

# Thinning – a Tool for Restoration of California’s Southern Sierra Nevada Blue Oak Woodlands<sup>1</sup>

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## Abstract

Fire frequency on a blue oak (*Quercus douglasii*) dominated rangeland in California’s southern Sierra Nevada foothills was approximately every 10 years until 1965, followed by a 30 year period of fire exclusion. This resulted in a dense tree overstory with small diameters, high crown cover, poor acorn and forage production, and limited complexity in vertical habitat structure. Tree thinning was evaluated as a treatment to restore pre-fire stand structure to these rangeland areas. Three thinning treatments were evaluated: (1) thin one-third of the standing tree basal area (resulting in a post-thin crown cover of 33 percent, 66 square feet per acre of tree basal area, and 160 trees per acre); (2) thin two-thirds of the standing tree basal area (resulting in a post-thin crown cover of 12 percent, 35 square feet per acre of basal area, and 100 trees per acre); and (3) control/no thin (crown cover of 55 percent, 97 square feet per acre of basal area, and 247 trees per acre). Acorn production was monitored annually since 1995, and showed that both thinning levels significantly increased the proportion of trees with acorns, although per acre acorn yields were not affected. Significant increases in forage production were documented with the heavier thinning intensity. Over 50 percent of the stumps in the thinned areas resprouted. There was significantly higher height growth in the two-thirds thinned area than the one-third thinned area. Periodic annual increment for the stands was not affected by thinning, although individual tree diameter growth was positively affected by the heaviest thinning. Crown cover of the heaviest thinning had grown back to the same level as the moderately thinned treatment after thirteen years. Thinning results in more open stands, with larger average tree size, larger individual crowns, and a larger proportion with acorns compared to unthinned controls.

*Key words:* blue oak, oak thinning

## Introduction

Blue oak (*Quercus douglasii*) woodlands are widespread in California, occurring on 1.2 million hectares (3 million acres), representing the state’s largest oak woodland cover type (Waddell and Barrett 2005). Blue oak is found in California’s Sierra foothills, the southern Cascades, and the Coast range. The overstory tree canopy is predominantly in the oak genus (*Quercus* spp.) with an understory of exotic annual grasses and forbs, and occasional native perennial grasses (Bartolome 1987).

Since European settlement of California, blue oak woodlands have been managed primarily for livestock production (Huntsinger and others 1997). They also have high levels of biodiversity (Garrison 1996), and provide water, outdoor recreation and aesthetics. Over 90 percent of California’s blue oak woodlands are privately owned (Waddell and Barrett 2005).

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At the landscape scale, oaks have been subject to land use change from land clearing, urbanization, and conversion to agriculture (Standiford 2001). At the stand level, blue oak had a trend of increasing canopy cover and basal area over the past 60 years (Holzman and Allen-Diaz 1991).

Fire has been part of California's oak woodland ecosystem for the past several thousand years (Byrne and others 1991). It has been used as a management tool by Native Americans to improve game habitat and enhance desirable vegetation types (Anderson 2007). Ranchers also used fire to enhance forage production and maintain an open stand structure (Allen-Diaz and others 2007). McClaren and Bartolome (1989) showed a mean fire interval for central Sierra Nevada blue oak woodlands of 25.2 years between 1681 and 1848, 7.1 years from 1849 to 1948, and no fires from 1949 to the present. Standiford and others (2012) also showed a mean fire interval of 12.8 years from 1850 to 1965 in blue oak woodlands, with no fires since.

Increases in blue oak density from fire exclusion partially explains poor recruitment of the relatively shade intolerant blue oak (Bartolome and others 1987). Increasing density also impedes forage production for the silvopastoral management system practiced on blue oak woodlands (Frost and others 1997).

To date, there have been no studies on thinning in blue oak woodlands. There is a long-term study on thinning coastal oak woodlands (Bonner and others 2008). An individual tree growth model for blue oak has been developed from a statewide assessment, allowing thinning level impacts to be modeled (Standiford 1997).

This study was designed to evaluate a controlled thinning experiment to restore pre-fire stand structure in blue oak woodlands by evaluating the effect of different canopy densities on a range of vegetation variables over time.

