Influence of Fire on Oak Seedlings and Saplings in Southern Oak Woodland on the Santa Rosa Plateau Preserve, Riverside County, California[1]

Earl W. Lathrop Chris D. Osborne[2]

Abstract: One wildfire and two prescription burns were monitored at 15 oak seedling/sapling regeneration sites and at four non-burned comparison sites to study the effect of fire on seedlings and saplings of *Quercus engelmannii* (Engelmann oak) and *Q. agrifolia* (coast live oak). The number of initial top-killed seedlings and saplings, initial survivors, postburn resprouts and total survivors at the end of the study were compared between fire study sites and the non-burned comparison sites. The initial top-kill rate was higher in the burn sites than in comparison sites. Although top-killed seedlings and saplings in burned sites resprouted at a higher rate than top-killed seedlings and saplings in unburned sites, the differences were not statistically significant. Total overall survival of test seedlings and saplings at the end of the study was slightly higher in burned sites than in non-burned sites. Resprouting after fires may compensate for the high initial top-kill rate of fire in oak woodlands and contribute to the early recovery and total survivorship of the young oak population following fires.

This study reports the influence of three burn experiments monitored in 1988 and 1989—one wildfire and two planned prescription burns on seedlings of *Quercus engelmannii* Greene (Engelmann oak). *Q. agrifolia* Née (coast live oak) occurs as a co-dominant with *Q. engelmannii* in the "Engelmann oak phase" of southern oak woodland (Griffin 1977). Of the total seedling and sapling oak samples (N=791) in the 15 bum test sites, 699 were *Q. engelmannii,* the focus of this study, and 92 were *Q. agrifolia.* Snow (1980) reported on the differential response of *Q. engelmannii* and *Q. agrifolia* seedlings to prescription fires. He states that buds of *Q. engelmannii* are better protected and/ or more resistant to fire and heat than those of *Q. agrifolia.* The few *Q. agrifolia* oak samples in our burn sites were included in the total analysis.

Wildfires can be very destructive to the mature oak trees, depending on the season, climatic conditions and fuel properties. Wildfires may burn at high intensity (104-132 °F) and may kill surface or subsurface perniating buds (Lathrop and Martin 1982b). However, prescription burns are typically light-intensity (98 °F) mosaic fires initiated when fuel moisture, humidity, and wind velocity make the fires controllable. Studies have shown that burning initially involves a major disturbance to vegetation, but tends to generate new and fresh plant growth (Sugihara and Reed 1987, Lathrop and Martin 1982a,b). Sugihara and Reed state that periodic low intensity burning can result in long-term preservation of one of California's threatened oak woodland types. The vulnerability of above ground parts of shrubs or saplings to fire is due to the thin bark (surrounding their trunks) and damage to the cambium. Low or light-intensity fires cause little apparent injury to trees, except where heavy fuel has built up directly under or adjacent to canopies. Seedlings and saplings less than 5 cm diameter breast height (DBH) will be top-killed by most fires, including light intensity mosaic burns (Plumb 1980).

This paper reports on the number of oak seedlings and saplings at field test sites which survived or were top-killed as a direct result of the three fires studied, subsequent resprouting of destroyed above ground parts, and total survivors at the end of the study period.

STUDY AREA

The 1255 hectare (ha) Santa Rosa Plateau Preserve (SRPP), located on the Santa Rosa Plateau in the southeastern part of the Santa Ana Mountains of the Peninsular Ranges (Lathrop and Thorne 1978,1985a, 1985b) is a complex mosaic of vegetation communities: southern California grassland; riparian woodland; southern oak woodland; chaparral; and vernal pool ephemeral. Among management objectives of the prescribed burns on the SRPP, conducted by the California Division of Forestry (CDF) in cooperation with the California Nature Conservancy, were to: 1) reduce mulch layer 50-75 pct; 2) remove non-native grasses; 3) reduce shrub fuel load below the canopy and adjacent to *Quercus engelmannii* by 50-75 pct; and 4) reduce chaparral shrub canopy by 75 pct. This was part of an effort to restore native plants to the SRPP, and to increase species richness. The prescribed burns also reduce fire hazard, improve wildlife habitat, and increase water runoff (without running the risk of erosion) to enhance stream flow.

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[2]Professor, Department of Natural Sciences, Loma Linda University, Loma Linda, California; and Life Science Teacher, Acacia Middle School, Hemet, California.

