

Understanding the Long-Term Fire Risks in Forests Affected by Sudden Oak Death¹

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Abstract

It is assumed that large numbers of dead and down tanoak in forests infested by *Phytophthora ramorum* contribute to increased fire hazard risk and fuel loading. We studied the impact of *P. ramorum* infestation on surface fuel loading, potential fire hazard, and potential fire behavior in Douglas-fir- (*Pseudotsuga menziesii*) dominated forest stands with a significant tanoak (*Lithocarpus densiflorus*) component in Sonoma, Mendocino, Humboldt, and Del Norte Counties in northern coastal California. We also tested the feasibility of using stands in which tanoaks were treated with herbicides as a proxy for stands that have been heavily impacted by *P. ramorum* over a long time period, especially in areas where stands have not been impacted by the pathogen over the desired timeframe. In each county, plots were established to assess surface fuel loadings in both *P. ramorum*-infested and uninfested forest stands. Plots were stratified by (1) whether tanoaks were killed by *P. ramorum* or by herbicide (as a surrogate for areas or time frames that were not present) and (2) length of time the plot has been known to be infested or since herbicide application (in groups of approximately 2, 10, and 20 years). Within each plot, environmental information, disease information, canopy characteristics, and fuel loading as measured by the planar intercept method, including forest floor bulk density measurements, were obtained. Stands treated with herbicides 5 to 8 years ago had significantly more surface fuel than stands treated more recently or those infested with *P. ramorum* within the past 5 years. Additionally, fuel amounts were very similar between stands treated with herbicide recently and recently infested stands, suggesting that further study may establish the former condition as a study surrogate for the latter. Fuel amounts from this study fit a fuel model from the existing literature fairly well, information that could be of use for fire behavior analysts and fire ecologists.

Introduction

Public and land manager concern about interactions between *Phytophthora ramorum*-caused tree mortality and fire has been present for some time, driven by the perception that oak and tanoak mortality in coastal forests contributes to substantially increased fuel loading. Changes in fuel dynamics range from overstory changes, as trees die and retain dead leaves for some time, to changes in surface fuel amounts and arrangement, as trees break and drop to the forest floor. Most predictions of fire spread and behavior on the ground are based on Rothermel's (1972) model that uses the number of surface fuel particles in several size classes as inputs along with several other measurable forest floor parameters; most predictions of crown fire

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ignition and spread are based on the model presented by van Wagner (1977). Relatively little work has been done to understand the nature and quantity of these fuels in areas infested by *P. ramorum*.

To address this perception, we studied the impact of *P. ramorum* infestation on surface fuel loading in Douglas-fir- (*Pseudotsuga menziesii*) dominated forest stands with a significant tanoak (*Lithocarpus densiflorus*) component in Mendocino and Humboldt Counties in northern coastal California⁶. In these geographic areas it is not known how long tanoak surface fuels persist. As a result of *P. ramorum*-caused mortality, will fuel levels be elevated for 5, 10, 20, or more years? *P. ramorum* has not been established in California forests for long enough to address these issues. Observations suggest that forest stands in which tanoaks were treated with herbicides to prepare sites for optimal conifer growth appear very similar to some stands heavily impacted by *P. ramorum*. Based on this observation, we tested the feasibility of using stands in which tanoaks were treated with herbicides as a proxy for the kinds of stands present farther south along the coast that have been heavily impacted by *P. ramorum* over a long time period. It was hoped that the observed fuel values in the plots in this study would then inform the construction of benchmark safety values for a Workplace Safety Analysis for fire suppression activities in areas affected by *P. ramorum*.

Methods

In each county, plots were established to assess surface fuel loadings in both *P. ramorum*-infested and uninfested forest stands. Locations of plots are depicted in fig. 1. Plots were stratified by (1) whether tanoaks were killed by *P. ramorum* or by herbicide (as a surrogate for areas or time frames that were not present) and (2) length of time the plot has been known to be infested or since herbicide application. The length of time was divided into “short” (approximately 2 to 5 years) and “medium” (approximately 5 to 8 years). A total of 35 plots were visited. Stand variability was reduced by selecting stands on southerly aspects (upper third of the slope where possible) with relatively young Douglas-fir and an abundance of tanoak that would match up with timber-type fuel models rather than shrub-type fuel models.

