

# Effects of Livestock Grazing on Blue Oak Saplings<sup>1</sup>

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**Abstract:** Effects of two systems of livestock grazing and no grazing on the growth of blue oak (*Quercus douglasii* H. & A.) saplings were examined over a 4-year period in western Colusa County, California. In grazed plots, base and height growth and moisture stress of saplings were less, while soil bulk density was mostly higher. Residual dry matter increased in non-grazed plots but not in grazed plots. Effects of the two grazing systems on sapling and plot variables did not differ significantly except for browse utilization which was significantly higher under high-intensity, short-duration grazing than under traditional, moderate grazing in 3 out of 4 years.

The dynamics and management of California's hardwood rangelands, and in particular of the blue oak (*Quercus douglasii* H. & A.) dominated foothill woodlands, are of considerable interest to researchers, private landowners, and public resource management agencies (Muick and Bartolome 1986). Several studies have reported on the poor regeneration and recruitment of blue oak in various parts of its natural range (Bolsinger 1988, Mayer and others 1986, Mensing 1992, Muick and Bartolome 1986).

Predation on acorns and seedlings by wildlife and livestock, altered fire frequency and intensity, and altered competitive relationships with herbaceous vegetation have been suggested as possible causes of poor regeneration and recruitment in oaks. Hall and others (1992) reported on the effects of cattle grazing on 1-year-old blue oak seedlings. They found that spring and summer grazing resulted in the most seedling damage and lowest seedling survival. They also found that seedling damage (but not survival) increased with livestock density for both spring and summer grazing.

In this study the effects of two systems of livestock grazing and no livestock grazing on the growth of well-established blue oak saplings were examined over a 4-year period.

## Study Area

The study was conducted on Walnut Valley Ranch, located in western Colusa County near Lodoga, California, in the foothills of the northern Coast Range (Lat. 39° 17'N, Long. 122° 28'W). The study area supports a mosaic of blue oak woodland and chamise chaparral and occurs at elevations from 400 to 540 m. It receives an average of 50 cm of annual rainfall between mid-October and late April. Preliminary soil survey data (Southard 1993) classify the soils as Contra Costa loamy clay (clayey-skeletal, mixed, thermic Typic Palexeralf). Aspect is easterly (65°), slopes range from 15 to 20 percent, and elevation is 475 m.

Ownership of the land has changed several times over the past hundred years, but land use at the study site has always been livestock grazing. In the late 1950's or early 1960's, when blue oak removal in California was widespread and recommended to increase grazing, the trees on the site were chained and burned (Bell 1984) and the area seeded with Harding grass (*Phalaris aquatica* L.). Under current ownership, grazing is light to moderate and occurs from late winter through late spring.

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## Methods

In spring 1991, nine rectangular 0.1-ha plots were established at the study site. Three treatments (no grazing; traditional moderate grazing; and high-intensity, short-duration grazing) were randomly assigned to these plots (*table 1*). The non-grazed control plots were fenced to exclude livestock, while the high-intensity, short-duration grazed plots were fenced to include and confine livestock for a single, 10-hour grazing period each year. All plots were accessible to deer (*Odocoileus hemionus columbianus*). Treatment replication was limited because of the relatively small size of the area containing an adequate number of blue oak saplings.

*Table 1—Grazing treatments during the 4-year study.*

Year	Grazing period	Days of grazing	Cow-calf pairs	Stocking rate (AUD <sup>1</sup> ha <sup>-1</sup> )	
				T.M. <sup>2</sup>	H.I.S.D. <sup>3</sup>
1991	3 - 13 May	9.7	33	18	220
1992	16 May -9 June	22.8	32	46	182
1993	19 Mar - 3 Apr	14.2	31	27	177
1994	16 Mar -1 Apr	16	35	34	—
	21 Apr - 7 May	15.8	37	34	87

<sup>1</sup>Animal unit days

<sup>2</sup>Traditional, moderate grazing

<sup>3</sup>High-intensity, short-duration grazing

Blue oak saplings in the plots were mapped and measured for height and basal diameter. In each plot, eight saplings measuring between 45 and 175 cm in height were randomly selected from those present for detailed study of treatment effects. On each of these selected saplings, three branches on the outside perimeter within reach of livestock were randomly selected and tagged in order to measure browse utilization and branch diameter growth. While we took measurements on the same saplings throughout the study period, we could not always use the same tagged branches. Some branches died, some grew unevenly in diameter, and others produced too many or too few leaves and twigs for reliable estimation of browse utilization. In addition, some tagged branches were broken off by livestock as was clearly evident from hair and rubbing marks.