## Methods

The study area chosen was a relatively dense blue oak stand on a private ranch in the southern Sierra Nevada foothills near the town of California Hot Springs in Tulare County, California. The elevation averaged 838 m (2750 ft). The slopes ranged from 8 to 18 percent, with a northwest aspect. The area was seasonally grazed as part of a cow-calf livestock operation. The area averaged 90 square feet of basal area and 45 percent overstory canopy percent.

The study was designed to investigate two different thinning intensities (one-third and two-thirds of the basal area removed) against an untreated control. Nine 404.7 m<sup>2</sup> (one-tenth ac) plots were established in the study area and complete data was taken on tree cover, basal area, volume and number of stems. The three thinning treatments were assigned to the nine plots in a randomized, complete plot design.

Three plots were thinned to one-third of their original basal area, three plots were thinned to two-thirds of their original basal area, and the remaining three plots were untreated controls. As part of the thinning design, trees were felled with a stump height of 15.24 cm (0.5 ft) in the six plots with thinning treatments. The trees were randomly selected to meet the post-thinning basal area goals. Table 1 gives the summary statistics for the nine thinning blocks immediately following treatment in the fall of 1995.

**Table 1—General summary statistics for nine thinning blocks after treatment – fall, 1995**

Stand characteristics	Statistics	Treatments		
		Thin 2/3 of BA	Thin 1/3 of BA	No thin
Trees/ac	Mean	100	160	247
	(std. error)	(23)	(46)	(48)
Basal area/ac (sq. ft./ac)	Mean	35.3	65.6	96.7
	(std. error)	(2.1)	(5.2)	(15.5)
Cu. ft./ac.	Mean	518.8	1148.7	1668.9
	(std. error)	(100.2)	(332.6)	(350.9)
Crown cover Pct.	Mean	12	33	55
	(std. error)	(2.3)	(0.6)	(11.5)

Acorn production, stump sprouts, forage composition, and forage yields were evaluated in each study block. Individual tree height, diameter at breast height (1.37 m, DBH) and crown radius in two directions were measured. Merchantable wood volumes were calculated (Pillsbury and Kirkley 1984), as well as crown cover percent. The study area excluded livestock with electric fencing for the duration of the study. It was accessible to deer and rodents.

## Results

### ***Forage production and composition***

Forage yields in total pounds per acre were sampled in the summer of 1997, 1998 and 1999 (2, 3 and 4 years after the thinning). Figure 1 shows the trend of higher forage yield as thinning intensity increased for each year sampled. The two-thirds thinning treatment had significantly higher production than the control in two of the three years. The one-third thinning level was not significantly different than the control.

Point counts were taken to evaluate understory vegetation cover at the genus level. The only significant treatment effect was the percent of bare soil the year after thinning (12 percent bare soil in the two-thirds treatment, versus 3 percent in the one-third treatment and 0 in the control). This effect disappeared by the second year after thinning. There were no significant thinning effects on forage composition.