⁶ This study is part of a larger ongoing study that includes Sonoma and northern Humboldt Counties. Additionally, other, simultaneous studies seek to address the crown fire segment of wildland fire dynamics in these forests (Kuljian and Varner, these proceedings).

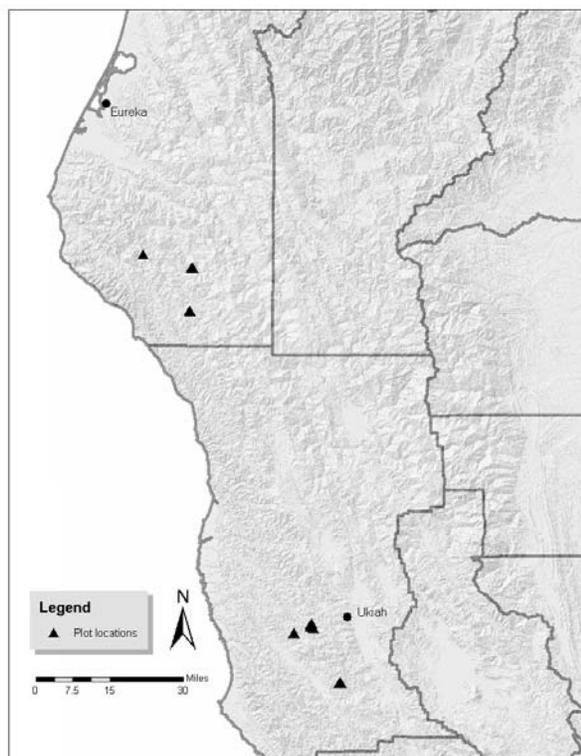


Figure 1—Plot locations in Humboldt and Mendocino Counties.

Plots were located randomly within the appropriate stands. Within stands infested by *P. ramorum*, plots were located at least 100 m from each other to avoid the likelihood that separate plots were part of the same infection event. Within each plot, topographic information (slope and aspect) was recorded, the UTM coordinates of the plot center noted, and observations made about the time since herbicide application or disease establishment, as well as a subjective measure of disease severity.

Stand information collected in each plot included (1) a variable-radius estimate of basal area obtained using a standard wedge prism; (2) an inventory of trees, both dead and living, within a fixed 1/10-acre (0.04 ha) circular plot, by species and diameter to the nearest inch; (3) presence or absence of foliage on each tree; (4) canopy position (dominant, co-dominant, intermediate, or suppressed) of each tree; and, (5) for selected trees, total tree height and height to the lowest live branch for the derivation of live crown ratios.

Surface fuel loading information collected included the standard variables measured for the planar intercept method described by Brown (1974). Three transects per plot were established at angles of 120 degrees from each other, with the first transect azimuth established randomly. The total length of each transect varied according to the distance to the nearest 1000-hour fuel particle (diameter >3 inches). Along each transect, data collected included numbers of 1-hour (diameter <1/4 inch), 10-hour (diameter 1/4 to 1 inch), 100-hour (diameter 1 to 3 inches), and 1000-hour fuels and the condition of 1000-hour fuels (“sound” or one of four “rotten” categories), as well as duff and litter depths at three points along each transect. Additionally, forest floor bulk density was calculated at a random point within each plot by measuring duff and

litter depths at four points within a 30 cm X 30 cm square to calculate volume and then collecting and measuring dry weight of the litter and duff within the square.

