

Effects of Wildfire on Blue Oak in the Northern Sacramento Valley¹

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Abstract

The objective of this project was to develop a technique for rapidly determining the extent of wildfire damage to blue oaks (*Quercus douglasii*) that would be usable by landowners without requiring extensive training. In late winter 2000, 100 oaks of various sizes and degrees of damage were selected from 10 plots located where wildfires had burned in the previous year. Measures of individual tree parameters, stand structure and scorch characteristics were taken and tested for their adequacy in predicting mortality. These same oaks were re-evaluated in August 2000. Sixteen percent of the sample trees were top-killed (50 percent of the seedlings, and 8 percent of the saplings and mature trees). Eighty-eight percent of the top-killed oaks re-sprouted from the base. Only two of the top-killed oaks in this study failed to re-sprout. Logistic regression models based on tree size and wildfire effects are presented as preliminary tools to predict wildfire effects. The low level of mortality confirms the tolerance of blue oak to low- to moderate-intensity wildfires.

Introduction

Because the major oak woodland species have not been considered commercially important in California, only relatively recently has there been much demand for information on the effects of fire on mortality and recruitment. As a consequence, the impacts of fire on these hardwood species are not entirely understood.

Although oaks are generally resistant to damage by fire (Mooney 1977, Plumb and Gonzalez 1983), accumulations of fine fuels, combustible debris and increasing densities of shrub species that can convey fire into oak canopies may create fire conditions that may result in catastrophic damage to trees in oak woodlands (Mensing 1992). These hazardous conditions appear to have become more prevalent over the last 60-70 years as a result of increased fire suppression efforts (McClaran

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and Bartolome 1989). In the aftermath of fires, landowners and managers may desire to identify trees that have been severely injured in order to estimate losses to property values and to plan restoration efforts. A method for rapidly assessing the severity of burn damage to affected oaks would be useful for restoration projects and for the management and monitoring of prescribed burns.

This research project was designed to develop a method for evaluating fire-damaged oaks that private landowners and forestry professionals alike can use for rapidly estimating mortality in various size classes of blue oaks. In the process we expected to add to the body of knowledge about fire ecology in oak woodlands.

Methods

Four study sites were selected in blue oak woodlands that were burned by wildfires in the summer of 1999 at the north end of the Sacramento Valley in eastern Tehama County. Descriptive measures of tree characteristics (diameter breast-height, total height, crown height and width, height base to live crown and bark thickness), stand structure (basal area, canopy cover, presence of ladder fuels) and scorch characteristics (percent bole charred, height of bole char, bole char severity, bud damage and percent crown scorch) were recorded for each of the trees in winter 2000. In August 2000 height base to live crown, presence of acorns, vigor (Dead, Low, Moderate, Good) and sprouting (Absent, Weak, Vigorous) were evaluated for these same trees. Fire effects were evaluated by the height of crown foliage scorch, the percentage of the live crown affected, and the amount of bud damage. The charring on the bark was evaluated as a proxy for the heat reaching the cambium. Components of bark charring included height of char, the amount of bark consumed and the percent circumference of the bole charred. Bud damage was categorized as “all dead,” “some live,” or “most/all live.”

Mortality data were analyzed using two sample t-tests and a maximum likelihood estimation procedure. Using the t-test approach, trees were tested as two classes: live (those with intact above-ground tissues remaining) and dead (those that had been top-killed and may or may not have re-sprouted the following spring).

The hypothesis was that the probability of survival the following growing season was a function of tree size and condition (height, diameter breast-height, crown width, crown length, bark thickness), apparent fire effects (percent crown scorch, bud damage, bole char), and adjacent vegetation (basal area of competition, presence of ladder fuels). The predicted value of the dependent variable, LIVE, can be interpreted as the probability of a particular tree surviving the fire.

$$\text{LIVE} = f(\text{tree size and condition, fire effects, adjacent vegetation}).$$

Since the dependent variable, LIVE, is a discontinuous variable having a value of 0 (tree died) or 1 (tree survived), logistic regression procedures were used to develop the statistical model. This process transforms the dependent variable using the logistic function, and estimates the coefficients for the independent variables shown in the general equation below using a maximum likelihood estimation process (Wonnacott and Wonnacott 1979).

$$\text{LIVE} = \frac{1}{1 + e^{-(x'\beta)}}$$

Where: LIVE = dependent variable (1 = tree survived, 0 = tree top-killed)

x = vector of independent variables

β = logistic regression coefficients

Results

In the August 2000 assessment, 16 percent of the trees had been top-killed. Of these, however, only two had failed to re-sprout. A summary of t-test results for variables significantly associated with top-kill are given in *table 1*.