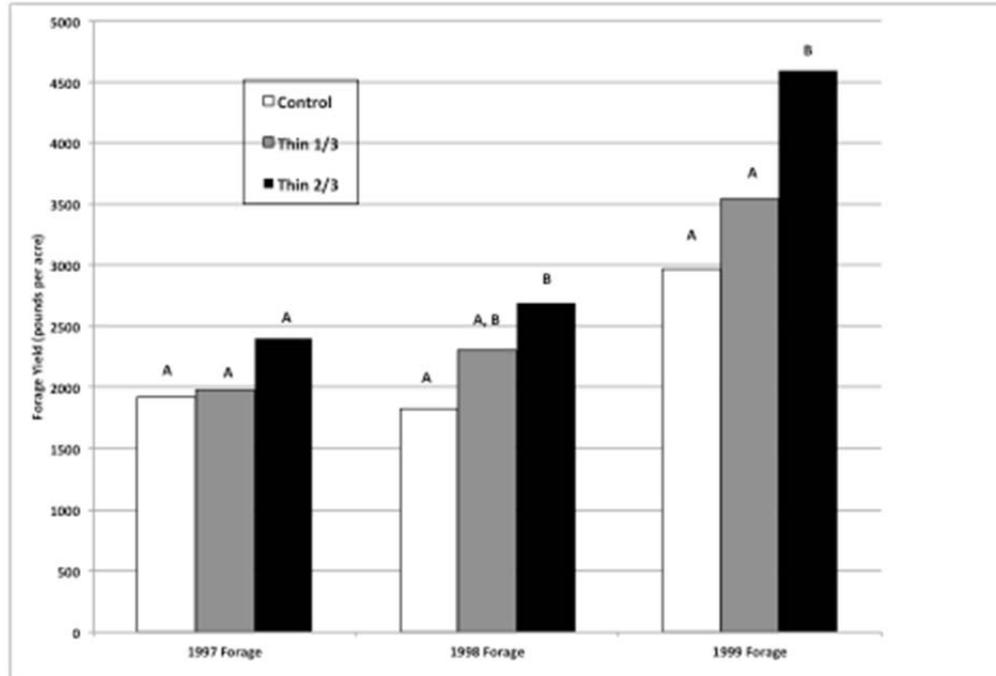


Figure 1—Forage yield for 1997, 1998 and 1999. Note: Means with different letters are significantly different at the 0.05 level.

### ***Stump sprouting***

Figures 2 and 3 show the percent of stumps with living sprouts and average sprout height. There was a significant sprouting percent difference by treatment in only 1 year out of 9. After 7 years, the proportion of stumps with living sprouts decreased dramatically due to the high levels of stem girdling by rodents, resulting from the high thatch levels in the study area because of grazing exclusion.

The two-thirds thinning treatment has a general trend of increased sprout height that was significant in 4 of the first 6 years after thinning. High mortality rates from rodent girdling resulted in non-significance in the last three measurements.

### ***Acorn production***

Acorn production was evaluated on all residual trees using the visual estimation methodology described by Graves (1980). All trees were placed into one of the four classes described by Graves (Class 1 = no acorns; Class 2 = acorns visible on close exam; Class 3 = acorns readily visible, don't cover entire tree; Class 4 = acorns readily visible, cover entire tree). Figure 4 shows the proportion of trees with acorns (Classes 2, 3 or 4). There was a significant effect from the thinning treatment on the proportion of trees with acorns in 5 of the 7 years surveyed.

To test if there was a significant effect on the total production of acorns from the thinning treatments, the expansion factor described by Graves (1980) was applied to each tree (Class 1 = 0 pounds; Class 2 = 0.1 pounds of acorns per 10 sq. ft. canopy; Class 3 = 0.7 pounds per 10 sq. ft. canopy; Class 4 = 2.3 pounds per 10 sq. ft. canopy). Figure 5 shows that per acre acorn production was not significantly affected by the thinning treatment.