Stand information was summarized. Surface fuel loadings between plots were compared using ANOVA. For each stand condition group, mean size class fuel loading by location was used to construct a custom fuel model and predicted fire behavior characteristics assessed using BehavePlus 4.0 (Andrews and others 2008), a fuel modeling and fire behavior simulator based on Rothermel (1972). Parameters for the fire behavior simulation described a typical warm, dry summer day (August 14 at 1400 hours, temperature 32.2 °C, 22 percent relative humidity) on a south-facing 45 percent slope with surface wind speed from 0 to 8 km/hour (0 to 5 m/hour).

Results

Stand Conditions

Stand basal areas are summarized in fig. 2. As expected, the proportion of live tanoak decreased across a continuum of increasing time since treatment or infection—from control stands to *P. ramorum* early stands to herbicide medium (older) stands—and the proportion of dead tanoak increased, while the proportion of other species remained relatively constant. Additionally, total plot basal area decreased in the older plots because more killed tanoaks have fallen down. Regenerating Douglas-fir and other conifers in older plots were still generally small with the exception of occasional rapid-growing redwood stump sprouts.

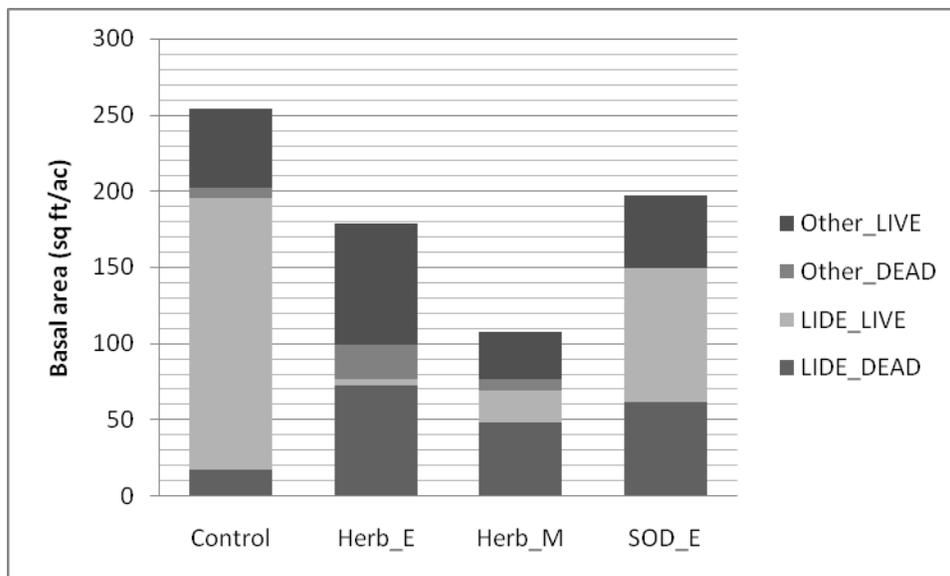


Figure 2—Comparison of stand basal area by species and stand condition type.

Distribution of trees by diameter class followed a standard reverse J-shaped distribution (fig. 3). *P. ramorum* early plots generally had fewer small trees than the other stand conditions, and the pathogen killed more codominant trees in these plots than those in other canopy positions (fig. 4). No dead trees in herbicide-killed or control plots, and relatively few trees in *P. ramorum*-affected plots, still had leaves

attached (fig. 5). The presence of dead, dry leaves in the canopy is a possible factor in crown fire risk (Van Wagner 1977). The presence of these leaves in *P. ramorum*-affected plots is probably related to the ongoing nature of tree mortality there, as opposed to the one-time pulse of mortality in herbicide-treated stands.

