—Recovery of *Phytophthora ramorum* (a) or other *Phytophthora* spp. (b) from baited buckets placed underneath tanoak or California bay laurel. Arrows indicate the recovery of *P. ramorum* (a) or any culturable non-*P. ramorum* species (b) from at least one fog trap. Weather data: Redmound RAWS weather station.

Recovery From Fog Traps

A low amount of precipitation reached the buckets during periods without any rain, although recovery of culturable species (*Phytophthora* or *Pythium* spp.) coincided with the onset of seasonal rains (fig. 2b). *Phytophthora ramorum* was recovered on three dates over the baiting period from two of the three fog traps (fig. 2a).

Discussion

In describing the epidemiology of SOD in California, most research has focused upon the importance of *U. californica*, predominantly because of this host's capacity to produce large quantities of sporangia (Davidson et al. 2008). In contrast, our preferential recovery of *P. ramorum* from tanoak is consistent with prior observations that *N. densiflorus* is an important contributor to the establishment and spread of SOD in Oregon. It remains unclear if the differences we observed in infection and sporulation between California and Oregon can be attributed to differences in forest composition, environment, host phenology, or the retention rates of infected foliage on either host (Davidson et al. 2011, Hüberli et al. 2011).

Despite the differences in recovery rates from buckets underneath either host, the temporal pattern of recovery is similar between this and prior studies. Davidson et al. (2008) noted that spore quantity increased over the rainy season for California bay laurel, but not tanoak. Our consistent recovery of inoculum in the autumn months from tanoak but not California bay laurel corroborates these findings. Due to differences between the methods employed in California and Oregon, however, a direct comparison is difficult. Baiting buckets with water and leaves provides a crude estimate of spore quantity. This method may increase our sensitivity during the drier months, although it is prone to saturation during times of high inoculum production.

As we only recovered *P. ramorum* in fog traps during periods of rain, we cannot conclude that movement in fog, specifically, has contributed to the capture of inoculum via this new method. While we did observe fog condensing on the screens, very little moisture was recovered in the buckets in the absence of rain. This is most likely due to rapid evaporation once the fog lifted at the sampling locations. An improvement upon our design would include the ability to periodically wash the traps and capture any rinsate, which may then be baited. Nevertheless, we have confirmed the capture of *P. ramorum* 25 m away from the nearest inoculum source.

Acknowledgments

Thanks to the USDA Forest Service, Pacific Northwest Region (Region 6) Forest Health Monitoring Program and the Pacific Southwest Research Station for funding.

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