METHODS

Prior to the burns, 15 study sites were selected at given *Quercus engelmannii* trees which had naturally occurring oak seedlings (basal stem diameter <1 cm) and saplings (basal stem diameter ≥1 cm - <10 cm dbh) under the canopy and in the immediate vicinity surrounding the tree. Three of these sites were fortuitously set up in an area subsequently burned by wildfire. The sample number (N) was determined as the number of live (with green stems and leaves) sample seedlings and saplings at all study sites prior to the wildfire and prescription burns. Each oak seedling or sapling was flagged and tagged with 3/4 inch numbered metal tags at each study site. Seedlings and saplings at sites within the prescription burns and the wildfire were counted prior to and within a short time after the fires to determine the number of survivors (S) and those which were top-killed (Tk) by the fire. Survivorship rate was determined as a function of the initial number of live oak samples (N) which survived the fire. Resprouts (Rs) were those seedlings and saplings which were initially top-killed by fire but subsequently produced new above ground growth. Total survivorship (TS) was determined as the number survivors at the last interval plus resprouts (Rs) minus secondary top-killed (STk) specimens. Desiccation (Des) and browsing (Brw) by small rodents (i.e: *Peromyscus* sp. [deer mouse], *Spermophilus beecheyi* [California ground squirrel], *Perognathus californicus* [jumping mouse], and *Thomomys bottae* [California pocket gopher]) were the usual cause of secondary top-kill following fire. Oak samples were considered to have sustained top-kill if there were blackened remains, above-ground parts completely destroyed by contact with flames, or if leaves and stems were brown from being heat-killed. It is well known that most oak species vigorously resprout (Rs) from root crowns and at the below-ground bud zone (Plumb 1980). The *Quercus engelmannii* and *Q. agrifolia* seedlings that were top-killed by fire or heat may still have remained alive at their roots, below-ground buds, and stem buds and thus, may have retained the ability to resprout from these buds.

Burnt wire flag markers were replaced with new flags and the metal specimen number tags were left in place for each seedling/sapling sample in the test population at the first postfire monitoring. We conducted postburn measurements at all test sites each fall and spring seasons, usually in November and May because these times of the year correspond to the greatest periods of regrowth and mortality. Postburn data collected were: 1) number of secondary top-killed (STk) seedling and saplings; 2) resprouts (Rs) of original fire damaged samples; and 3) number of total survivors (TS). Following fire, renewal of seedlings and saplings may take place by resprouting. However, many resprouted seedlings die-back and resprout several times. The frequency of resprouting of *Quercus engelmannii* seedlings, however, tends to diminish with age and may cease altogether before reaching the more stable sapling stage.

The wildfire of August 31, 1988 burned over grassland and oak woodland, mainly on the north slope and top of Mesa de Colorado on the SRPP (table 1). The two prescription fires burned through valleys and gentle slopes on November 16, 1988 (four sites) and June 13, 1989 (eight sites), respectively (table 1). Four comparison sites, containing a total N of 703 seedlings and 38 saplings of *Quercus engelmannii* and 14 *Q. agrifolia* seedlings in adjacent non-burned oak woodland on the SRPP, were monitored over approximately the same seasons as the burn sites to compare recovery and frequency of resprouting between burn and non-bum sample seedlings and saplings (table 2).

Table 1—***Description of fire conditions and area of burns in hectares (ha) of one wildfire and two prescription burns on the Santa Rosa Plateau Preserve. S= number of study sites; N= total number of preburn seedlings (sdl) and saplings (spl). W spd.= wind speed; RH= relative humidity; high intensity fire= 104-132°F; low intensity fire= 98°F.***

Fires	N Sdl	N Spl	Conditions	Type
WILDFIRE				
August 1988			Temp. 85°F	Moderately high intensity
121 ha, 3 sites			W spd. 15/mi/hr	Fire carried by
Q. agrifolia	2	1	RH semi-dry	ground/shrub cover
Q. engelmannii	79	43		
PRESCRIPTION BURN 1				
November 1988			Temp. 68°F	Medium intensity
109 ha, 4 sites			W spd. 1-2/mi/hr	Fire carried by
Q. agrifolia	62	5	RH 45 pct	ground cover
Q. engelmannii	132	9		
PRESCRIPTION BURN 2				
June 1989			Temp. 70°F	Low intensity
170 ha, 8 sites			W spd. 3-5/mi/hr	Fire carried by
Q. agrifolia	22	0	RH 27 pct	ground cover
Q. engelmannii	436	0		

