

Effects of a Prescribed Fire on Oak Woodland Stand Structure¹

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Abstract

Fire damage and tree characteristics of mixed deciduous oak woodlands were recorded after a prescription burn in the summer of 1999 on Mt. Hamilton Range, Santa Clara County, California. Trees were tagged and monitored to determine the effects of fire intensity on damage, recovery and survivorship. Fire-caused mortality was low; 2-year post-burn survey indicates that only three oaks have died from the low intensity ground fire. Using ANOVA, there was an overall significant difference for percent tree crown scorched and bole char height between plots, but not between tree-size classes. Using logistic regression, tree diameter and aspect predicted crown resprouting. Crown damage was also a significant predictor of resprouting with the likelihood increasing with percent scorched. Both valley and blue oaks produced crown resprouts on trees with 100 percent of their crown scorched. Although overall tree damage was low, crown resprouts developed on 80 percent of the trees and were found as shortly as two weeks after the fire. Stand structural characteristics have not been altered substantially by the event. Long term monitoring of fire effects will provide information on what changes fire causes to stand structure, its possible usefulness as a management tool, and how it should be applied to the landscape to achieve management objectives.

Introduction

Numerous studies have focused on the effects of human land use practices on oak woodland stand structure and regeneration. Studies examining stand structure in oak woodlands have shown either persistence or strong recruitment following fire (McClaran and Bartolome 1989, Mensing 1992). Others studies show a high tolerance and survivability of trees (Griffin 1980, Haggerty 1994, Plumb and Gomez 1983), although high intensity fires can cause substantial damage and mortality to stands depending on the species (Plumb 1980, Plumb and Gomez 1983). Despite this, information on fire and maintenance of oak woodlands is deficient (Barbour 1988, Haggerty 1994). This paper reports on preliminary damage and recovery of oak trees two years after a prescribed burn.

Study Site and Methods

This study was conducted on the west-facing slopes of Poverty Ridge (37°25'N, 121°45'W, elev. 800 m.) in the Mount Hamilton area, Santa Clara County, on the northern end of the Diablo Range. Mean annual precipitation is 59 cm for this area

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and was such during the two years of this study. Mean seasonal temperatures for winter and summer are 17°C and 8°C, respectively. Although the burn site is predominantly on the west side of Poverty Ridge, narrow, deeply cut drainages create a rugged terrain with steep slopes. Concomitantly, the oak woodlands vary in cover and species assemblage ranging from single black (*Quercus kelloggii*), blue (*Quercus douglasii*), and valley oak (*Quercus lobata*) stands to mixed codominance. The woodlands are relatively dense, mean canopy density is approximately 50 percent, but are parceled by grassland openings across the site. Associated overstory species *Quercus agrifolia* Nee (coast live oak), *Aesculus californica* (Spach) Nutt. (California buckeye), *Umbellularia californica* (Hook. & Arn.) Nutt. (California bay) and *Platanus racemosa* Nutt. (western sycamore) are relatively rare and found exclusively in drainages and on mesic, north-facing slopes. The understory consists mostly of forbs and annual grasses such as *Bromus diandrus* Roth (ripgut grass), *B. hordeaceus* L. and *Avena* (oats), *Carduus pycnocephalus* L. (italian thistle), and a negligible shrub cover.

Tree diameter ranged from 3.5 cm to 137.3 cm at breast height (dbh, 1.37 m), with an average of 48.8 cm. There are very few seedlings and saplings across the site; a recent survey showed the majority of them found in blue oak dominated stands.

The three hundred acre burn was conducted on June 24, 1999, commencing on the northeastern corner of the unit near the ridge. Weather conditions at time of ignition were: 20°C, R.H. at 55 percent, and the wind was 2-4 mph from the southwest. The carrier of the fire was mostly annual grasses and forbs, typical of a fuel model 1 or 2. Fine fuel moisture estimated from weather conditions ranged from 6-8 percent. The area burned mostly under backing and flanking conditions early on and throughout most of the day. Fireline intensity was relatively low in this area as flame lengths ranged from several centimeters to 0.5 meters. Extensive black lining was established before pen flares were shot into drainages to induce spot firing. The bottom of the unit was ignited in the early afternoon where it burned under head fire conditions towards the burned areas upslope. Weather conditions during this time were 22°C, R.H. at 42 percent, and the wind was 2-4 mph out of the northwest. The drier conditions strongly influenced fireline intensity and produced brief moments of flame lengths up to 2.5 meters in height. In this area many trees were exposed to extreme heat and their crowns were completely scorched with a few incidences of leaves on lower parts of the canopy catching fire. Overall, the fire burned under conditions that kept fireline intensity fairly low and consequently limited damage to the trees; only minimal scorching on the bottom of crowns occurred with a small number of trees having 100 percent of their crown scorched. This burn could be classified as a low-to-moderate ground fire where most of the understory was consumed except for patches in drainages and on mesic slopes with dense canopies. Estimates of fireline intensity ranged from 15-750 kW/m using observations of fuel and weather conditions at the time of the fire (Rothermel 1983).

