

Blue Oak Regeneration in Southern Sierra Nevada Foothills¹

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Abstract: A survey of blue oak stands in four southern Sierra areas indicated there was a substantial number of seedlings and mature trees, but there were considerably fewer trees in the sapling and pole size class. These differences prompted a long-term survival study. After 6 years, 68.5 percent of the trees were still present and had grown 0.02 inches. A study of aging seedlings showed that the percentage of seedlings less than 10 years old ranged from 52.7 percent to 98.4 percent for the three sites. More than 10 percent of the seedlings in one site were more than 25 years old. A 2-year study evaluating acorn quality showed that acorns from Madera County had a faster and higher emergence rate than acorns from Kern County.

The Southern Sierra Hardwood Range region, consisting of Madera, Fresno, Tulare, and Kern Counties contains almost 1.5 million acres of hardwood rangeland. Eighty percent of this land is privately owned, and blue oak (*Quercus douglassii*) is the most abundant oak species. Obtaining adequate natural regeneration to maintain current stands of blue oak is of concern for some landowners, government agencies, and conservationists. Studies were conducted to evaluate regeneration factors such as blue oak size classes, acorn quality, and natural seedling survival. These studies have been carried out over the past 9 years to better understand the biology of blue oaks growing under natural conditions. Data were analyzed using an analysis of variance and differences between means were determined using Duncan Multiple range. Significance is expressed as $P \leq 0.05$.

A Survey of Blue Oak Height Classes in Madera, Fresno, Tulare, and Kern Counties

In 1987, a preliminary survey was conducted in Kern County to inventory the population and height classes of blue oaks. The following year the survey was expanded to include Tulare, Fresno, and Madera Counties. Regeneration transects were established in each of the four counties, beginning at low-elevation and open blue oak savannas. The oak-covered hardwood rangeland began at an elevation of about 600 feet in the northernmost transects of Madera County, and about 1,600 feet in the southernmost transects of Kern County. Annual rainfall at these low elevations averaged 10-15 inches (table 1). The elevational transects passed through the hardwood range sites heading uphill, generally west to east, until they reached the transition between hardwood range and mixed conifer forest at elevations of 3,000 feet in Madera County to 4,800 feet in Kern County.

Fourteen to twenty regeneration survey plots were located at random in patterns radiating out from each of the four elevational transects. Random plot locations were checked to ensure that they occurred in the blue oak woodland vegetation type. If a plot did not match the blue oak hardwood type, another location was randomly selected. Plots were located exactly 200 feet to the north or south of the main elevational transect. Altogether, 68 plots were sampled for this study. Each sample location was a strip transect 100 feet long and 12 feet wide (0.028 acres). Trees were classed as seedlings (trees less than a foot tall),

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Table 1—Rainfall zones for the four South Sierra Nevada counties of Madera, Fresno, Tulare, and Kern.

Rainfall zone	Elevation of rainfall zones within each county				
	Rainfall	Madera	Fresno	Tulare	Kern
	<i>inches</i>	<i>feet</i>			
Low	10-15	500-1,000	500-1,000	1,100-1,600	1,500-2,000
Medium-low	15-17	1,000-2,000	1,000-2,000	1,600-2,600	2,000-3,000
Medium	17-22	2,000-3,000	2,000-3,000	2,600-3,600	3,000-4,000
High	22-26	3,000-4,000	3,000-4,000	3,600-4,600	4,000-5,000

Table 2—Number of blue oak trees per acre, by height class for four different rainfall zones in Madera, Fresno, Tulare and Kern Counties

Rainfall zone	Number of blue oak by height class per acre			
	<1 ft	1 to 5 ft	5 to 10 ft	>10 ft
Low	61.43	2.79	8.38	47.47
Low-Medium	254.10	7.64	7.64	42.03
Medium	237.97	18.15	6.05	68.57
High	116.97	86.72	30.25	86.72

saplings (trees 1 to 5 feet tall), poles (trees 5 to 10 feet tall), and mature (trees over 10 feet tall). A total of 68 sample transects were taken across four rainfall zones (Standiford and others 1991) in the four counties.