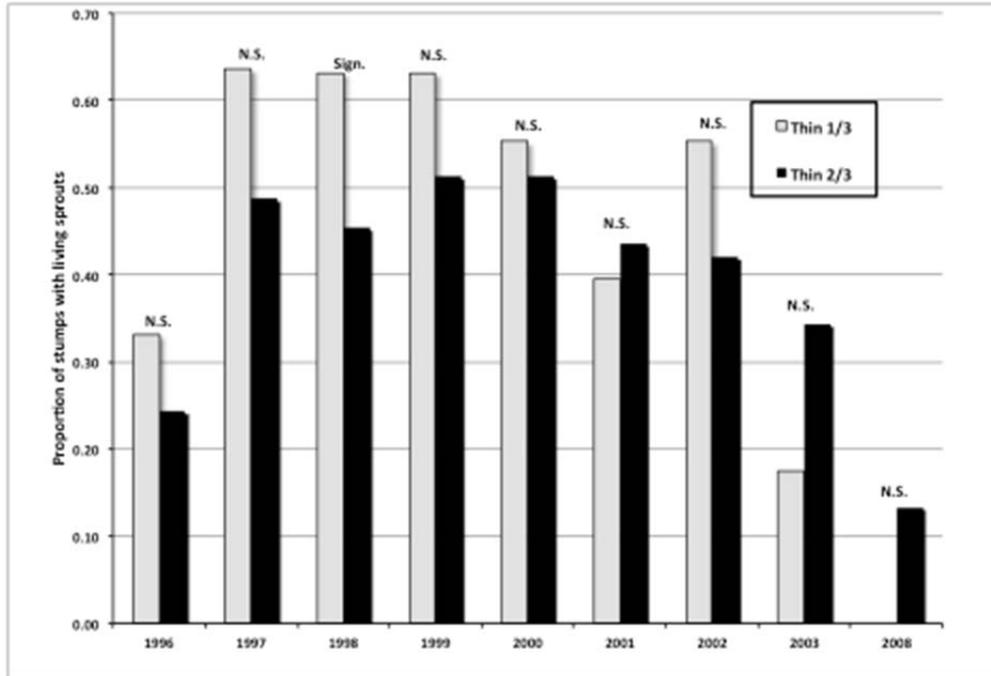


Figure 2—Proportion of stumps with living sprouts for two thinning treatments. N.S. indicates not significant at 0.05 level, and Sign. indicates significant at 0.05 level.

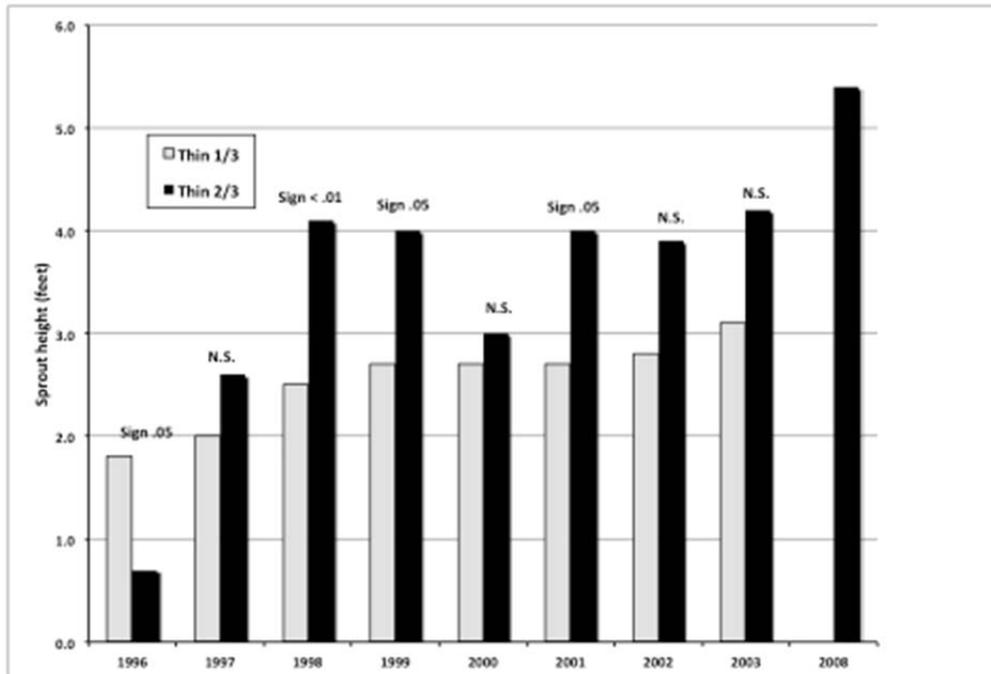


Figure 3—Sprout height for two thinning treatments. N.S. indicates not significant at 0.05 level, and Sign. indicates significant at either the 0.01 or 0.05 level.