The results of the maximum likelihood estimation procedure for seedlings (less than 3 feet tall) and saplings (trees 3 to 10 feet tall) are shown below in *table 2*. The results of tree survival (trees > 10 feet tall) are shown below in *table 3*. Because these variables explain between 86 percent and 96 percent of the variation in mortality, we believe they represent an adequate prediction set for identifying trees that have a high likelihood of succumbing to fire effects.

Table 1— *T-test results for parameters significant at P<.01.*

Variable	Class means	
	Live	Dead
Bole char severity	2.5	1.3
Crown diameter (ft.)	13.0	5.6
Diameter (cm)	7.6	2.1
Tree height (ft.)	20.4	10.3
Bark thickness (cm)	0.49	0.11
Percent scorch	66	98
Bole char (pct)	31	74

Table 2—*Logistic analysis of blue oak seedling and sapling survival (under 10 feet tall) following wildfire.¹*

Variable	Coefficient (significance)
Constant	-5.2002 (**)
BA = Stand basal area in square feet per acre	0.07607 (*)
HT = total tree height (feet)	0.68888 (**)
CHARHT = height on bole with blackened char (feet)	-2.9331 (**)
CHARSEV = char severity rating (1 = completely black, bark reduction; 2 = black into crevices, no bark reduction; 3 = black on surface, not inner crevices; 4 = no char)	2.5328 (**)
Equation significance	(**)
Percent of variability in survival explained by model	0.86

¹ Significance with one (*) indicates variable was significant at p=.05. Two (**) indicate variable was significant at p=.01

Equation (1) shows the blue oak seedling and sapling survival equation developed from the transformed logistic regression (see *table 2* for a description of variables). A similar transformation is made to develop the blue oak tree survival model from the results shown in *table 3*.

$$(1) \text{LIVE} = \frac{1}{1 + e^{-(-5.2002 + 0.07607 \times \text{BA} + 0.68888 \times \text{HT} - 2.9331 \times \text{CHARHT} + 2.5328 \times \text{CHARSEV})}}$$

Table 3—Logistical analysis of blue oak survival (> 10 feet tall) following wildfire.¹

Variable	Coefficient (significance)
Constant	-1.1703
DBH = Diameter at breast height (inches)	0.83702 (**)
CHARPCT = percent of bole circumference with char at 1 foot	-6.4627 (**)
CHARSEV = char severity rating (1 = completely black, bark reduction; 2 = black into crevices, no bark reduction; 3 = black on surface, not inner crevices; 4 = no char)	2.1847 (**)
Equation significance	(**)
Percent of variability in survival explained by model	0.96

¹Significance with one (*) indicate variable was significant at p=.05. Two (**) indicate variable was significant at p=.01

Discussion

The severity of damage from fire is largely dependent on the temperature reaching the living cells of the cambium beneath the bark (Plumb and Gomez 1983). Owing to their greater thickness of protective bark, larger trees are much more resistant to high temperature fires than small trees. Fire can also seriously damage trees when it reaches the crown. Taller trees with elevated crowns are more immune to crown fires than shorter trees, but ladder fuels can make all tree classes vulnerable and high tree densities can lead to the spreading of crown fires once they occur. In the case of the trees we examined, blue oaks proved highly resistant to top-kill from fire except for those in the smallest size classes and those individuals that were in close proximity to ladder fuels that carried fire into the crown and fallen debris that burned at high temperature in close physical proximity to the bole. We noted that damage to oaks was relatively minor in areas where fine fuels had been reduced by grazing prior to the fire. *Figures 1-4* illustrate how tree survival changes with tree size, char height and char severity. The three lines in each graph represent the three char severity ratings (CHAR 1 is most severe, CHAR 3 is least severe—see *table 2* for description of char variable). *Figures 1 and 2* present the data for seedlings and saplings grouped within two char height classes, representing tree size in terms of total height. *Figures 3 and 4* present the data for older trees grouped within two bole diameter classes, representing fire effects in terms of percent bole char.

