Wildfire and Oak Regeneration at the Urban Fringe[1]

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Abstract: *In July 1992, wildfire burned 500 acres of rural lands owned by Stanford University. Within the fire zone are five plots, ranging in size from 0.1 acre to more than 1 acre, on which nearly 600 naturally established juvenile California oaks (*Q. agrifolia, Q. douglasii, *and* Q. lobata*) have been monitored since 1990. Surveys following the fire revealed that although 32 percent of the oaks up to 10 inches tall died, only 9 percent of the oaks taller than 10 inches died. Twenty-two percent of all juvenile oaks were topkilled, but 22 percent of those resprouted in years following the fire.*

Both naturally occurring and human-induced fires have been important elements of California native oak ecology. In recent decades, people have prevented or rapidly suppressed many fires in oak habitat. As humans have built and paved in and near oak habitat, we have extended the urban-open space interface, and fire management has become an increasing concern. Land managers and restoration ecologists are accordingly interested in the effects of fire and its suppression on native oak populations.

However, only a few studies have explored how fires—whether uncontrolled or managed—affect California oaks (Allen-Diaz and Bartolome 1992, Haggerty 1991). This paper describes the effects of a 1992 wildfire on young, naturally occurring oaks located within a 500-acre oak woodland at the urban interface.

Site Description and Methods

Stanford University lands include approximately 1,600 acres adjacent to the central campus that remain rural in character. This property, denoted "Academic Reserve," is currently used for recreation, livestock grazing, and a handful of academic programs, and is adjoined by housing developments. Located at 38° north latitude, 20 miles inland from the Pacific Ocean and 3 miles from the San Francisco Bay, Stanford enjoys a Mediterranean climate, with mild winters and warm, dry summers. Average annual rainfall is 14.8 inches, almost all of which falls between October and May. The Reserve is divided by a prominent, flat-topped southeast-northwest ridge with relatively steep (sometimes >30°) slopes. Soils vary and may be loosely classified as loams, clays, and stony clays with zones of admixture.

Oak woodlands cover many northern exposures on the ridge; grassland and oak savanna dominate southern slopes. A few areas of chaparral persist, and native woody plants like toyon (*Heteromeles arbutifolia* [Lindley] Roemer), coyote brush (*Baccharis pilularis* DC.), chamise (*Adenostoma fasciculatum* Hook. & Arn.), and poison oak (*Toxicodendron diversiloba* [Torrey & A. Gray] E. Greene) occur widely. Native grasses and forbs have been largely supplanted by exotic annuals like wild oat (*Avena fatua* L.), rye grass (*Lolium multiflorum* Lam.), nonnative mustard (*Brassica* spp.), and milk thistle (*Carduus nutans* L.). The oak population consists of coast live (*Quercus agrifolia* Née), blue (*Q. douglasii* Hook. & Arn.), and valley (*Q. lobata* Née) oaks.

In the early 1980's, University land managers became concerned that too few seedlings were surviving to maintain stable oak populations. Severely skewed age

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distribution of oaks on the Reserve indicated that for several decades, relatively few seedlings had been surviving beyond their 10th year (Zebroski and McBride 1983). For more than 50 years, a lessee had grazed cattle on the Reserve from December through May. In 1984, University planners closed part of the Reserve to grazing. In 1989, they expanded the area of cattle exclusion (*fig. 1*).