The average number of blue oak trees per acre by rainfall zone for the four counties is shown in *table 2*. A general pattern emerged that showed significantly more seedlings per acre than mature trees in all but the low zone. In the lowest zone, there were about the same number of seedlings and mature trees. There were fewer sapling- and pole-size trees per acre in all rainfall zones than seedling and mature size classes. This was more pronounced in the three lower rainfall zones. These data suggested that few of the seedlings were growing into the sapling or pole size class.

Studies to Evaluate Survival and Aging of Native Blue Oak Seedlings

The survey clearly indicated that blue oak seedlings were not developing into pole or mature trees. So in 1989, a study was started to monitor the survival of naturally occurring blue oak seedlings (Phillips and others, in press). The study was conducted in Kern County on three sites with four to five replications. Each replication was 0.01 acre. Each tree was permanently marked with an identification number. The number of trees per replication ranged from 25 to 128 for a total of 605 trees. The height of each tree was measured. Yearly survival data were collected in early summer, and each surviving tree was remeasured to evaluate seedling height growth in 1994.

The percent survival of blue oak seedlings, by site, from 1990 through 1995 is as shown in *figure 1*. After 6 years, 68.5 percent of the original trees were still alive. These results were higher than those of Allen-Diaz and Bartolome (1992) who reported a 50 percent seedling survival over several years. There was no significant difference in blue oak survival among the three sites.

Seedling change in height over the 5 years of the study was significantly different on each site. Trees at Site 2 increased in height by 0.65 inches, while trees at Site 1 decreased in height by 0.17 inches and trees at Site 3 decreased by 1.21 inches. The overall change in average height for the three sites was 0.02 inches.

The initial (1989) and final (1993) tree height measurements were taken during an extended drought (1986 through 1993). During the study, the seedlings would have green shoots in the spring, but by late August many of the shoots had dried up and appeared to be dead. The average percentage of seedlings at each site that had green leaves in the spring but had lost them by fall were: Site 1, 10.59 percent; Site 2, 4.94 percent; and Site 3, 16.70 percent. The following spring, the dry shoot did not green up; instead a new shoot developed from the root.

These new shoots were shorter, possibly because of the extended drought. All three sites were grazed by cattle, but at different times of the year. There was no evidence of large ungulate grazing on the oak seedlings during the yearly evaluation of each seedling. There appeared to be a relationship between the percent of seedlings that dried up during the summer and the change in the height of the seedlings; the greater percentage of seedlings that dried up, the shorter the subsequent seedling growth. Swiecki and others (1991) observe similar results of seedlings sending up shoot from the root each spring.

Numerous years of observation of blue oak seedlings in the field indicated that most of the seedlings were older than their height would suggest. On the basis of this observation, Phillips and others (in press) developed a procedure to estimate the age of seedlings. Regression equations were developed using root crown diameter and seedling age as determined by counting the growth rings above the root crown. This work indicated that the equations were site specific; thus an equation was developed for each of three sites.

Counting growth rings of blue oak seedlings could be off by 1 or 2 years because of false growth rings caused by animal browsing or mid-summer regrowth. Since no animal browsing was observed over the 5 years of the study, and summer rains did not occur in the study area, these two factors had minimal effect on the ring counts.

