Potential Susceptibility of Eastern Forests to Sudden Oak Death, *Phytophthora ramorum*

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Abstract

Sudden oak death is caused by the fungus-like organism, *Phytophthora ramorum*, and was first discovered in central coastal California in 1995. The non-native disease has killed large numbers of oaks (coast live oak (*Quercus agrifolia*), California black oak (*Q. kelloggii*), and Shreve oak (*Q. parvula* var. *shrevei*)), tanoaks (*Lithocarpus densiflorus*), and Pacific madrone (*Arbutus menziesii*) and has recently been found in coastal Oregon. The organism has not affected California species in the white oak group. Greenhouse tests of eastern oak species pin oak (*Q. palustris*) and northern red oak (*Q. rubra*) have shown these species to be just as susceptible to sudden oak death as their west coast relatives. We developed a preliminary map of the potential risk to Eastern forests in order to prepare for quarantine and management actions should the pathogen be introduced or move naturally to the Eastern US.

The map was developed using FIA periodic inventory plot data from the Eastwide database. While only two species have been tested, based on the California data, we assumed that all species in the red oak and live oak groups in the East would be susceptible to the pathogen. The proportion of the total plot basal area that included these oak species was mapped for all Eastern state periodic FIA points. Median indicator kriging was used to develop a surface of red and live oak relative density from the point data. A forest density layer was used to mask the surface to remove non-forest areas and to reduce the proportions based on forest density. The Northeastern states conducted a shrub inventory during these periodic inventories. This shrub data was recently obtained and binary classifications were used based on presence or absence of *Phytophthora ramorum* shrub hosts, primarily evergreen ericaceous species. Indicator kriging was used to generate a two probability surfaces: one of shrub host presence and one of overstory host presence. These probability surfaces were multiplied to create a probability surface of host presence in the overstory and understory.

The result of the overstory tree analysis is a map that shows potential susceptibility of forests containing those two oak groups for the Eastern US. This map shows that over half of the forests in the Eastern US contain some susceptible hosts. The majority of these susceptible forests contain only a small percentage of susceptible hosts (<20%), so impacts on these forests may be less critical than in the areas that contain large percentages (up to 90 percent in some areas). Areas with high proportions of susceptible hosts include the Ozark-Ouachita Highlands, pin oak sand flats in the Lake States, and live oak areas in Florida. These susceptible areas can be further defined by using understory hosts. Shrub data from the Northeastern states was used to further refine the overstory susceptibility for that area. Climatic factors are also an important component of vulnerability of hosts to the pathogen. Future work will add these factors into the analysis.

The Eastern oak forests of the US appear to have plenty of susceptible hosts, both overstory and understory, that would make the establishment of *Phytophthora ramorum* in these forests a very serious threat. In a worst case scenario, it could rival or exceed the chestnut blight in its impact on the forest ecosystems of the East.

Introduction

Over the past five years, large numbers of tanoaks (*Lithocarpus densiflorus*), coast live oaks (*Quercus agrifolia*) and black oaks (*Quercus kelloggii*) have been dying in California's coastal counties. The epidemic, referred to as sudden oak death (SOD), was first seen on tanoak in Mill Valley (Marin County) in 1995. Since then, it has been confirmed in 10 central coastal counties as of October 19th, 2001: Marin, Santa Cruz, Sonoma, Napa, San Mateo, Monterey, Santa Clara, Mendocino, Solano and Alameda, as well as in Curry County, Oregon (Fig. 1).

Objective

To develop a preliminary map of the potential risk to Eastern forests should *Phytophthora ramorum* become established in the East.

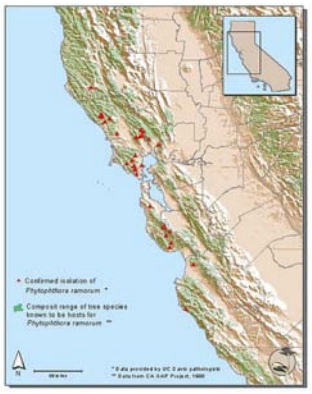

Figure 1. Sudden oak death in California as of July 2001.

Methods

FIA plot data were classified according to the percent of forest basal area composed of the red and live oak groups. This analysis was done using the most recent FIA data from each state in the eastwide FIA database. The classified plots were further classified using a hierarchical ecological classification system of ecoregion provinces and sections (Bailey 1995, Fig. 2).