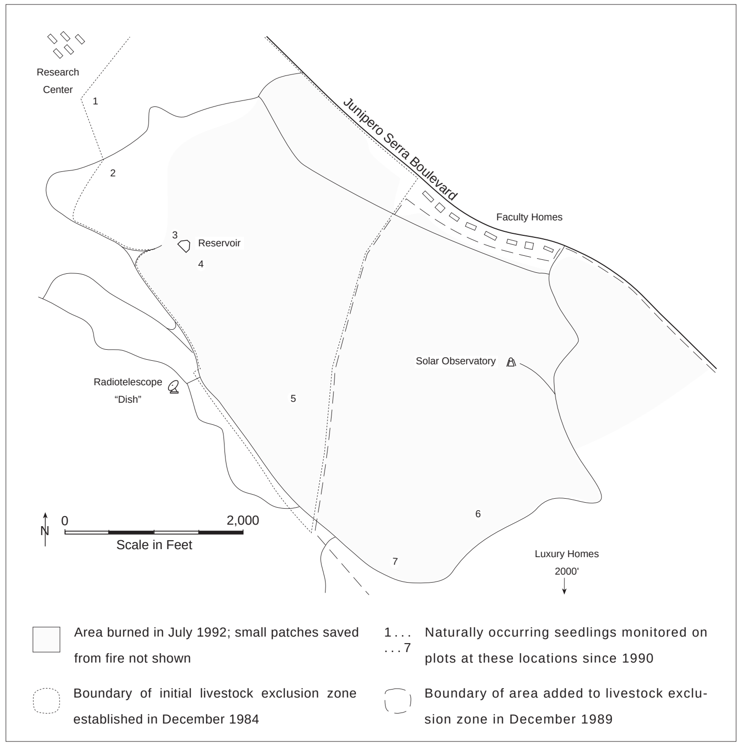


Figure 1—Map showing area burned in July 1992, including portions of livestock exclusion zones, homes and academic facilities at risk, and plots being monitored for natural regeneration.

To determine whether oaks released from grazing pressures were successfully regenerating, and to help determine when young trees might be able to withstand reintroduction of livestock, we selected seven plots for careful monitoring (*fig. 1*). The plots varied in slope, exposure, and vegetative cover and ranged in size from 0.1 acre to several acres. We mapped each plot to show the location, size, and species of juvenile oaks (i.e., oaks less than 10 feet tall). In the summers of 1990, 1991, 1993, 1994, and 1995, we surveyed all juvenile oaks in the sample plots, measuring their heights and noting their condition and vigor. In 1992, only the two plots that were not burned were surveyed.

University land managers had long acted to prevent and rapidly suppress fires, and in the several decades before 1992, only small (less than 1-acre) fires burned in the Reserve. Heavy rainfalls in the springs of 1991 and 1992 led to unusually lush growth of grasses, forbs, and other understory plants. In the absence of grazing, herbaceous vegetation grew densely and reached heights of 8-10 feet in some areas. When these plants dried, they created an exceptional fire hazard—extremely combustible material, with a high surface-to-mass ratio, which was well-aerated yet compact and reached into the edges of mature oaks' canopies.

Early in the afternoon of July 7, 1992, during a midsummer heat wave that saw temperatures climb above 90 °F, a wildfire began. Though quickly contained within a 500-acre area (*fig. 1*), the blaze burned through the night and into the next day, as brush accumulated over decades was consumed and large-diameter standing and fallen deadwood was reduced to ash.

Because five of our seven plots, holding 558 juvenile oaks, lay entirely within the fire zone, we were able to calculate rates of fire-related mortality and annual rates of growth before and after fire in these plots. Although some deaths would have been likely to occur even without fire, for purposes of our calculations, we defined fire-related mortalities to be monitored oaks which were last noted as alive in 1991. The mortality of oaks that were alive in 1993 but died in subsequent years was not considered to be fire-related. We applied *t*-tests to test the significance of mean differences between pairs of data sets. We used Chi-square tests to compare frequencies of fire mortality between species.

Results

Fire topkilled 22 percent of the 558 juvenile oaks in the five plots in the fire zone. Twenty-two percent of these resprouted from the root crown in the following 3 years. Thus, the fire killed 17 percent of the original 558 juvenile oaks. For comparison, 4 percent of monitored juvenile oaks died in the more typical year, July 1990 to July 1991, before the fire. Postfire survival and resprouting generally followed similar patterns across the three species. However, compared to *Q. douglasii* and *Q. lobata*, a significantly greater ($P < .001$) percentage of *Q. agrifolia* juveniles were topkilled (30 of 67) (*table 1*).

Table 1—Pre- and postfire annual growth of monitored juvenile oaks within and outside of burned area[1]

	Mean annual growth (sample size)		
	Q. douglasii	*Q. lobata*	*Q. agrifolia*
	inches		
Fire fatalities, 1990-91	1.4 (45)	2.0 (27)	1.0 (27)
Fire survivors, 1990-91	2.4 (214)	4.4 (132)	1.4 (34)
Fire survivors, 1993-95[2]	3.2 (170)	1.3 (105)	6.2 (28)
Unburned plots, 1990-91	7.3 (36)		
Unburned plots, 1993-95	2.0 (33)		