Table 2—*Overall breakdown of total number (N), total number initial top-killed (Tk), total initial survivors (S), total resprouts (Rs), total secondary top-killed (STk), and total survivors (TS) of seedlings (A) and saplings (B) at each of the 15 burn sites and jour comparison sites from Fall 1988 - Spring 1990 on the Santa Rosa Plateau Preserve.*

	Wildfire			Prescribed 1				Prescribed 2								Comparison			
Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A. SEEDLINGS										NUMBER									
N	25	38	18	113	2	19	60	69	38	142	30	26	54	50	49	47	123	335	212
Tk	15	35	18	88	2	14	50	69	35	136	30	24	54	50	49	8	14	48	70
S	10	3	0	25	0	5	10	0	3	6	0	2	0	0	0	39	109	287	142
Rs	13	24	4	75	0	8	29	48	26	96	19	11	29	14	15	0	10	15	51
STk	6	4	1	10	0	3	5	5	1	6	0	0	0	2	3	5	67	122	78
TS	17	23	3	90	0	10	34	43	28	96	19	13	29	12	12	34	52	180	115
B. SAPLINGS																			
N	14	30	0	0	7	0	7	0	0	0	0	0	0	0	0	0	0	5	3
Tk	11	30	-	-	0	-	7	-	-	-	-	-	-	-	-	-	-	0	0
S	3	0	-	-	7	-	0	-	-	-	-	-	-	-	-	-	-	35	3
Rs	7	28	-	-	0	-	7	-	-	-	-	-	-	-	-	-	-	0	0
STk	0	0	-	-	0	-	0	-	-	-	-	-	-	-	-	-	-	7	0
TS	10	28	-	-	7	-	7	-	-	-	-	-	-	-	-	-	-	28	3

The chi-square goodness of fit test (Zar 1984) was used to test the null hypotheses that initial top-kill, resprouts, and long term survival rates do not differ between comparison and burn sites and between *Quercus agrifolia* and *Q. engelmannii.*

RESULTS

The initial top-kill for the wildfire (table 1) was 109 individuals out of 125 (tables 2, 3). Of this number, 11 *Quercus engelmannii* seedlings and five *Q. engelmannii* saplings survived. All three of the *Q. agrifolia* samples (two seedlings and one sapling) were top-killed. Sixty-eight *Q. engelmannii* seedlings out of 81 (83.9 pct) sustained top-kill, as did 40 *Q. engelmannii* saplings out of 45 (88.9 pct; table 3). However, 72 individuals (66 pct of top-killed specimens) resprouted by may 1989 (10 months postburn), plus three surviving stems (three stems perished) make 68 pct of the original preburn N of 125 (table 3). Only six resprouts died in the next year. Thus the seedling and sapling population at the wildfire test sites remained at or near 81 through the monitoring period (tables 2, 3).

The second fire examined was a prescription burn of November 1988 (table 1). One hundred sixty-one of the 208 preburn sample seedlings and saplings (78.3 pct) were top-killed by the fire (tables 2, 4). Sixty seven of the 208 samples specimens were *Quercus agrifolia* (62 seedlings and five saplings). Of the *Q. agrifolia* samples, 59 seedlings (88.0 pct) were top-killed by fire. Ninety-five of the 132 *Q. engelmannii* seedlings and seven of nine saplings did not survive the fire (tables 2, 4). By May 1989 resprouts of *Q. agrifolia* (32) and of *Q. engelmannii* (80) the previous winter season brought the total live stems back to 40 for *Q. agrifolia* and to 116 (including three top-kills by desiccation) for *Q. engelmannii.* Total survivors by the end of the study (May 1990) was 32 samples of *Q. agrifolia* out of the initial N of 67 (47.7 pct) and 110 live stems of *Q. engelmannii* out of the original N of 141(78.0 pct; table 4). This recovery was due in part to continued survival of most of the fire escapees and from resprouting of top-killed seedlings and saplings in the test population.