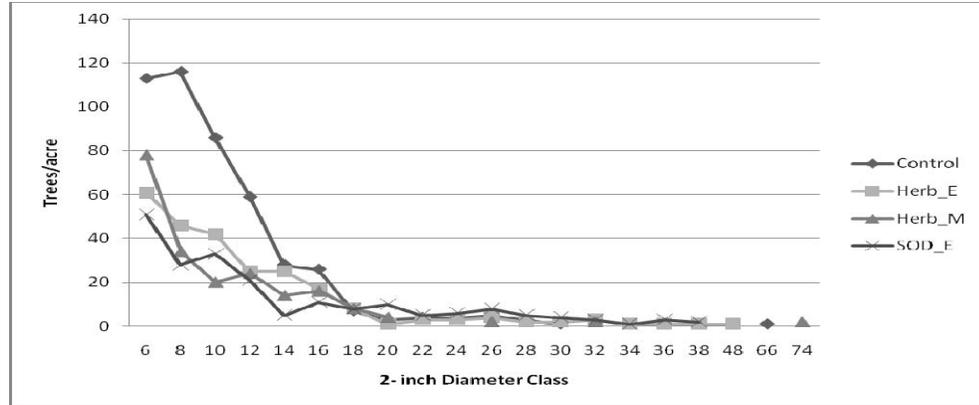


Figure 3—Number of trees by diameter class for each stand condition in the study.

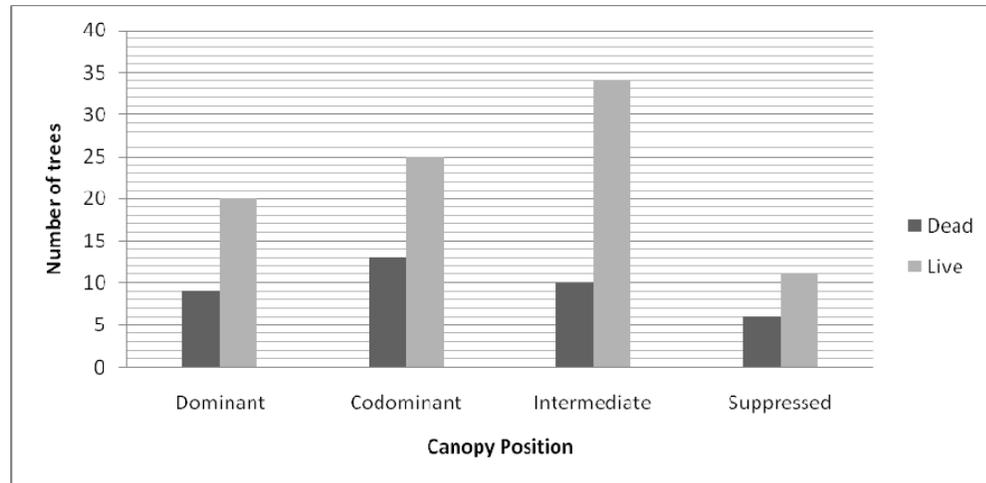


Figure 4—Living and dead trees by canopy position in *P. ramorum*-affected plots.

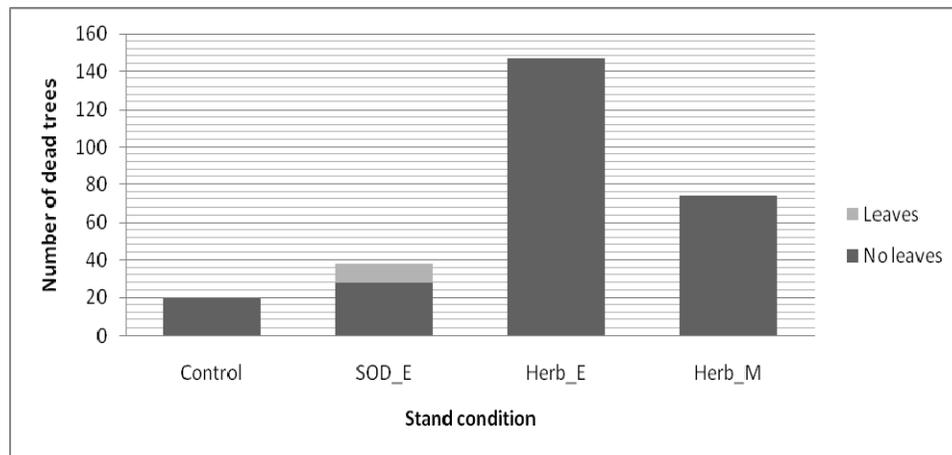


Figure 5—Number of dead trees with leaves attached in study plots.