These analyses indicate that a 4-point bole char severity rating plus char height and total tree height (young oaks) or percent bole charred at 1 foot and bole diameter (older trees) provided good prediction of mortality. The bole char severity rating procedure can easily be taught to general audiences and the remaining three measurements are likewise straightforward and require no special training or tools.

We therefore believe that we have the basis for a useful tool that we can provide to all groups interested in oak fire assessment.

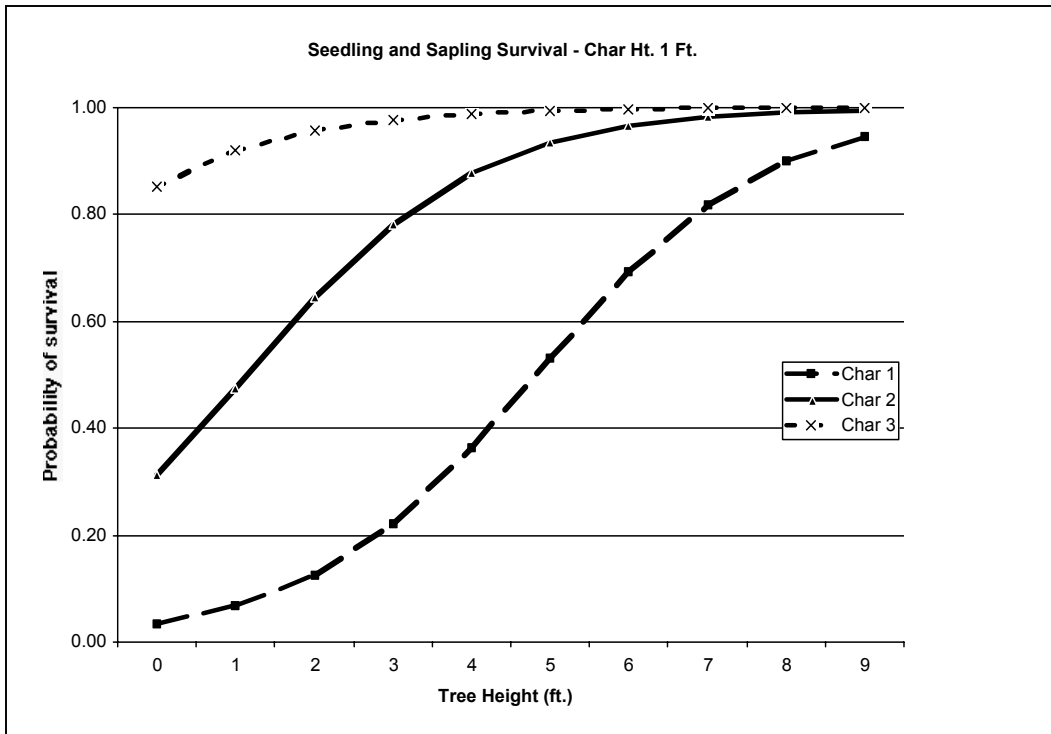


Figure 1—Seedling and sapling survival, char height 1 foot.