Sapling basal diameter was measured within 10 cm of the soil surface and the exact location of measurement recorded and later marked with a semi-permanent pin. Sapling height represents total height from soil surface to highest living branch or bud. It was measured within 50 cm of, and level with, the sapling base. This location was recorded and later marked with a semi-permanent spike. A caliper and a surveying rod were used for diameter and height measurements, respectively.

Browse utilization by deer and livestock on the tagged branches was measured twice a year: in mid-March just before bud break and livestock grazing began in the pasture (except in the first year of the study when it was measured in mid-April) and again shortly after livestock removal from the pasture, which varied from mid-April to mid-June. Browse utilization was measured by counting all grazed twigs and the total number of twigs on tagged branches and expressing the ratio as a percentage. Twigs were considered grazed if leaves and/or stem were partially or completely removed. Twigs less than 2.5 cm in length were considered to be spurs and were not used in the utilization counts.

As noted, sapling branch diameter, basal diameter, and height were measured at the beginning of the study and in November of each year to determine annual growth in diameter and height.

Sapling moisture stress was determined with a portable pressure chamber (Cleary and Zaerr 1984). Measurements were taken between the hours of 10 p.m. and 5 a.m., and used leafy twigs produced during the current season. Sampling occurred in late-June and mid-August each year.

Three soil bulk density determinations were made in each of the nine plots, using the compliant cavity method (Grossman 1983). Soil cavities measured 12.5 cm in diameter and 7.5 cm in depth. Plot sampling was restricted in its randomness, so that each sample contained an observation from the lower, middle, and upper portions of the plot. Samples were collected in late June every year.

In mid- to late October, a sample of six observations on residual dry matter was taken in each of the nine plots by clipping and removing all above-ground dry matter from 1-ft<sup>2</sup> circular quadrats. Sampling for residual dry matter was also restricted in its randomness so that each sample contained two observations from the lower, middle, and upper portions of the plot.

The 24.5-ha pasture containing the study plots was grazed every year with cow-calf pairs with an average weight of 727 kg. While in the pasture, the livestock grazed the unfenced plots (traditional, moderate grazing) and were rotated through the fenced plots for high-intensity, short-duration grazing (*table 1*).

Livestock spent approximately 10 hours in each of the high-intensity, short-duration grazed plots. During the last year of the study, animal stress, possibly brought on by consumption of goldenbush (*Haplopappus* sp.) and aggravated by confinement and lack of water in the fenced plots, led us to reduce both animal density and amount of time spent in these plots.

Treatment effects on blue oak saplings and plot variables were analyzed for each year of the study with a completely randomized design using analysis of variance. Cumulative treatment effects on sapling dimensions and growth were also analyzed with this design as well as with a completely randomized design with a split. The split treatment is initial sapling height. Oak saplings taller and shorter than 122 cm are the two levels of this treatment. Means were compared with the Duncan Multiple Range (DMR) test where significant treatment effects were detected.

## Results

### **The 1991 Grazing Season**

Grazing treatments were applied during the first 2 weeks of May (*table 1*). Mean browse utilization levels and mean branch diameter growth differed significantly at  $P < 0.001$  and  $P < 0.05$ . Other sapling and plot characteristics did not differ significantly (*table 2*).

At the time of grazing, all oak saplings had completed leaf and twig growth. In June, more than 90 percent of the saplings in the high-intensity, short-duration grazed plots had resprouted compared to approximately 50 percent in the traditional, moderately grazed plots. Only about 5 percent of the saplings in the non-grazed plots resprouted.

### **The 1992 Grazing Season**

Grazing occurred during the last 2 weeks of May and the first week of June (*table 1*). The longer and later grazing season resulted in mean browse utilization levels of 72.6 percent in the traditional, moderately grazed plots and 91.9 percent in the

Table 2—Annual browse utilization, growth, and moisture stress for blue oak saplings; and soil bulk density (B.D.) and residual dry matter (R.D.M.) in plots receiving three grazing treatments over 4 years.