Median indicator kriging was repeated separately for each ecoregion section in the East to estimate the percent of forest basal area of the red and live oak groups. The kriging results were put together into a mosaic. These percent basal area estimates were then adjusted for forest density using a land cover (proportion forest) map generated from Multi-Resolution Land Characteristics Consortium (MRLC) data. Each 30-m pixel was classified as either forest or non-forest and then pixels were aggregated into 1-km percent forest pixels. The forest density map values were multiplied by the percent basal area values of the intial kriged map to create an adjusted kriged red oak and live oak group sudden oak death susceptibility map.

The Northeastern states conducted a shrub inventory during these periodic inventories. This shrub data was recently obtained and binary classifications were used based on presence or absence of *Phytophthora ramorum* shrub hosts, primarily evergreen ericaceous species. Indicator kriging was used to generate a two probability surfaces: one of shrub host presence and one of overstory host presence. These probability surfaces were multiplied to create a probability surface of host presence in the overstory and understory.

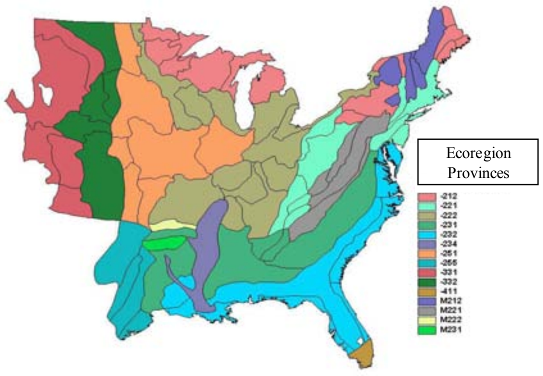

Figure 2. Ecoregion map of provinces (colored areas) and sections within provinces (black lines) (Bailey 1995).

Sudden Oak Death Hosts and Symptoms

Sudden oak death appears to have two types of hosts. The organism has susceptible hosts – ones that are infected but do not die (Švihra et al. 2001). The infections on these susceptible hosts are usually limited to spotting on leaves (Fig. 3) and branch tip dieback (Fig. 4). Hosts in this group include rhododendron (*Rhododendron macrophyllum*), huckleberry (*Vaccinium ovatum*), California bay laurel (*Umbellularia californica*), Common manzanita (*Arctostaphylos manzanita*), California buckeye (*Aesculus californica*), and Big-leaf maple (*Acer macrophyllum*).

In addition to susceptible hosts, the organism has vulnerable hosts, where it not only infects the hosts but also kills them. In addition to leaf spotting and twig dieback, these hosts show bleeding on the bark (Figs. 5, 6). Hosts in this group include tanoak, coast live oak, California black oak, and Pacific madrone (Švihra et al. 2001). Recent greenhouse tests with pin oak and northern red oak seedlings have shown these eastern oak species to be vulnerable (D. Rizzo, personal communication).

Figure 3. Rhododendron leaf with sudden oak death blotching.

Figure 4. Drooping (wilted) tanoak shoot.

Figure 5. Bleeding on coast live oak.

Figure 6. Bleeding on tanoak trunk.

Results

We first made a map of all FIA plots in the eastern United States showing the percent forest basal area composed of the red and live oak groups susceptible to sudden oak death (Fig. 7). Kriging produced a probability surface where the estimated percent forest basal area in the red and live oak groups varied from 0 to 89 percent (Fig. 8). One problem with these kriged surfaces is that non-forested land is included in the surface. Using the forest density map (Fig. 9) as a filter, we can adjust the probabilities to values that are more representative of actual forest occurrence. The resulting surface is reduced both in area (non-forest areas dropped) and in probability with the range now varying from 0 to 84 percent (Fig. 10).

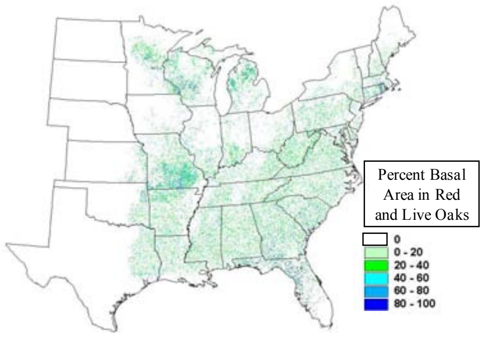

Figure 7. Percent forest basal area in the red and live oak groups based on FIA plot data.