All of the surviving trees were aged in 1992 using the corresponding regression equation for each site. Trees at Site 1 were significantly older (averaging 14.5 years) than trees at Site 2 (averaging 5.2 years) and Site 3 (averaging 7.2 years). *Table 3* shows the percent of trees on each site in each of the age groups. Significantly more of the seedlings in Site 2 (98.39) and Site 3 (88.78) than Site 1 (52.72) were in the 1- to 10-year group. Surprisingly, 17.95 percent of the seedlings in Site 1 were more than 20 years old, and 10.56 percent were more

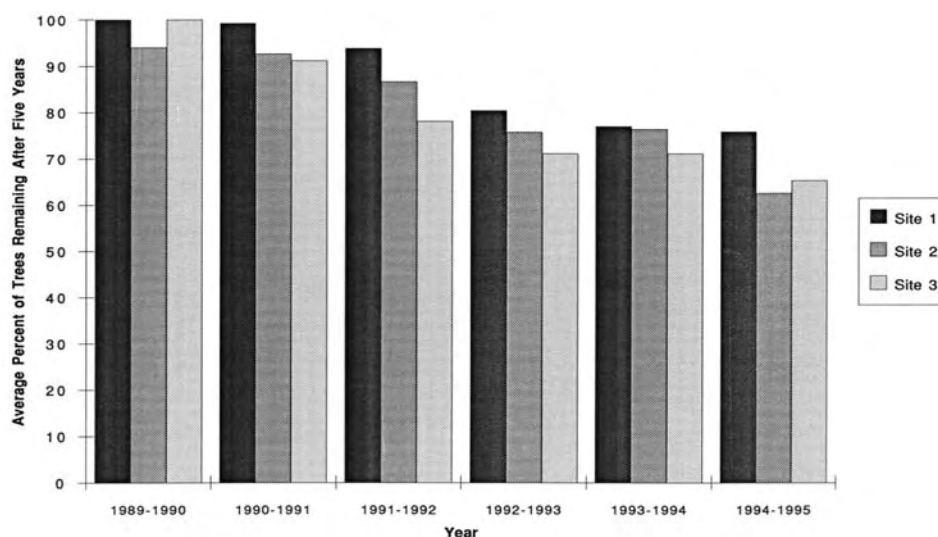


Figure 1—Average percent of blue oak seedlings that survived from 1990 through 1995 for the three sites in Kern County.

Table 3—The percent of blue oak seedlings in five age groups at three sites in Kern County

Location	Age groups (yr)				
	1-10	11-15	16-20	21-25	26 and older
Site 1	^a 52.72	^a 19.90	^a 9.36	^a 7.39	^a 10.56
Site 2	^b 98.39	^b 1.00	^a 0.61	^a 0.00	^a 0.00
Site 3	^b 88.78	^{ab} 6.88	^a 1.11	^a 1.67	^a 1.56

^{ab}Values within columns with different letters were different at $P \leq 0.05$

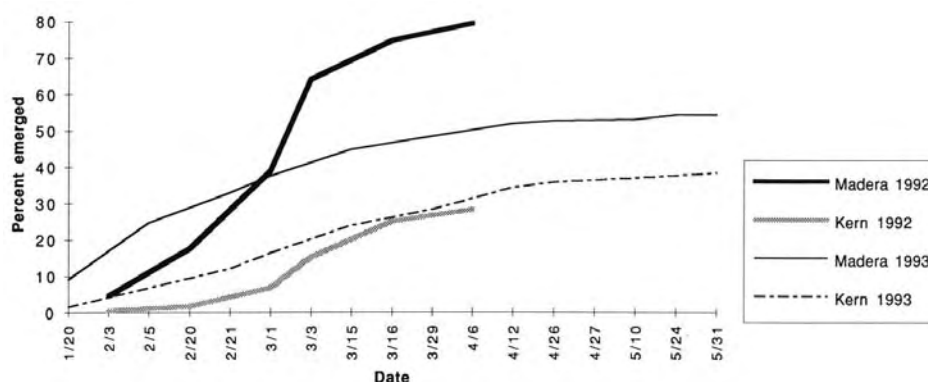
than 26 years old when compared to Site 2 (0.0 and 0.0, respectively) and Site 3 (3.23 and 1.56, respectively). It appears that the seedlings that do survive grow very slowly and live for a long time in the seedling size class.