The burn area was stratified into four plots in an effort to capture the variation in fire intensity: northeast (NEAST), northwest (NWEST), southeast (SEAST) and southwest (SWEST). The NEAST plot was on the east side of the ridge near the ignition point and was the first area to burn under low intensity. The trees in this area received minimal scorching of the canopy. The NWEST and SEAST plots burned under a number of fire line conditions midday and had variable crown scorch. Lastly, the SWEST plot was the last to burn under head fire conditions and received the greatest degree of damage.

Parallel line transects were placed in each of the four plots two months after the burn (August 1999). At randomly selected points along each transect the point-centered quarter sampling method (Mueller-Dombois and Ellenberg 1974) was used to select trees for long-term monitoring of damage and recovery. In each of the four quarters, the closest oak tree was tagged and measured for diameter at breast height (dbh), height, and fire damage. Tree-damage measurements included bole-char height, presence of previous trunk scars, a visual estimation of percent of the crown scorched broken into classes, and any crown or basal resprouting. The trees did not abscise the scorched leaves following the fire, allowing for an estimate of tree damage and a 'preburn' estimate of canopy cover. A total of 208 oak trees were tagged and resampled in the summer of 2000 and 2001 for evidence of damage, recovery and survival.

Tree damage characteristics, such as amount of crown scorch and bole-char height, were tested for significant differences between plots varying in fire intensity and tree size using nonparametric ANOVA with multiple comparisons. Paired t-tests were used to tests for differences in canopy density before and after the fire within plots. Chi-square tests were used to test for differences in occurrence of fire scarring and resprouting, while binary logistic regression was used to determine the relationships between resprouting with tree size and fire damage and site characteristics such as slope, aspect, and canopy density.

A seedling survey was conducted after the burn for size, density, and resprouting. Since a pre-burn survey could not be conducted, mortality from the fire could not be determined so data will not be reported.

Results

Fire Damage

Overall, trees received minimal scorching from the fire (*table 1, fig. 1*). Approximately 78 percent of the trees, mostly valley oaks, had less than 50 percent of their crown scorched. Of the 21 black oaks sampled, only one had greater than 50 percent of its crown scorched. Black oaks on this site are found on more mesic north facing slopes where the fire was not as intense and, consequently, received less damage. Using the Kruskal-Wallis test, mean crown scorch and mean bole char height differed significantly between plots ($p < .005$ for both, *table 1*). Crown scorch on the SWEST plot was significantly higher than on all other plots, although only 18 percent of the trees had completely scorched crowns and contained the only tree that died directly from the fire. This tree was entirely burned out through the bole, probably from a preexisting scar, and fell soon after the fire. Despite this, SWEST had only a slightly higher mean bole scorch height than the lowest fire damaged NEAST plot. There was no significant difference in fire damage characteristics for tree size.

The 2-year post-burn survey revealed only two trees died during the second year after the fire, a black oak on the NWEST plot and valley oak on the SEAST plot. The black oak had a preexisting trunk scar which allowed the fire to burn out the inside of the bole, and eventually felling the weakened tree. The valley oak had a thin crown before the fire and although it resprouted from the crown and bole, it had no green foliage in the summer of 2001 and is presumed dead. Neither tree has since

resprouted from the base. The deficiency of dead trees from this burn prohibited any statistical analysis on tree mortality.

Table 1—Site and tree damage characteristics for oak woodlands two years post-prescription burn on Poverty Ridge in the Mt. Hamilton Range. Means with different letters within rows indicate significant difference by ANOVA ($p < .05$).

	Low <- - - - Fire Intensity - - - -> High			
	Plot			
	N-EAST	N-WEST	S-EAST	S-WEST
Site characteristics				
Aspect	50°	305°	180°	238°
Slope (pct)	35	41	32	45
Canopy cover (pct)	54	36	48	41
Trees/plot (Bl-Bk-Vy)	0-2-50	29-18-17	18-0-30	20-1-23
Density (# /Ha)	32.6	67.9	73	77.5
Fire damage				
Mean crown scorch (pct)	14 a	26 a	35 b	50 c
100 pct crown scorch (n)	0	3	1	8
Mean bole char ht (cm)	6.3 a	24 ab	17 b	8.3 a
Fire effects				
Above ground mortality	0	2	1	0
Fire scars (pct)	9.1	4.2	12.5	3.9
Mean bole scar ht (cm)	2.7	0.8	5.6	3.1