Surface Fuel Loadings

Across all timelag fuel-size categories (1-hour, 10-hour, 100-hour, and 1000-hour), the herbicide medium stand condition had significantly more fuel than the other three conditions (control, *P. ramorum* early, and herbicide early). No significant differences appeared between these latter three treatments. The differences between the herbicide medium and other treatments are especially noteworthy (two to three times greater in the herbicide medium condition than the others) in the 1-, 10-, and 100-hour fuels (fig. 6). These are the most “fire-sensitive” fuels, in other words, the fuels that would contribute most to fireline intensity, flame length, and rates of spread (Agee 1993).

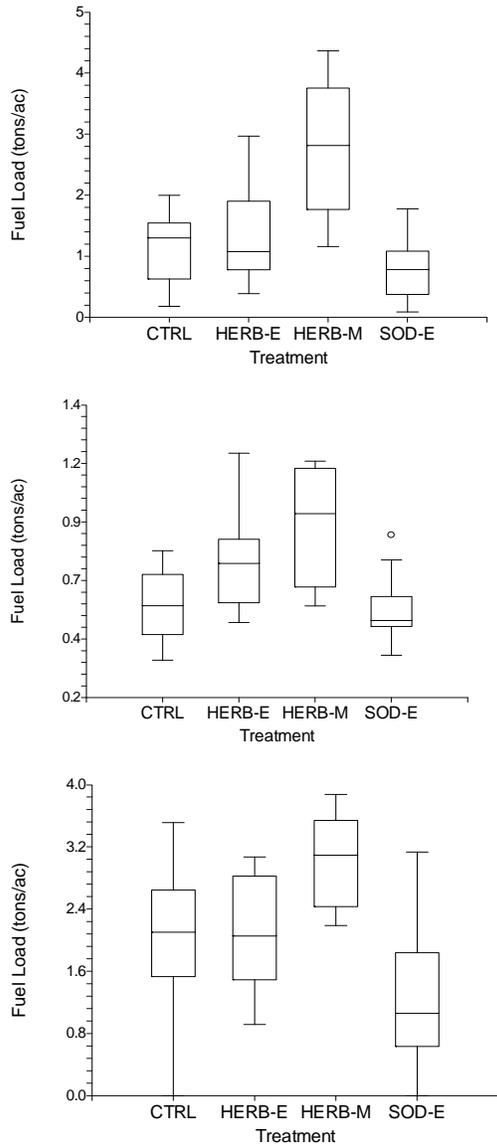


Figure 6—Comparison of surface fuel loading in tons/acre by stand condition. Top graph represents 1-hour fuels, middle graph 10-hour fuels, and bottom graph 100-hour fuels.

Phytophthora ramorum early and herbicide early conditions did not differ in 1-, 10-, 100-, or 1000-hour fuels or in litter depth. This provides some evidence that the herbicide early condition may be a relatively accurate surrogate for *P. ramorum*-infested stands during the first few years after infection, although further data collection is needed.

Fire Behavior

The fire models from the existing literature that most closely tracked the fire behavior predicted by the simulation were Model 8: Closed Timber Litter (Anderson 1982) and TL2: Low Load Broadleaf (Scott and Burgan 2005). Of the two, Model TL2 was superior. Whereas Model 8 over-predicted fire behavior produced from the fuel beds as sampled, Model TL2 was very close to the predicted values. Fig. 7 shows this for rates of fire spread. Predicted rates of spread matched the TL2 model somewhat better than did fireline intensity or flame length. In this figure, curves that continue to increase across the entire graph represent fuel models 8 and TL2; graphs that level off represent modeled rates of spread for the various represented stand conditions (the points of level-off represent wind speeds above which rates of spread do not continue to increase).