Acorn Viability from Kern and Madera Counties

Early work by Phillips (1992) indicated there was a difference in acorn germination rate between locations and elevations in Kern and southern Tulare Counties. Based on these findings, two studies were conducted in 1992 and 1993 to evaluate viability of acorns from Madera and Kern Counties (northern and southern extremes of the survey study). Forty acorns were collected from five trees in the four rainfall zones in each county (Phillips and others 1995). The acorns were planted in outside germination frames containing sand. The first-year emergence and germination data were collected from November 3, 1991, through May 15, 1992. The second year the same data were collected from October 16, 1992, through June 8, 1993. At the end of emergence phase of the studies, each acorn was evaluated for emergence, sprouting, and not sprouting. If the radicle had erupted from the acorn, it was classified as sprouted, and the shoot must have broken the soil surface before the acorn was classified as emerged.

Both years of emergence data (fig. 2) showed that the acorns from Madera County emerged earlier and at a significantly faster rate than acorns from Kern County. Figure 3 shows data for emergence and sprouting over 2 years. The percent of acorns that did not sprout was inconsistent. Kern County had the largest percentage in 1992 (30.0 percent vs 8.5 percent), but Madera County had the largest percentage in 1993 (21.4 percent vs 7.75 percent). During both years, a significantly larger percent of the acorns from Kern sprouted but did not emerge (41.3 percent vs 12.3 percent, 1992; 56.5 percent vs 25.3 percent, 1993). Also, during both years there was a significantly higher percent of emergence for Madera County than

Figure 2—Average percent emergence of seedlings by date, for Madera and Kern Counties for years 1992 and 1993.



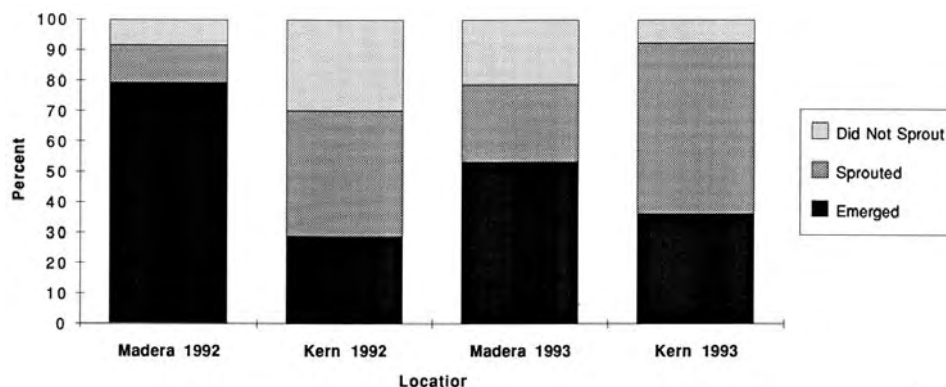


Figure 3—Average percentage of acorns that sprouted, emerged, or did not sprout, for Madera and Kern Counties for years 1992 and 1993.

Kern County (79.3 percent vs 28.7 percent, 1992 and 53.4 percent vs 36.3 percent, 1993). In 1993, "the sprouted but did not emerge" categories were divided into live sprouts/dead sprouts. Acorns from Kern County had more dead sprouts (41.6 percent) than those from Madera (21.1 percent).

This trial showed that something was preventing a large percentage of the acorns from Kern County from emerging after they sprouted. Acorn weight could account for part of the difference in emergence because acorns from Madera County were consistently heavier (1.4 grams the first year and 1.9 grams the second year) than the acorns from Kern County. However, these weight differences were not significant for both years. The possibility of genetic difference between the two oak populations could be an explanation and needs further study.

Conclusions

The survey study indicated there was a good population of the seedling and mature size classes of blue oaks. However, the population of trees in the sapling and pole size classes was limited and could raise concern regarding maintaining blue oak stands in this region. The survival rate of seedlings appeared to be adequate during the short time frame of this study, but the seedlings did not grow in height during the 4-year drought period. The age data indicated that many of these trees have been around for many years even though they were not growing in height. There appear to be geographic factors affecting the emergence of blue oak seedlings.

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