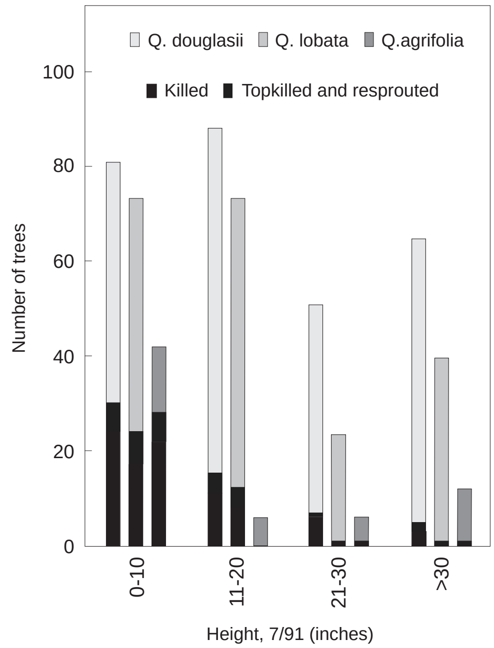
[1]For discussion of statistical significance, see text.
[2]Numbers in this row are not equal to those in second row because seedlings that died in 1994 or 1995 are not included here.

The likelihood of postfire survival generally improved with increasing prefire height of the juvenile oaks. Thirty-two percent of the juvenile oaks up to 10 inches tall died, whereas only 9 percent of those more than 10 inches tall died (*fig. 2*). Among topkilled trees, we found no significant association between resprouting rates and prefire height. The lack of correlation may reflect the fact that sample sizes were too small to reveal trends. Only 16 topkilled trees were taller than 20 inches, and only 27 trees of any height resprouted.

Prefire (1990-91) growth of juvenile valley, blue, and coast live oaks, taken as a group, was not significantly associated with postfire survival. When each species was analyzed separately, prefire growth was significantly related to survival ($P = .01$) only for juvenile valley oaks. *Q. lobata* juveniles that survived the fire grew, on average, 4.4 inches from July 1990 to July 1991; those that died in the fire grew only 2.0 inches during the same period (*table 1*).

Overall, pre- and postfire average annual growth of surviving juvenile oaks in the burned area did not differ significantly. The 479 juvenile oaks of all three species that had sprouted by July 1990 in the plots in the fire zone grew an average of 2.7 inches from July 1990 through July 1991. From 1993 through 1995,

Figure 2—Juvenile oaks surviving, topkilled, and killed in 1992 fire, by 1991 size class and species.



juvenile oaks in the five plots in the fire zone grew an average of 3.6 inches annually. However, a breakdown of average growth rate by species shows that *Q. agrifolia* increased from 1.4 to 6.2 inches per year (significant at $P < .01$), *Q. lobata* declined from 4.4 to 1.3 inches (significant at $P < .01$), and *Q. douglasii* did not change significantly (*table 1*).

Growth rates of oaks within and outside of the fire zone are not strictly comparable. Only 49 juvenile oaks lay within the two plots beyond the fire zone, and they were, on average, older and taller than those inside it; their average height in 1991 was 41 inches, compared to 18 inches for those in the fire zone. Still, the trend in growth rates before and after the fire is strikingly different between burned and unburned plots. *Q. douglasii* in unburned plots grew an average of 7.3 inches in 1990-91 but only an average of 2.0 inches per year in 1993-95 (significant at $P = .002$); as noted above, juvenile blue oaks in burned plots showed no significant change in annual growth over that period (*table 1*). There were too few *Q. lobata* and *Q. agrifolia* on these plots to calculate meaningful growth rates.

Many young oaks of all species, across the entire Reserve, suffered partial or complete dieback due to rodent girdling (removal of bark and cambium layers around the base of the trees) in 1992 and 1993. The postfire drop in the growth rate of monitored blue oaks outside the burned area reflects the fact that many oaks in these plots declined in height between 1993 and 1995. When oaks that declined in height between 1993 and 1995 were removed from the sample, average annual growth for that period was 6.5 inches, not significantly different from 1990-91 growth. Unfortunately, we cannot calculate a comparable number for burned sites, since any declining heights may be due to either rodent damage or fire-related damage. Of 36 blue oaks in the unburned plots in July 1991, 8 percent died by July 1993 and 33 percent declined in height between 1993 and 1995. By comparison, 14 percent of juvenile blue oaks in burned areas died between 1991 and 1993, presumably because of the fire, and 15 percent declined in height between 1993 and 1995. Evaluators have observed that rodent damage has been the most common cause of large declines in seedling and sapling height on the parts of the Reserve from which livestock have been excluded.

No additional trends became apparent in either burned or unburned areas when growth rates of juvenile oaks were broken down by size class. Differences in survival and growth rates between plots were difficult to assess because no one species occurred in great enough numbers on all plots.