Treatment	Browse util'n	Sapling growth			Moisture stress		Soil B.D. g cm <sup>-3</sup>	R.D.M. g ft <sup>-2</sup>
		Branch	Base	Height	Spring	Summer		
	pct	mm	mm	cm	bars	bars		
-----1991-----								
No grazing	0.5c	1.3a	2.9	7.8	11.4	29.0	1.35	25.2
T.M. <sup>1</sup>	28.2b	0.8b	1.5	6.4	10.1	26.8	1.42	22.2
H.I.S.D. <sup>2</sup>	78.8a	1.4a	1.9	3.2	9.0	23.0	1.46	26.3
CV <sup>3</sup> (pct)	18.1	11.8	53.1	49.3	15.7	17.1	7.9	19.1
DMR <sup>4</sup> test (P)	0.001	0.05	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
-----1992-----								
No grazing	0.9c	1.5	1.5	8.1ab	18.1	40.8	1.21	34.6a
T.M.	72.6b	1.3	0.9	4.4b	17.4	35.7	1.23	32.7a
H.I.S.D.	91.9a	1.4	1.5	8.7a	17.0	35.1	1.25	26.6b
CV (pct)	6.0	18.7	50.4	27.1	13.8	10.0	4.3	8.7
DMR test (P)	0.001	N.S.	N.S.	0.05	N.S.	N.S.	N.S.	0.05
-----1993-----								
No grazing	0.7	1.5	3.6a	9.0a	13.7	16.9	1.36	36.0a
T.M.	21.6	1.3	2.6b	2.2b	14.8	20.7	1.31	22.4b
H.I.S.D.	44.0	1.5	2.7b	5.0ab	12.8	16.4	1.42	22.3b
CV (pct)	115.9	23.7	17.0	68.7	10.0	18.0	11.7	16.2
DMR test (P)	N.S.	N.S.	0.10	0.10	N.S.	N.S.	N.S.	0.01
-----1994-----								
No grazing	2.5b	0.8	2.3	7.4	24.0a	48.2a	1.25b	43.0a
T.M.	61.4a	0.7	1.5	4.4	21.6ab	47.2ab	1.48a	19.1b
H.I.S.D.	74.2a	0.6	1.6	4.8	15.8b	45.0b	1.37ab	20.6b
CV (pct)	25.4	34.7	33.0	58.7	14.8	3.5	7.5	16.6
DMR test (P)	0.001	N.S.	N.S.	N.S.	0.05	0.10	0.05	0.01

<sup>1</sup>Traditional, moderate grazing

<sup>2</sup>High-intensity, short-duration grazing

<sup>3</sup>Coefficient of variation

<sup>4</sup>Duncan Multiple Range: Means in the same column followed by the same letter are not significantly (N.S.) different at the indicated level of probability.

high-intensity, short-duration grazed plots. Mean browse utilization levels differed significantly among all treatments at the  $P < 0.001$  level. Mean sapling height growth and mean residual dry matter levels differed significantly among grazed treatments at the  $P < 0.05$  level. Other sapling and plot variables showed no significant differences among treatments (table 2).

Resprouting following livestock grazing occurred on 70 percent of the saplings in the high-intensity, short-duration grazed plots, on 40 percent of the saplings in the traditional, moderately grazed plots, and on less than 5 percent of the saplings in the non-grazed plots. As was the case in 1991, summer (mid-August) moisture stress levels in the oak saplings in the grazed plots were considerably lower than in the saplings in the ungrazed plots; however, these differences were not significant.

### The 1993 Grazing Season

Grazing occurred during the second half of March and first few days of April (table 1) and, thus, much earlier in the season than during the previous 2 years. Although mean browse utilization levels of the saplings differed considerably among treatments, these differences were not significant. In grazed versus non-grazed plots, mean growth in basal diameter and height differed significantly ( $P < 0.10$ ), as did the mean residual dry matter levels ( $P < 0.01$ ). Other sapling and plot variables showed no significant treatment effects (table 2).

The stocking rate in the high-intensity, short-duration grazed plots was about the same as in 1992; however, browse utilization was only half as much. Stocking rate in the traditional, moderately grazed plots was intermediate between 1991 and 1992 levels, but browse utilization was lower. Browse utilization was highly variable in all grazed plots and resulted in a coefficient of variation (CV) with the unusually high value of 115.9 percent.

The low and highly variable browse utilization levels in 1993 may be related to the early grazing period. Saplings were still in the early stages of leafing out, while forage plants were green and highly palatable.

