

The Importance of Humans in the Dispersal and Spread of *Phytophthora ramorum* at Local, Landscape, and Regional Scales¹

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Abstract

Determining how *Phytophthora ramorum* is dispersed across the landscape is critical for understanding the ecology and epidemiology of this influential pathogen. To date, researchers have shown that abiotic factors – such as rain-splash, wind-blown rain and down-stream transport of inoculum – are critical mechanisms for the dispersal of this pathogen. In contrast, little research has focused on the potential for human dispersal of *P. ramorum*, although work on other pathogens – such as *P. lateralis* attacking Port Orford cedar – suggests that humans can play an influential role in disease spread. Here, we summarize results from a study conducted in Sonoma County that addresses three research questions examining the importance of human dispersal at the local, landscape and regional scales: 1) Is *P. ramorum* more frequently found in soil along hiking trails than in soil off trail? 2) Do areas visited intensively by humans have a greater proportion of hosts showing symptoms of infection by *P. ramorum* than areas visited less frequently? and 3) Do wildlands surrounded by dense human populations have greater levels of infection by *P. ramorum* than areas surrounded by less dense populations?

To address the ability of humans to disperse *P. ramorum* in soil along hiking trails, we conducted a study during the spring of 2003 within different habitat types at Sonoma State University's Fairfield Osborn Preserve in eastern Sonoma County. We assessed soil samples for the presence or absence of *P. ramorum* on the trail surface and at adjacent locations 2 m off trail in three habitat types that we hypothesized differed greatly in the amount of pathogen inoculum present in the soil: woodlands dominated by infected bay (*Umbellularia californica*) and coast live oak (*Quercus agrifolia*), open grassland lacking foliar or terminal hosts, and stands of white oak (*Quercus garryana*; a non-hosts species). As expected, we found that *P. ramorum* was equally common in soil on and off trail from infected bay/coast live oak woodlands. However, for grasslands and white oak woodlands – habitats that lack *P. ramorum* hosts – our data showed that the pathogen was commonly found in soil samples collected on trail, while being virtually absent off trail. These data suggest that hikers are effective

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dispersal agents of *P. ramorum* and are able to transport the pathogen into areas that lack a local source of inoculum.

To determine whether disease symptoms were greater in areas with high human activity, we used 202 15x15-m plots established in a 275-km² area in eastern Sonoma County. Approximately half of these plots occurred in areas that experienced high visitation rates by humans (primarily county and state parks), whereas the other half occurred in areas that had low visitation rates (primarily rural private land). During the spring and early summer of 2004, we sampled all foliar and terminal hosts in these plots for symptoms of infection by *P. ramorum*. After taking into account the influence of elevation, precipitation, solar radiation (February-April), topography, and cumulative DBH of bays (a host that is thought to play an important role in disease establishment), we found that the proportion of symptomatic bay trees was significantly greater in plots experiencing high levels of human activity than those with low activity levels. We also performed the same analysis on terminal hosts – coast live oak, black oak (*Q. kelloggii*), and tanoak (*Lithocarpus densiflorus*) with trunk cankers and/or canopy dieback – but did not detect a significant effect of human activity level. We hypothesize that effects similar to those found for bays will eventually appear, but that there are lag effects because foliar hosts at a site get infected by *P. ramorum* first and only later do terminal hosts become infected.

To evaluate the relationship between human density surrounding wildlands and disease incidence, we first delineated a 'zone of infestation' in the 14 Bay Area counties of northern California where *P. ramorum* and sudden oak death are known to occur. This was achieved by inscribing a 20-km buffer around the 275 sites that have been confirmed by the California Department of Food and Agriculture (CDFA) to contain host plants infected with *P. ramorum* (see the California Oak Mortality Task Force's webpage: www.suddenoakdeath.org). Within this zone, we examined the infection status of all foliar hosts present at 166 randomly located sites, based on data collected by Meentemeyer et al. (this volume). Two 50 x 10-m belt transects were established at each site, foliar hosts contained within these transects were assessed for evidence of infection by *P. ramorum*, and tissue from all symptomatic hosts was evaluated by CDFA to test for the presence of *P. ramorum*, using culturing and PCR techniques. Results from this assessment revealed that *P. ramorum* was detected on foliar hosts at 33 sites, whereas hosts at 133 sites showed no evidence of disease. We then evaluated the degree to which human density predicted the presence of *P. ramorum* at these 166 sites, after taking into account the influence of six potentially influential variables. Human population density within a 50-km radius of each site was quantified in a GIS using data from the U.S. Census Bureau; minimum daily temperature (December-February), maximum daily temperatures (December-May), annual precipitation, and relative humidity (December-May) were estimated using the PRISM model; fire history since 1950 was estimated from records compiled by the California Department of Forestry and Fire Protection; and the presence or absence of bay and tanoak was quantified in the field at each of the 166 sites by Meentemeyer and others (this volume). Our analysis indicated that *P. ramorum* was more likely to be present in wildlands that were surrounded by high human population density. In addition, *P. ramorum* was more likely to be found in plots containing bay and receiving greater amounts of precipitation.

In summary, we have presented three lines of evidence – at the local, landscape and regional scales – which each suggest that intensive human activity is associated with – and we hypothesize leads to – increased levels of disease in bays, a foliar host that is thought to play a key role in the establishment

and spread of sudden oak death. Our data indicate that there may be conflicts between recreation and disease spread, and that efforts to address this epidemic may require active management of human activity.