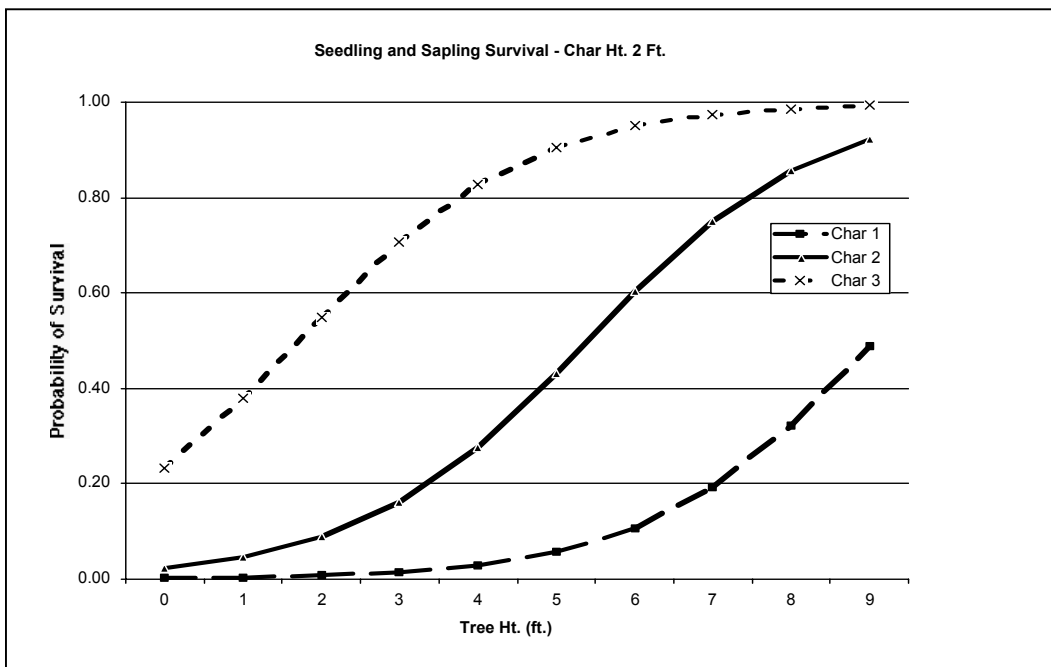


Figure 2—Seedling and sapling survival, char height 2 feet.

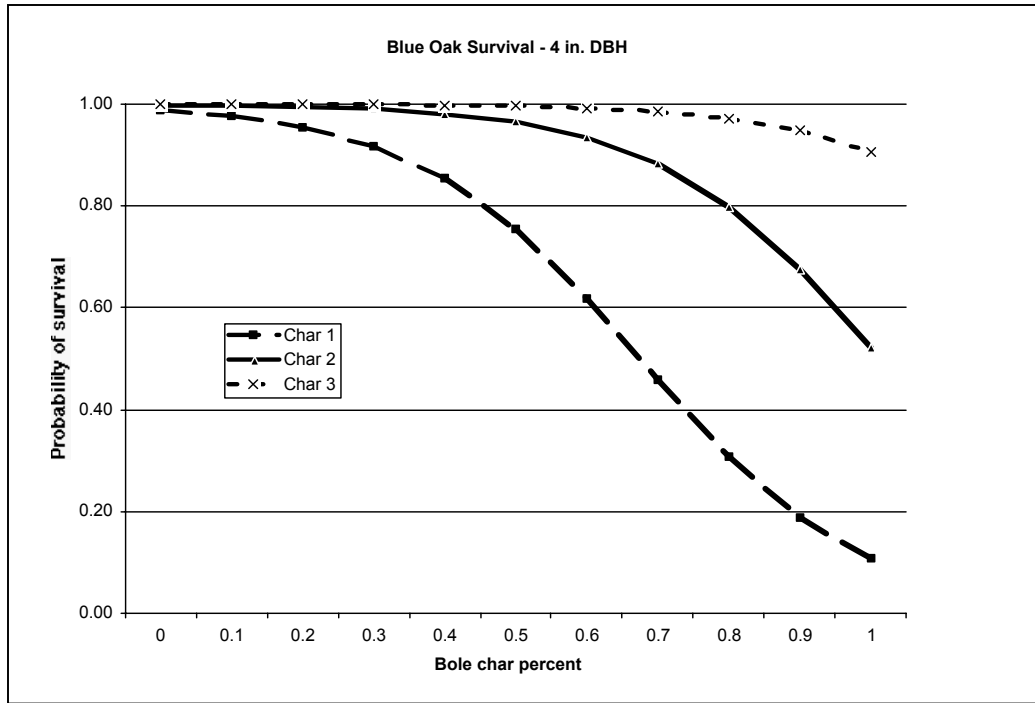


Figure 3—Tree survival, DBH 4 in.