### The 1994 Grazing Season

There were two grazing periods of about equal length in 1994 (*table 1*). During the first grazing period, the saplings were still in bud, and no browsing by livestock was observed. During the second grazing period the saplings were fully leafed out and were browsed.

Grazing treatments resulted in significantly different browse utilization levels ( $P < 0.001$ ) between grazed and nongrazed plots but not between the traditional, moderate and high-intensity, short-duration grazed plots. Mean growth in branch and basal diameter, and height of saplings did not differ significantly among treatments. Both spring (end-June) and summer (mid-August) moisture stress levels in saplings differed significantly at the  $P < 0.05$  and  $P < 0.10$  levels, respectively. Mean soil bulk density (B.D.) and residual dry matter (R.D.M.) of plots also differed significantly at  $P < 0.05$  and  $P < 0.01$  levels, respectively. As was the case in 1993, all significant treatment differences were between grazed and non-grazed plots (*table 2*).

### Cumulative Treatment Effects over Study Period

Initial and final dimensions, and total growth in mean basal diameter and height of short (initial height less than 4 feet), tall (initial height more than 4 feet), and combined (short and tall) saplings are shown in *table 3*. Total diameter growth of the short and tall saplings differed significantly ( $P < 0.10$ ) in the nongrazed plots, while total height growth of short and tall saplings differed significantly ( $P < 0.10$ ) in the high-intensity, short-duration grazed plots. Differences among short and tall saplings in other plots were not significant.

*Table 3—Blue oak sapling dimensions and growth under three grazing treatments and for two sapling height classes from April 1991 to November 1994.*

Treatment	Height class <sup>1</sup>	Initial dimensions		Final dimensions		Total growth	
		Base	Height	Base	Height	Base	Height
		<i>mm</i>	<i>cm</i>	<i>mm</i>	<i>cm</i>	<i>mm</i>	<i>cm</i>
No grazing	1	31.2ab	87.8b	40.3bc	119.7b	9.1b	31.8ab
	2	39.1a	139.8a	51.9a	170.1a	12.8a	30.3ab
	combined	35.1	108.7	45.3	139.2	10.2	30.5
T.M. <sup>2</sup>	1	25.3b	76.0b	31.8c	97.7b	6.5bc	16.6ab
	2	41.4a	143.0a	47.2ab	167.2a	5.8c	24.2ab
	combined	27.4	84.4	33.8	102.0	6.4	17.6
H.I.S.D. <sup>3</sup>	1	30.3ab	90.7b	37.7bc	103.9b	7.5bc	13.2b
	2	37.2a	137.4a	45.4ab	172.4a	8.2bc	35.0a
	combined	33.3	105.2	40.9	128.1	7.7	22.9
CV <sup>4</sup> (pct)		15.5	10.5	12.7	8.0	22.1	48.8
DMR <sup>5</sup> test ( <i>P</i> )		0.05	0.01	0.05	0.01	0.10	0.10

<sup>1</sup>Class 1 = shorter than 122 cm; class 2 = taller than 122 cm

<sup>2</sup>Traditional, moderate grazing

<sup>3</sup>High-intensity, short-duration grazing

<sup>4</sup>Coefficient of variation

<sup>5</sup>Duncan Multiple Range: Means in the same column followed by the same letter are not significantly different at the indicated level of probability.

When short and tall saplings in plots were considered as a single response group, combined saplings in traditional, moderately grazed plots increased less in basal diameter and height than saplings in non-grazed plots (differences in growth were significant at  $P < 0.05$  and  $P < 0.10$ , respectively, but could not be shown in *table 3*). However, because the initial dimensions of the saplings in the traditional, moderately grazed plots are considerably less than those of saplings in the other plots, it is entirely possible that the effect of the grazing treatment on growth is confounded with the possible effect of initial sapling size on growth.

## Discussion

When livestock grazing occurred during a single, early grazing period (second half of March 1993) and saplings were in the early stages of leafing out while forage plants were green and succulent, browse utilization levels were highly variable (CV = 115.9 percent) and low (21.6 and 44 percent, respectively) under regimes of traditional, moderate grazing (27 animal unit days (AUD) ha<sup>-1</sup>) and high-intensity, short-duration grazing (177 AUD ha<sup>-1</sup>) (*tables 1 and 2*).