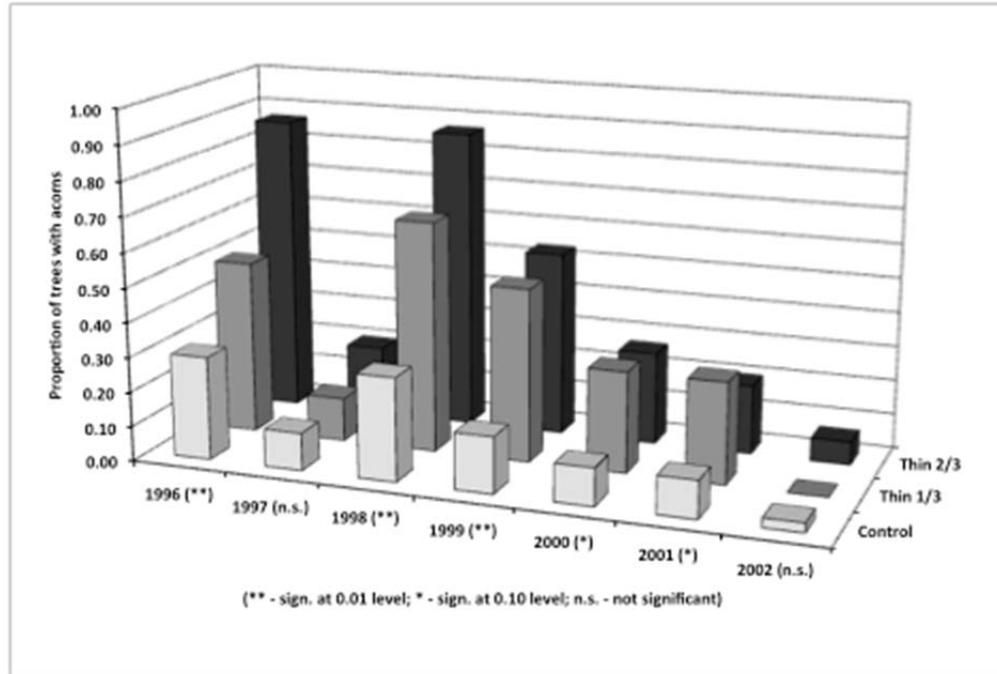


Figure 4—Proportion of trees with acorns for the three thinning treatments. Significance evaluated with Chi-square analysis.

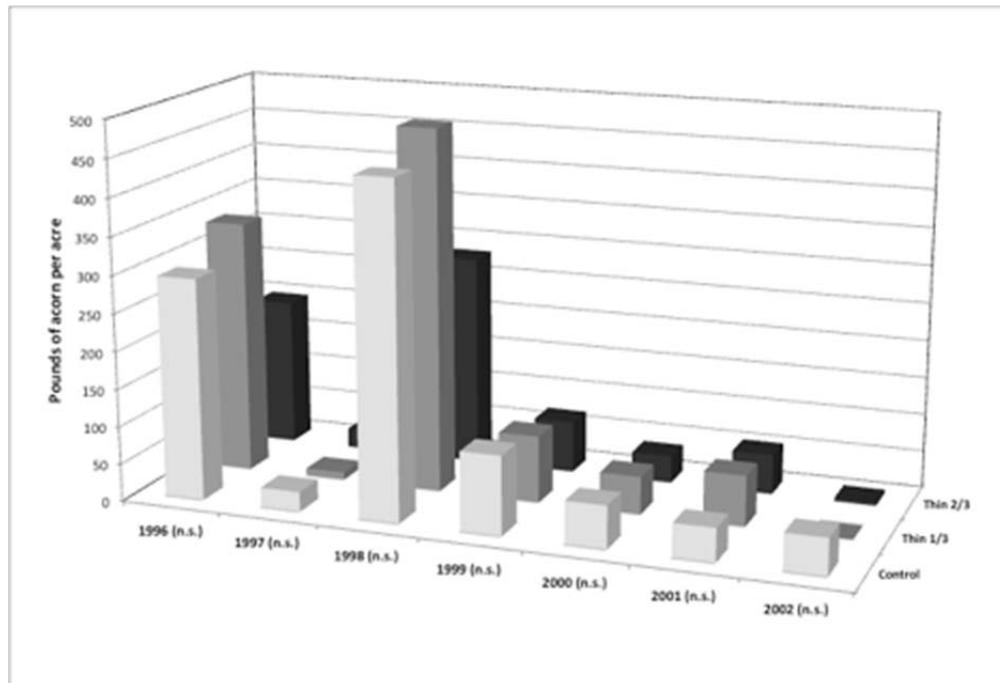


Figure 5—Acorn yield expressed in pounds per acre for the three thinning treatments. N.S. indicates not significant at the 0.05 level.

**Stand and tree growth and development**

Crown cover, merchantable wood volume per acre, and individual tree growth was evaluated over the 13 years of the study. Table 2 below shows the general results.

Periodic volume and crown growth at the stand level was not significantly affected by the thinning treatment. Only individual tree diameter growth showed a significant increase.