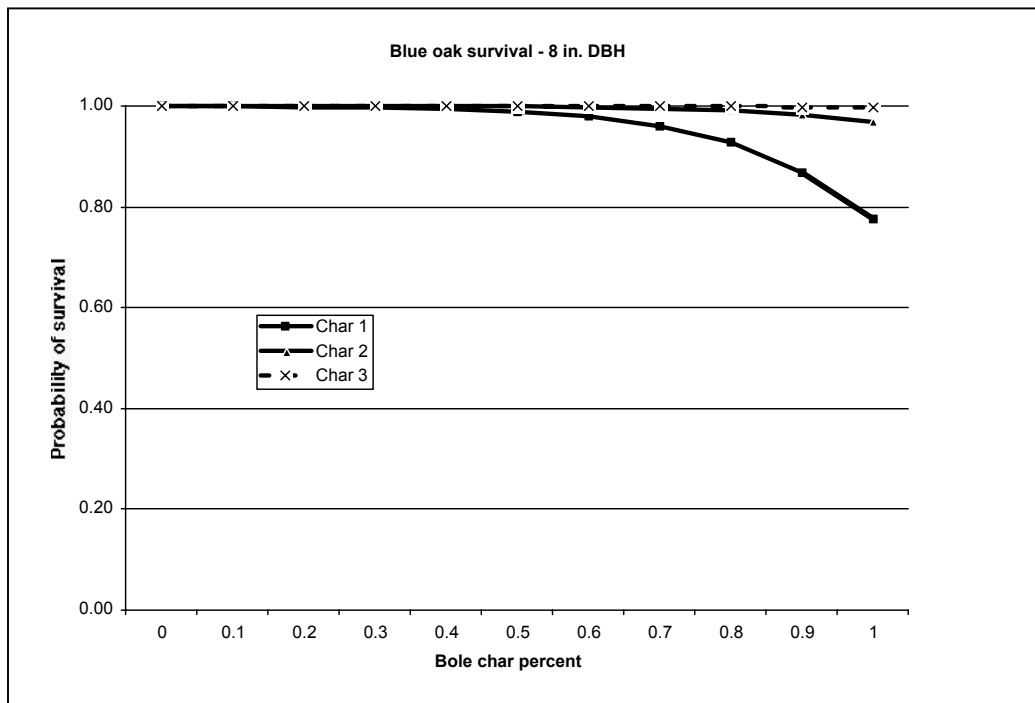


Figure 4—Tree survival, DBH 8 in.

Conclusions

The techniques applied in this study have produced procedures that correctly predict the likelihood of top-kill in blue oak stands following fire for over 85 percent of the trees analyzed. The parameters used in the model are straightforward enough to be used by landowners and other non-professionals after minimal training. Further refinements to these models following more extensive applications may produce some improvement in accuracy, usefulness and scope.

In terms of mortality effects, it seems that size is an indication of the likelihood of trees dying from the fire as several different variables that were related to size were significantly different for alive and dead trees with small trees more likely to be killed (diameter, height, bark thickness, crown diameter).

References

- McClaran, Mitchel P.; Bartolome, James W. 1989. **Fire-related recruitment in stagnant *Quercus douglasii* populations.** Canadian Journal of Forest Research 19: 580-585.
- Mensing, Scott. 1992. **The impact of European settlement on blue oak (*Quercus douglasii*) regeneration and recruitment in the Tehachapi Mountains, California.** Madrono 39(1): 36-46.
- Mooney, H. A., ed. 1977. **Convergent evolution in Chile and California Mediterranean climate ecosystems.** Stroudsburg, Pennsylvania: Dowden, Hutchinson and Ross, Inc.
- Plumb, T. R.; Gomez, A. P. 1983. **Five southern California oaks: identification and postfire management.** Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, USDA Forest Service. Gen. Tech. Rep. PSW-71; 56 p.
- Wonnacott, R. J.; Wonnacott, T. H. 1979. **Econometrics.** 2nd ed. New York: Wiley.