When livestock grazing occurred late (May and early June 1992), after saplings had completed shoot growth and when forage plants were dry or drying, browse utilization levels were very uniform (CV = 6 percent) and high (72.6 and 91.9 percent, respectively) under regimes of traditional, moderate grazing (46 AUD ha<sup>-1</sup>) and high-intensity, short-duration grazing (182 AUD ha<sup>-1</sup>). It is probable that the high variability and rather low levels of browsing during early grazing are the result of low livestock preference for oak browse at this time. The reverse situation may also be true.

Small branch diameter growth was generally unaffected by timing or intensity of livestock grazing, while basal diameter growth was mostly too variable to allow for detection of possible treatment effect. Total cumulative diameter growth of saplings was less in grazed than in nongrazed plots, but these differences are significant only when comparisons were made with the saplings in the traditional, moderately grazed plots. Differences in initial sapling dimensions are also possible causal factors (*table 3*).

The variability in annual height growth of saplings was even greater than the variability in annual diameter growth (*table 2*). This higher variability may be partly due to different initial sapling heights, and partly to different degrees of height reduction by grazing. Differences in annual height growth between no grazing and traditional, moderate grazing were significant in 2 out of 4 years. Total cumulative sapling height growth in traditional, moderately grazed plots was 43 percent less than in nongrazed plots. The effect of high-intensity, short-duration grazing on sapling height growth was difficult to determine. Annual height growth of saplings under this grazing treatment was usually greater than for saplings with moderate, traditional grazing, and less than for saplings with no grazing. Total cumulative height growth of saplings in high-intensity, short-duration grazed plots was 25 percent less than in non-grazed plots. To understand why the saplings with the high-intensity, short-duration grazing did at least as well as those with the traditional, moderate grazing treatment, grazing effects on short and tall saplings were analyzed separately (*table 3*). Short saplings grew somewhat less than tall saplings in traditional, moderately grazed plots, and significantly less ( $P < 0.10$ ) in the high-intensity, short-duration grazed plots. Short and tall saplings in the non-grazed plots grew by approximately the same amount. Variability in height growth among plots with the same treatment was highest for the two grazing treatments and lowest for the nongrazing treatment. In 3 out of 4 years, two plots with high-intensity, short-duration grazing contained the sapling with the most height growth observed for all plots.

Sapling moisture stress was usually less (but not significantly so) in grazed than in nongrazed plots, and was lowest for the plots with high-intensity, short-duration grazing. An exception occurred in 1993 when grazing was early and browse utilization in the traditional, moderately grazed plots was light (*table 2*). Significant differences in sapling moisture stress occurred only once (1994), and then between nongrazed and high-intensity, short-duration grazed plots. Grazing during the growing season decreases leaf surface areas of grasses which in turn decreases the depletion rate of soil water (Miller and others 1990). It is not clear from this study whether the browsing of the saplings or the grazing of the forage plants contributed more to the lowering of moisture stress in the oak saplings.

Differences in soil bulk density among treatments were not significant in 3 out of the 4 years of the study. Soil bulk density was mostly higher in grazed than in nongrazed plots, except in 1993 when it was lowest in the traditional, moderately grazed plots. The following year it was highest in these plots (*table 2*). This rather large, year-to-year variation in soil bulk density may have been due to the small sample size for soil cores (three cores per plot) and the abundance of gopher mounds.

Residual dry matter increased gradually and consistently in the nongrazed plots, whereas it changed little in the grazed plots over the course of the study. As a result, the residual dry matter in the nongrazed plots was more than double that of the grazed plots by the fourth and final year of the study. In 3 out of 4 years, residual dry matter in the traditional, moderate and high-intensity, short-duration grazed plots did not differ significantly (*table 2*). Thus, the high stocking rates of high-intensity, short-duration grazing did not result in lower levels of residual dry matter. There are two possible reasons for this: (1) the livestock did not graze much during their 10-hour confinement to the plots; (2) the observations on residual dry matter consisted of plants and animal excretions, and an abundance of the latter material made up for a scarcity of the former.

## Conclusions

Timing of spring grazing (March versus May and June) had a major effect on browse utilization levels of saplings. Early spring grazing resulted in less browsing than late spring grazing. Both grazing systems caused reductions in total diameter and height growth, and seasonal moisture stress of saplings. With the exception of browse utilization, sapling height growth, and residual dry matter, the annual effects of treatments on sapling and plot variables did not differ significantly in 3 out of 4 years. When saplings were split into two height classes, the effects of high-intensity, short-duration grazing on the total height growth of saplings were uneven, resulting in very little growth for small saplings and excellent growth for tall saplings.

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