Discussion

The data we have collected about juvenile oaks, on a single reserve, responding to a single wildfire, is clearly limited in scope. Nevertheless, this case study is the first published report on fire-related growth and survival of California oaks in this size class. Several patterns are evident in the response of the juvenile oaks in our study to wildfire. First, a relatively small percentage of juvenile oaks taller than 10 inches perished. Second, comparisons of pre- and postfire growth within species on burned plots showed varied responses: coast live juveniles grew faster after the fire, valley oaks grew more slowly, and blue oaks showed no change.

Although overall growth of burned juvenile blue oaks was greater after the fire than that of blue oaks outside the fire zone, unburned blue oaks suffered significant rodent damage from 1993 through 1995. Thus, data on growth rates reflect the impact not only of fire but also of a sudden increase in rodent herbivory in the years of and following the fire. On the basis of the height data and field observations of rodent damage, we hypothesize that a causal relationship may exist between fire and rodent herbivory of juvenile oaks. As fire removes essential cover and food, rodents may overpopulate adjacent areas and increase herbivory of oaks there.

Q. agrifolia juveniles had lower fire survival rates but greater postfire growth than the other species. This could reflect a different, but not necessarily less successful, response to fire by juvenile live oaks compared with blue and valley oak juveniles. Alternatively, the apparent increase in *Q. agrifolia* growth might simply reflect the loss of most of the smallest (and perhaps slower-growing) coast live oaks from the sample. Further observations would be needed to test these hypotheses.

Our results generally support others' findings that a single wildfire may kill many of the smallest juveniles in an oak woodland but is unlikely to be devastating to the population as a whole. Haggerty (1991) found higher fire survival of blue oaks (93 percent compared to our 84 percent), but her sample consisted of both saplings and mature trees, whereas ours included only juveniles less than 10 feet tall. Allen-Diaz and Bartolome (1992) reported that prescribed burning had little impact on blue oak seedling recruitment, survival, or growth. However, they did not monitor individual seedlings before fire occurred, so their results are not readily comparable to ours.

On the basis of our data, we cannot draw firm conclusions about the relationship between fire suppression and native oak regeneration. So many human-mediated changes have been made to the ecosystem of our study site that it is very difficult to isolate the impact of any one. Extensive invasion of nonnative understory plants, decline of rodent predators such as fox, coyote, and bobcat, and falling water tables are all likely to contribute to an oak population's response to fire and its overall success or decline. Certainly, there will be some fire frequency at which oak regeneration will suffer. However, without further studies clarifying the effect of fire on seedling growth, we cannot weigh the costs and benefits of fire very precisely. Meanwhile, where intensive efforts are being made to restore a native oak population, particularly where artificial seeding has been deemed necessary, protection from fire damage may be desirable.

Land management implications of oaks' response to fire are further complicated by the fact that oak regeneration concerns typically compete with many other considerations—relative remoteness of the land, value of structures at risk, volume of public use, and livestock ranching concerns. On Stanford lands, proposals have been made to minimize fire risk via an integrated program of high-density, short-duration, rotational grazing; restoration of native understory plants; mowing; disking; spraying of herbicides; prescribed fire; and user education. Such a program faces formidable obstacles: animal management costs, air quality regulation, tenacity of established nonnative plants, steep terrain that is difficult to mow, community intolerance for herbicides, and growing year-round recreational use (500-1,000 visitors per day during peak use in 1995).

We have chosen a less controversial, less resource-intensive, and more seedling-specific approach to reducing fire risk to seedlings on the Academic Reserve. We have surrounded hundreds of naturally occurring and artificially planted seedlings with a 3-foot diameter piece of plastic landscape fabric, covered by a 4-inch thick layer of native rock. With this treatment, we aim to reduce the amount of readily burned fuel near the young trees and to provide a heat sink to prevent temperatures from rising to damaging or fatal levels if nearby understory plants and litter burn. We currently lack data to quantify these effects, but we have observed that the combination of rock over plastic does effectively suppress vegetation around young trees.

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References

Allen-Diaz, Barbara H.; Bartolome, James W. 1992. **Survival of *Quercus douglasii* (Fagaceae) seedlings under the influence of fire and grazing.** Madroño 39(1): 47-53.

Haggerty, Patricia K. 1991. **Fire effects in blue oak woodland**. In: Standiford, Richard B., technical coordinator. Proceedings of the symposium on oak woodlands and hardwood rangeland management; 1990 October 31-November 2; Davis, California. Gen. Tech. Rep. PSW-126. Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 342-344.

Zebroski, Ortha; McBride, Joe. 1983. **Vegetation management plan**. Stanford, CA: Stanford University Planning Office; 61 p.