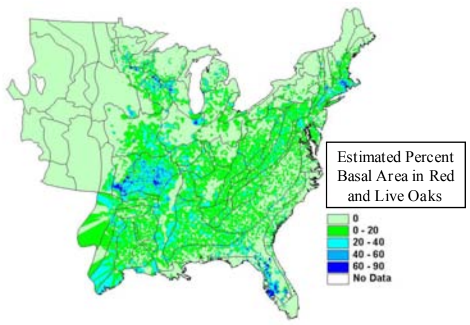

Figure 8. Estimated percent forest basal area in the red and live oak groups based on kriging.

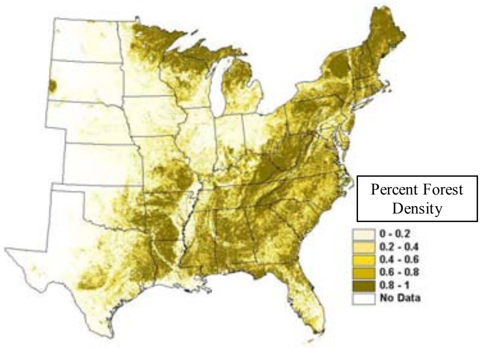

Figure 9. Percent forest density map based on MRLC data.

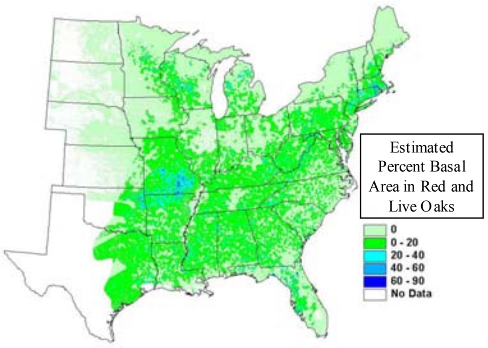

Figure 10. Kriged map of the estimated percent forest basal area for the red and live oak groups adjusted for forest density.

Binary classifications were used based on presence or absence of *Phytophthora ramorum* hosts in the overstory and understory for states in the northeast. Indicator kriging was performed to generate a probability surface of host presence in the overstory (Fig. 11) and understory (Fig. 12). The surfaces were multiplied to create a surface of probabilites for an area having hosts in both the overstory and understory; the probabilites were then adjusted for forest density (Fig. 13).

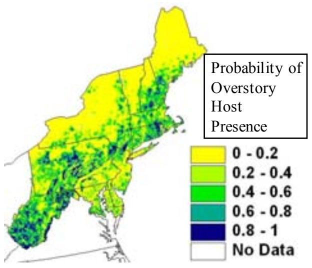

Figure 11. Kriged probability of presence of *Phytophthora ramorum* overstory hosts adjusted for forest density

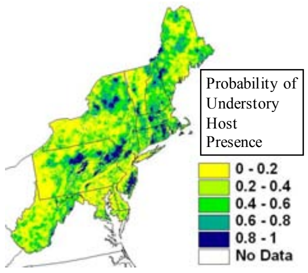

Figure 11. Kriged probability of presence of *Phytophthora ramorum* understory hosts adjusted for forest density

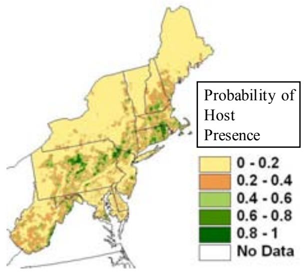

Figure 11. Probability of presence of *Phytophthora ramorum* overstory and understory hosts adjusted for forest density

Conclusions

- Potential susceptibility of eastern forest stands to sudden oak death based on their percent forest basal area of the red and live oak groups ranges from 0 to nearly 90%.
- It is probable that characteristics other than host species are important for *Phytophthora ramorum* to become pathogenic.
- Future work could include investigation of other factors (e.g. weather conditions, alternate hosts) that could further refine sudden oak death susceptibility in eastern forests.

Literature Cited

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