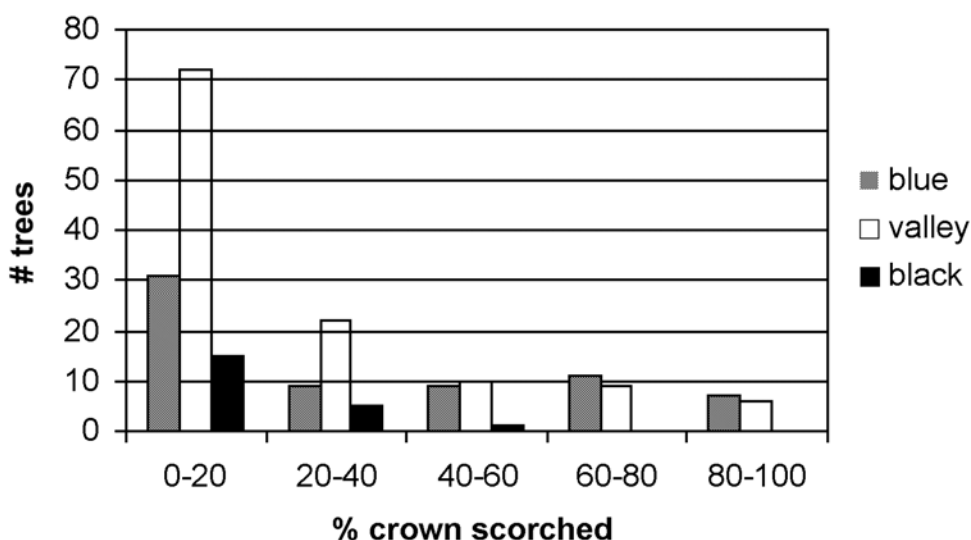


Figure 1—Amount of crown scorched, broken into size classes for three species of tagged oaks after a prescribed fire (n=208).

Recovery

Overall, percent canopy density was slightly higher for the 2001 measurements as compared to the measurements taken just after the fire in 1999 (46.67 percent and 44.14 percent, respectively). Paired t-tests showed only the SWEST and NWEST plots to be significantly different, a 7.2 percent and 5.8 percent increase two years postburn ($p < 0.05$, *fig. 2*). The two other plots, SEAST and NEAST, had a less than 2 percent decrease in canopy density.

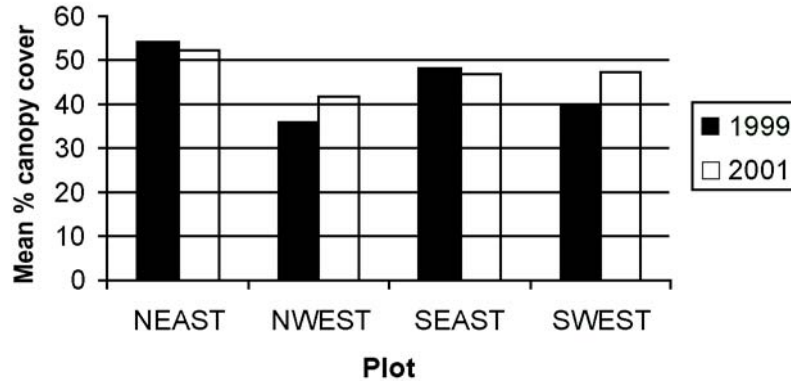


Figure 2—Comparison of average canopy cover in fire intensity plots immediately post-burn (1999) and two years post-burn (2001).

One year after the fire, crown resprouting occurred in 71.5 percent of the trees sampled, and new sprouts were seen developing on tree crowns as soon as two weeks after the fire. Less than 4 percent of the trees resprouted on the bole. Approximately 73 percent of the blue oaks and 81 percent of the valley oaks that were scorched resprouted from the crown. Resprouts occurred on at least 50 percent of the trees with as low as 20 percent of their crown scorched. Chi-square tests found a significant difference in number of trees resprouting between plots ($\chi^2 = 27.6$, $p = .000$). Only the NWEST plot had a lower number of resprouts than expected. Percent crown scorch ($p < .05$) and tree size (dbh, $p = .007$) were significant predictors of crown resprouting using binary logistic regression analysis. Trees with higher percentage of their crowns scorched were more likely to resprout from the crown (*fig. 3*). Resprouting also occurred on trees in all size classes. Aspect was the only environmental variable found to be significant ($p = .03$), with trees on southern exposures more likely to resprout.