Table 3—*Response and subsequent recovery of* **Quercus engelmannii** *and* **Q. agrifolia** *seedlings and saplings to wildfire. N= total number of live preburn oak samples at test sites within the burn area; Tk= number top-killed by fire; S= initial fire survivors; Rs= resprouts from fire-killed samples; STk= post burn secondary top-killed samples; TS=survivors of last interval plus resprouts (Rs) minus secondary top-killed (STk); Des= desiccation; Brw= browsing.*

Monitoring date							Pct secondary Tk	
	N	Tk	S	Rs	STk	TS	Des	Brw
WILDFIRE Aug.'88								
Quercus agrifolia	3	3	0	—	—	0	—	—
Quercus engelmannii	122	106	16	—	—	16	—	—
POST BURN								
May 1989								
Quercus agrifolia		—	—	1	0	1	—	—
Quercus engelmannii		—	—	71	3	84	100	—
Sep. 1989								
Quercus agrifolia		—	—	0	0	1	—	—
Quercus engelmannii		—	—	2	8	78	88	12
May 1990								
Quercus agrifolia		—	—	0	0	1	—	—
Quercus engelmannii		—	—	2	0	80	—	—

Table 4—*Response and subsequent recovery of* Quercus engelmannii *and* Q. agrifolia *seedlings and saplings to prescription burning. See legend table 3.*

Monitoring date	N	Tk	S	Rs	STk	TS	Pct secondary Tk Des	Brw
PRESCRIBED BURN 1								
Nov. 1988								
Quercus agrifolia	67	59	8	—	—	8	—	—
Quercus engelmannii	141	102	39	—	—	39	—	—
POST BURN								
May 1989								
Quercus agrifolia		—	—	32	0	40	—	—
Quercus engelmannii		—	—	80	3	116	100	—
Sep. 1989								
Quercus agrifolia		—	—	1	11	30	100	—
Quercus engelmannii		—	—	5	7	114	100	—
May 1990								
Quercus agrifolia		—	—	6	4	32	100	—
Quercus engelmannii		—	—	4	8	110	100	—

Table 5—*Response and subsequent recovery of* Quercus engelmannii *and* Q. agrifolia *seedlings and saplings to prescription burning. See legend table 3.*

Monitoring date	N	Tk	S	Rs	STk	TS	Pct secondary Tk Des	Brw
PRESCRIBED BURN 2								
June 1989								
Quercus agrifolia	22	21	1	—	—	1	—	—
Quercus engelmannii	436	426	10	—	—	10	—	—
POST BURN								
Sep. 1989								
Quercus agrifolia		—	—	1	0	2	—	—
Quercus engelmannii		—	—	74	6	78	100	—
Apr. 1990								
Quercus agrifolia		—	—	10	0	12	—	—
Quercus engelmannii		—	—	173	11	240	73	27

The fire at the second prescription burn of June 1989 (table 1) top-killed 97.6 pct of the total test seedlings (n=458; tables 2, 5). There were no saplings in any of the eight test sites. Twenty one *Q. agrifolia* seedlings out of 22 were top-killed by the burn (table 5). Only 10 *Q. engelmannii* seedling out of the preburn N of 436 were not top-killed by the fire (table 5). By September 1989, there was one resprout of *Q. agrifolia* and 74 resprouts of *Q. engelmannii* seedlings in the test sites, which brought the total live population from 11 after the burn to 80 (tables 2, 5). By April 1990, heavy resprouting of seedlings over the winter, brought the population up to 252, or 55.0 pct of the pre-fire value (tables 2,5).

The non-burn comparison sites (table 2, sites 16-19) were used to measure seedling and sapling recovery from fire as opposed to non-burned seedlings and saplings. The initial top-kill rate was higher in burn sites (90.6 pct, N= 791) than in comparison sites (18.5 pct, N= 755) where X^2= 809.96, df= 1, and P= <0.001. Although the resprout rate was higher in burn sites (63.2 pct, N= 717) than in comparison sites (54.3 pct, N= 140), it was not statistically significant (X^2= 3.55, df= 1, P= 0.059). Likewise, burn sites showed a higher long term survival rate (60.8 pct) than comparison sites (54.6 pct; X^2= 5.91, df= 1, P= 0.015).

The initial top-kill rates from fire were the same for both *Quercus agrifolia* (90.2 pct, N= 92) and *Q. engelmannii* (90.7 pct, N= 699; X^2=0.0, df= 1, P= 1.0), and there were no significant differences in the resprout rates during the study period for *Q. agrifolia* (55.4 pct, N= 92) and *Q. engelmannii* (59.8 pct, N= 699; X2=0.47, df= 1, P= 0.49). However, the long term survival rate during the study period was greater for *Q. engelmannii* (61.5 pct, N=699) than for *Q. agrifolia* (48.9 pct, N=92; X^2=4.87, df= 1, P= 0.027).

