

Sudden Oak Death Disease Progression in Oaks and Tanoaks¹

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Abstract

In March 2000, we established twenty disease progression plots in Marin County to monitor the progress of sudden oak death symptoms in coast live oak (*Quercus agrifolia*), California black oak (*Q. kelloggii*), and tanoak (*Lithocarpus densiflorus*) (McPherson and others 2005). Plots were located to encompass a variety of habitat types and species combinations, ten in China Camp State Park and ten in Marin Municipal Water District. We monitored every coast live oak (731), California black oak (52), and tanoak (181) with a stem diameter greater than 2.5 cm, four times a year. Trees were evaluated by symptom and not sampled for *Phytophthora ramorum* to avoid affecting disease progression. Bleeding coast live oaks were found to follow a consistent and predictable sequence: bleeding, then beetle colonization, followed by emergence of *Hypoxylon thouarsianum* reproductive structures, and then death. Results are reported for the period 2000 through 2003. For all three species, the combined number of bleeding and dead trees increased by 2003, with the greatest increases seen in tanoaks. The percentage of living coast live oaks that were bleeding remained relatively constant, at around 25 percent. The response of California black oaks was very similar to coast live oaks. The proportion of bleeding tanoaks increased from 39 percent to 72 percent. Through 2003, every plot with symptomatic coast live oaks in 2000 showed increased numbers of bleeding and dead trees. Approximately 50 percent of bleeding coast live oaks were under active attack by ambrosia and bark beetles (Coleoptera: Scolytidae) or showed

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past beetle activity during each March sampling period, from 2000 to 2003. Beetles had colonized every bleeding coast live oak that died during this study while each was still alive. Beetles colonized tanoaks much less consistently than coast live oaks during the study period. Structural failure on the main stem (bole) occurred in bleeding coast live oaks with a much greater frequency than in asymptomatic trees of this species, or in either bleeding California black oaks or tanoaks.

We used two approaches, Weibull regression and Cox Proportional Hazards models (Lee and Wang 2003), to describe the expected survival of coast live oaks and tanoaks, based on the disease progression symptoms described above (status in 2000). Weibull regression is a parametric model that requires assumptions about the distribution of the data and can be used to project survival trends beyond the time frame of the input data. The Cox Proportional Hazards model is non-parametric, thus requiring fewer assumptions about the data, but cannot be used to predict future outcomes. The models provided very similar estimates for survival of trees in the following initial disease categories; asymptomatic, bleeding only and bleeding with beetle colonization. Survival times were derived from the Weibull distribution (*fig. 1*). The median survival time for coast live oaks declined considerably as a function of disease state: asymptomatic, 29.5 yr; bleeding only, 7 yr; and bleeding with beetles, 2.6 yr. The presence of *H. thouarsianum* fruiting bodies in addition to beetle activity did not change survival. The median survival times for tanoaks also declined in this order: asymptomatic, 12.6 yr; bleeding only, 8.7 yr; and bleeding with beetles, 2.9 yr. The Weibull model was used in a health analysis to estimate the median asymptomatic time for tanoaks and coast live oaks, as a function of stem diameter (dbh). For both species, the predicted asymptomatic times declined as diameter increased, with the greater decline seen in tanoaks (*table 1*).

The impacts of sudden oak death on its principal fagaceous host trees continued to increase from 2000 through 2003. This effect was greatest in tanoaks. Scolytid beetles were consistently associated with approximately half the bleeding coast live oaks at any date. The tunneling activity of these beetles may contribute to structural failure in living trees. Stem diameter was positively associated with bleeding symptoms in both coast live oaks and tanoaks. Among all bleeding coast live oaks, beetles were positively associated with larger diameter trees (*fig. 2*). The Weibull and Cox Proportional Hazards models predict that bleeding tree survival will decline following beetle attacks and found that the presence of beetles was a better predictor of mortality than *H. thouarsianum* fruiting. These models also suggest that time from initial symptoms to death is similar for coast live oaks and tanoaks. The accuracy of the model-derived estimates is constrained by the limited period of observation and uncertainty about the timing of the first appearance of each disease stage. However, this initial effort to establish a time sequence for sudden oak death should facilitate

comparisons of disease progression in different host species and species combinations if *P. ramorum* becomes established in different geographic areas.