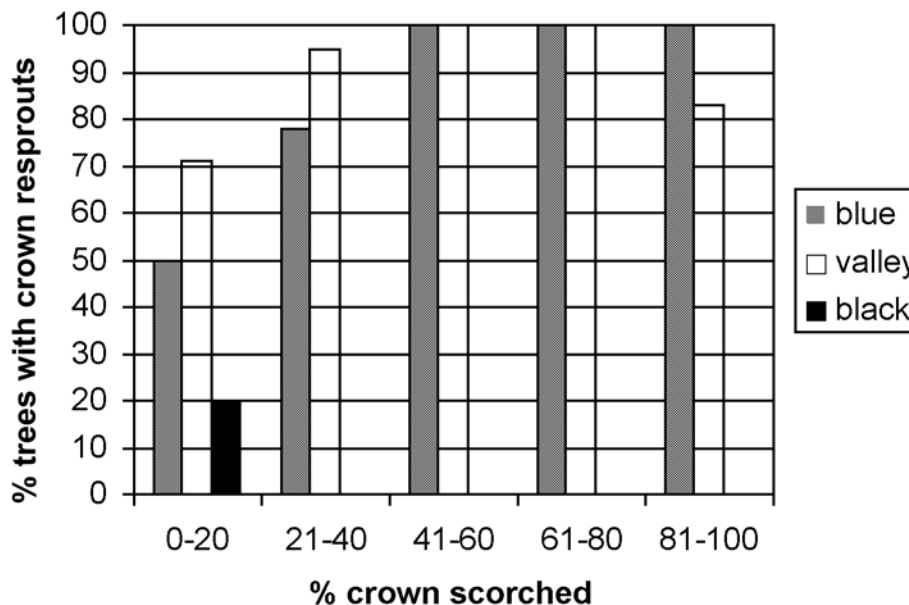


Figure 3—Tree crown resprouting as a function of crown scorched for three species of tagged oaks following a prescribed fire (n=208).

Scarring

Less than 8 percent of the trees received new trunk scars. Average scar height varied strongly between plots and occurred on just about all tree sizes. Chi-squared tests found no significant difference in occurrence of new scars between plots ($\chi^2=4.13$, $p=0.25$). Old trunk scars was the only significant predictor of new scars while tree size, percent crown scorch, and site variables were not significant when analyzed by regression. Trees having old trunk scars increased the likeliness of receiving a new trunk scar and only one occurred in previously undamaged bark.

Conclusion/Discussion

The plots differing in fire intensity identified from field observations corresponded well with the degree of crown damage, but not with the occurrence of trunk scarring. Although only a small number of trees received new scars (*table 1*), this effect can cause long-term damage by predisposing trees to rot and failure, (Plumb and Gomez 1983) altering stand characteristics. Two of the three trees that died had preexisting scars which were a likely factor in their deaths. Any concern for tree survival may need to focus on factors controlling trunk scarring and not crown scorching.

Area canopy density in this study was essentially unchanged two years following the fire, being higher for only two of the four plots (*fig. 2*). Whether this was caused by fire-stimulated emergence of dormant buds, creating denser canopies, or by other variables, such as precipitation, was not investigated. However, mean

annual precipitation during the two years of this study was approximate to the overall mean, although it was also about half as much as in 1998 (115 cm.).

Little change occurred in stand structural characteristics from the burn, indicating the overall low severity of the fire. Other than bole char/scars and a few clumps of dead leaves still in the canopy, most trees show no signs of the fire and have fully recovered. Species dominance was not substantially altered from this event since only three trees died, a black and two valley oaks. Although they were larger size trees (43-64 cm. dbh).

Although this is a single event, the damage, recovery, and mortality results of this study, along with previous studies (Griffin 1980, Plumb and Gomez 1983, Haggerty 1994), indicate a relative tolerance of oaks to fire. However, questions regarding the role of fire in oak woodland maintenance and recruitment still need to be investigated. It is unclear the amount of fire necessary, if at all, to sustain stands and how it influences regeneration. Overall canopy density was higher following the burn, indicating that trees had fuller, healthier crowns following the fire. Many resprouts observed from burned seedlings surveyed after the fire had greater than one shoot emerging. Increasing the numbers of shoots after a fire may increase growth rates and the chance of survival to young adults withstanding browsing pressure (Mensing 1992), competition with annuals, and subsequent fire. However, other studies suggest these factors may not play a critical role in survival (Allen-Diaz and Bartolome 1992, Sweicki and others 1990). Regeneration may be more dependent on factors controlling growth (Allen-Diaz and Bartolome 1992) such as light, temperature, and resource availability. Fire may be beneficial in creating canopy gaps allowing more light to reach the understory and creating suitable microclimate conditions for recruitment (Muick and Bartolome 1987 as referenced in Mensing 1992). A substantial increase in bare ground and percent cover of native understory plants, mostly wildflowers, was recorded following this burn as compared to the year prior (Homrighausen 2000). Studies have shown herbaceous cover, mostly grassland annuals, to increase moisture stress and deplete soil water availability, thereby adversely affecting oak seedling establishment and growth (Adams and others 1992, Gordon and Rice 1993).

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