DISCUSSION

Our data show that resprouting may occur several years following the initial demise of a particular seedling. Although there is an upsurge of top-kill to seedlings and saplings with fire, strong resprouting was noted to occur in all burns. Chi-square tests indicate significant differences in both initial top-kill rates and long term survival rates between burn and comparison sites. However, there were no significant differences in subsequent resprout rates between burn and non-burn sites.

Comparison of preburn and postburn data demonstrate the effect of the fire on the young oak seedlings and saplings (tables 2-5). Although the initial top-kill rates were essentially the same for both *Quercus agrifolia* and *Q. engelmannii,* long term survival from the fire was generally less for *Q. agrifolia* compared to *Q. engelmannii.* The mature *Q. engelmannii* and *Q. agrifolia* trees at the burn sites were not noticeably affected by the fires. However, each of the three fires studied destroyed several large and small trees where fuel build up was high beneath their canopies; for the most part only the lower canopy leaves and twigs were fire-scorched. New bud growth for twigs and leaves of partially burned trees were evident within a few months after the fires. Stump sprouts of destroyed saplings were noticed within weeks or days, particularly following the wildfire. Most oak seedlings in the path of the fire were top-killed directly by the fire or indirectly by the heat. Fire causes higher initial top-kills to oak seedlings and saplings, but ultimately enhances long term survival and recovery of the reproductive population.

MANAGEMENT RECOMMENDATIONS

Top-killed seedlings and saplings in burned sites apparently fared better than those top-killed by desiccation and browsing. The eventual success of the increased resprouting frequency following any fire may be influenced by the season of the burn. For example, the initial upsurge of resprouting of *Quercus engelmannii* and *Q. agrifolia* seedlings and saplings after fire will have a better chance of surviving their first season if burns occur in late summer or fall. This permits the newly regenerated oaks to avoid the summer drought. Regenerated oak seedlings, following our late summer and fall prescription burns, had relatively good survival during the ensuing winter months (tables 3, 4). Our study indicates that prescription burns intended to enhance regeneration in oak woodland might be better if conducted in late summer or early fall to permit better survival of fresh resprouts, without first having to withstand the summer drought, as a spring burn would entail.

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REFERENCES

Griffin, J.R. 1977.Oak woodland. In: Barbour, M. G.; Major, J., eds. Terrestrial vegetation of California. New York: Wiley-interscience: 385-415.

Lathrop, E. W.; Martin, B. D. 1982a. Fire ecology of deergrass (*Muhlenbergia rigens*) in Cuyamaca Rancho State Park, California. Crossosoma 5:1-10.

Lathrop, E. W.; Martin, B. D.1982b. Response of understory vegetation to prescribed burning in yellow pine forests of Cuyamaca Rancho State Park, California. Aliso 10: 329-343.

Lathrop, E. W.; Thorne, R. F. 1978. A flora of the Santa Ana Mountains, California. Aliso 9:197-278.

Lathrop, E. W.; Thorne, R. F. 1985a. A flora of the Santa Rosa Plateau, southern California. Southern California Botanists Spec. Publ. No. 1. 39 p.

Lathrop, E. W; Thorne, R. F. 1985b. A new preserve on the Santa Rosa Plateau. Fremontia 13:15-19.

Plumb, T. R. 1980. Response of oaks to fire. In: Plumb, T. R., tech. coord. Proceedings of the symposium on the ecology, management and utilization of California oaks. 1979, June 26-28, Claremont, California. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture; 202-215.

Snow, G. E. 1980. The fire resistance of Engelmann and coast live oak seedlings. In: Plumb, T. R., tech. coord. Proceedings of the symposium on the ecology, management and utilization of California oaks. 1979, June 26-28, Claremont, California. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 62-66.

Sugihara, N. G.; Reed, L. J. 1987. Prescribed fire for restoration and maintenance of Bald Hills Oak Woodlands. In: Plumb, T. R.; Pillsbury, N.H., tech. coords. Proceedings of the symposium on multiple-use management of California's hardwood resources. 1986, November 12-14, San Luis Obispo, California. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 446-451.

Zar, J. H. 1984. Biostatistical Analysis. 2nd ed. Engelwood Cliff, NJ: Prentice Hall, Inc.: 718 p.