**Table 2—13-year changes in periodic annual increment and per tree measurements (means with different letters are significantly different at the 0.05 level)**

Treatments	13-year growth			
	Volume (cu. ft./ac/yr.)	Crown cover incr. (pct./yr.)	Mean DBH incr. (in./tree/yr.)	Mean ht. incr. (ft./tree/yr.)
Control	14.7	1.02	0.03 A	0.11
Thin 1/3	22.3	1.02	0.06 A,B	0.26
Thin 2/3	18.8	1.58	0.09 B	0.32
Significance	N.S.	N.S.	Sign. at 0.05	N.S.

Figure 6 shows the 13-year growth in oak canopy cover percent after thinning. There was no significant difference in the two-thirds and the one-third thinning level, showing the rapid capacity of the heavily thinned blue oak crowns to occupy the site.

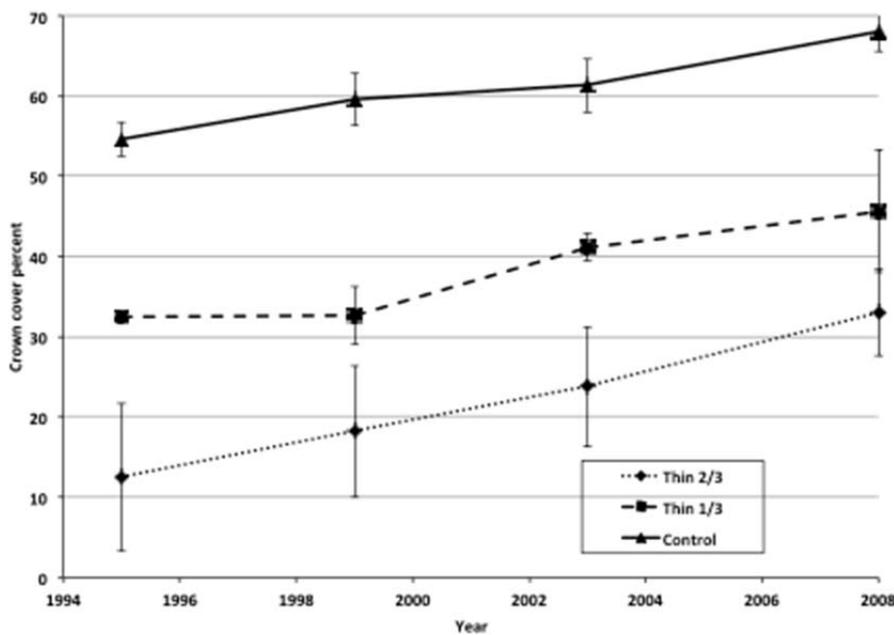


Figure 6—Blue oak crown cover percent over 13 years following thinning. Vertical bars represent standard errors about the mean.

## Discussion

This first ever study of blue oak thinning was developed to determine the effects of two thinning levels (one-third and two-thirds reduction of basal area). With the observation that blue oak in large parts of their range may be denser as result of fire suppression, the thinning was intended to be applied as a restoration tool to mimic the effects of a more regular fire return interval that has been disrupted for the last 50 plus years.

Thinning did increase the forage production levels for the heaviest thinning, although there was no change in forage composition at the levels investigated. Thinning also increased the vertical canopy diversity due to the resprouts. However, heavy rodent damage to respouts in these areas with no cattle grazing, had a significant negative effect on the success of coppice management. A study of coppice management of blue oak in the northern Sierra showed that livestock grazing had a positive effect on sprouting success and height growth (Standiford and others 2010).

Thinning did increase the probability of acorn production of residual trees in the stand. In several years, over 80 percent of the trees in the heavily thinned stands had acorns. This did not change the per acre production of acorns, due to the lower density of trees, but it will be useful to continue to monitor this effect to see if the enhanced per tree production has longer term impacts.

Although thinning did not have a significant effect on stand level growth, it did enhance individual tree growth. The effect of the thinning over time will be fewer, large trees as compared to the untreated controls. It is also important to note that the canopy cover of the most heavily thinned stand increased from 12 percent to over 30 percent in 13 years, and was statistically the same as the less heavily thinned treatments in canopy cover.

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