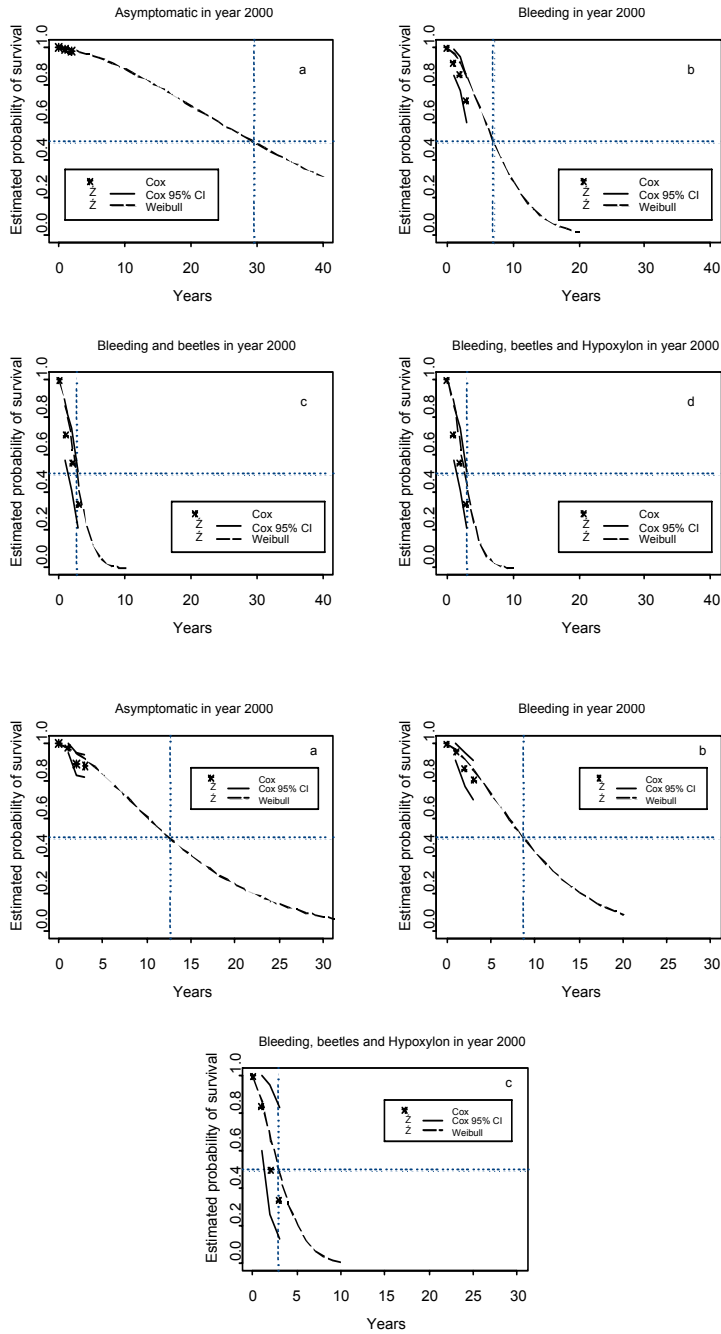


Figure 1—Weibull and Cox Proportional Hazards survival models for same-symptom cohorts of coast live oak (the four upper graphs) and tanoak (the three lower graphs); vertical dashed lines denote the predicted median survival times. All regressions were statistically significant ($p < .001$).

Table 1—Weibull health analysis of coast live oaks and tanoaks, showing the median asymptomatic time in years (\pm standard error) as a function of stem diameter (dbh) in 2000.

Species	Diameter (dbh) in cm					
	10	20	40	60	70	80
Coast live oak	18.5 (4.8)	15.9 (3.5)	11.4 (2.0)	8.1 (1.6)	-	5.8 (1.5)
Tanoak	3.8 (0.4)	3.2 (0.3)	2.3 (0.4)	1.6 (1.8)	1.4 (0.5)	-

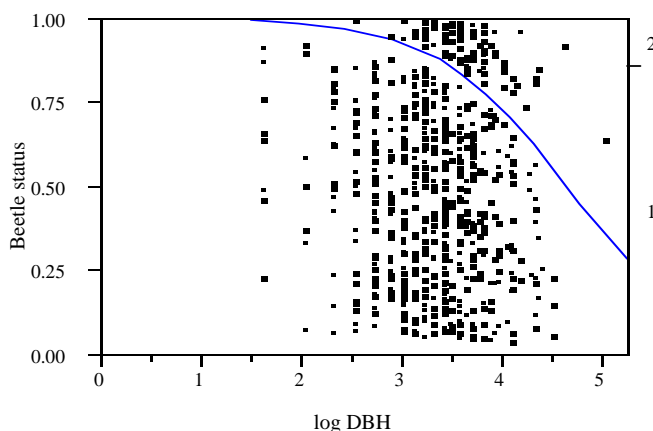


Figure 2—Beetles colonized bleeding coast live oaks as a function of stem diameter. Beetle status; 1 = no colonization, 2 = beetle colonization; analyzed by logistic regression ($p < 0.001$).

References

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