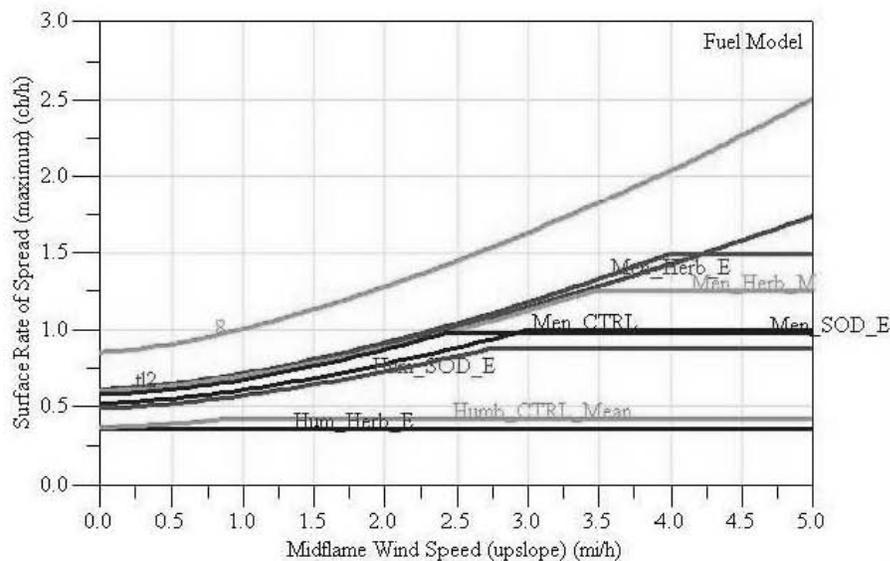


Figure 7—BehavePlus predicted rates of fire spread for stand conditions (separated by county) and for standard fuel model forest types according to Anderson (1982) ("8," complete curve at top) and Scott and Burgan (2005) ("tl2," other complete curve).

Discussion

Perhaps the most significant result of our study, and the one most useful to actual fire managers, is the discovery that, based on the data gathered so far, Model TL2 is a good fit for surface fuel loading conditions in *P. ramorum*- and herbicide-affected stands in Mendocino and Humboldt Counties. Land managers and scientists studying *P. ramorum* have questioned whether existing fuel models fit a situation with the unprecedented levels of tanoak mortality that are caused by this disease, or whether

the development of a custom fuel model might be warranted. This question is important because fire behavior analysts need to know which fuel models best approximate the conditions they see on the ground in a given area at the beginning of a fire incident. This helps them provide the most accurate fire behavior predictions possible in support of tactical and resource deployment decisions. Additionally, having an accurate extant model can help researchers who seek to understand the potential impacts of *P. ramorum* as they try to characterize those impacts for social, ecological, and economic analyses.

Since Model TL2 is a reasonably good fit, the creation of a formal custom fuel model for large amounts of hardwood mortality is probably not warranted at least for the two counties studied. The results suggest the possibility that the input of even large amounts of hardwood mortality to surface fuels, whether controlled by decay rates over time or by some other factor, is gradual enough—and the spatial arrangement of those fuels sufficiently dispersed over the area of mortality—that unusually large amounts of surface fuels do not build up at any one time.

This conclusion is provisional, however, for two important reasons. First, it includes only 2 out of 14 California counties infested by *P. ramorum*. Fire ecology can differ dramatically between different California ecoregions, even exclusively coastal ones (Sugihara and others 2006). Surface fuel accumulations might be expected to differ in redwood forests, or in mixed-evergreen forests dominated by hardwoods in the central coast. Second, the study does not yet include data on areas that have suffered severe hardwood mortality over time horizons longer than 5 years. It may be that tree failure rates and fuel accumulations cause more surface fuel accumulation at some point in time beyond 5 years.

Future study will go some way toward remedying these deficiencies. Study in Sonoma County (within which *P. ramorum* has been killing tanoaks for longer) and in the northern Humboldt County areas are scheduled soon, and further study will concentrate on plots that were herbicide-treated or where *P. ramorum* became established more than 8 years ago. These results also point out the need for further quantification of surface fuels in areas affected by *P. ramorum* in other parts of coastal California.

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