Coast Live Oak Long-term Thinning Study—Twelve-year Results[1]

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Abstract
A long-term thinning study was established in 10 stands of coast live oak (*Quercus agrifolia* Née) in the Central Coast of California. Information about diameter, basal area, and volume growth and yield has been obtained from unthinned control plots and from plots thinned to 50 and 100 square feet of basal area per acre measured in 1984, 1989 and 1996. Both basal area and total volume growth percentages were significantly greater in the thinned plots compared to the control plots.

Introduction

This paper is the third report that has been published on this long-term thinning study. The first report described the methodology and rationale for the thinning regime in significant detail (Pillsbury and others 1987).

The second report provided the first information on coast live oak about diameter, basal area, and volume growth and yield from unthinned control plots and from plots thinned to 50 and 100 square feet of basal area per acre measured. These results were reported in the proceedings of the 1990 oak symposium (Pillsbury and Joseph 1991).

This, the third report, extends our knowledge about the effects of thinning in coast live oak stands to a 12-year period.

There are no past or current studies that show the effects of thinning on the growth of coast live oak residual stands. Thinnings are normally conducted to stimulate the growth of the trees that remain and to increase the total yield of useful fiber from the stand. The basic objectives of thinning are: a) to redistribute the growth potential of the stand into fewer but larger trees, and b) to utilize all the merchantable material produced by the stand prior to harvest (Smith 1962).

The age that the final harvest would occur (rotation) for coast live oak was examined in a preliminary site, growth and yield study on the Central Coast (Pillsbury and De Lasaux 1985). Based on the growth rate and stand condition, a

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biological rotation of a stand could be as early as 50 years, although a harvest at age 75 or 80 would be feasible especially for stands on lower quality sites.

Currently, little is known about site productivity, regeneration, tree growth and the potential effects of harvesting on oak woodlands. Little information is available on different management practices and their effects. By developing a number of permanent plots, growth can be documented over time. These data will prove valuable to foresters and landowners that wish to maximize fiber production in existing stands or want to compare the potential for different management strategies.

The primary long-term goal of this study is to establish a series of permanent plots to develop long-term diameter, basal area and volume growth and yield information for thinned and unthinned stands of coast live oak in Monterey, San Luis Obispo, and Santa Clara counties.

Many of the stands measured in previous studies are near rotation age, therefore it is important to know if they could benefit from thinning. This study may help to determine if thinning of older stands will yield increased fiber while allowing for immediate income from the removed trees.

Methods

Site and Plot Selection

Ten sites were selected for this study and were distributed as follows: Monterey County—four sites; San Luis Obispo County—five sites; and Santa Clara County—one site *(fig. 1, table 1)*. Three plots were established at each site consisting of one control plot and two plots that were thinned to 50 and 100 square feet per acre, respectively. Plots were established in stands approximately 40 to 85 years old.

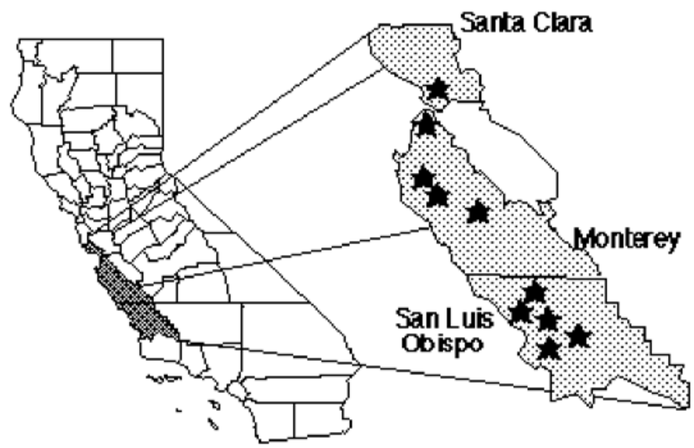


Figure 1—Map of coast live oak thinning plots.

Each plot is one-fifth acre in size and surrounded by a two-fifths acre buffer zone for a total area of three-fifths acre. Plots were established by compass and tape; metal rebar was used to monument plot corners.

Table 1—*Location, treatment and plot description.*[1]

	Treatment by site and plot number		
Location/USGS Quad./County	**Control**	**100 sf/ac**	**50 sf/ac**
Cuesta Grade/Lopez Mountain/San Luis Obispo	1-2	1-1	1-3
Elkhorn Slough Estuarine/Prunedale/Monterey	2-2	2-3	2-1
Arian Ramage/Adelaida/San Luis Obispo	3-3	3-2	3-1
San Carlos Ranch/Mt. Carmel/Monterey	4-3	4-1	4-2
Chualar/Gonzales/Monterey	5-2	5-3	5-1
Castro Valley Ranch/Watsonville/San Benito	6-2	6-3	6-1
Rana Creek Ranch/Rana Creek/Monterey	7-3	7-1	7-2
Presenti Winery/Templeton/San Luis Obispo	8-3	8-1	8-2
Prefumo Cyn/Morro Bay South/San Luis Obispo	9-3	9-1	9-2
Lopez Lake/Lopez/San Luis Obispo	10-2	10-3	10-1

[1] 1-2 means Site 1, Plot 2.

Data Collection

The following information was obtained for each tree in 1984, 1989, and 1997 (and was re-measured in summer 2001): tree number, species, dbh (inches), total height (feet), tree vigor (code) and crown class (code). The same data was collected for trees in the control plot.

The following plot information was obtained for each plot in 1984, 1989, 1997 (and was re-measured in summer 2001): percent crown closure, percent ground cover (bare ground/rock, grasses and forbs, and litter), percent and species of woody shrub cover, forage (species, extent and weight), sprouts and stumps (clump diameter, sprout height, sprout number, stump diameter, stump height, stump angle) and surface erosion (type and percent). Additional tree information obtained during the initial inventory in 1984 includes the following: merchantability indicator (code), azimuth from plot center and distance from plot center. The original azimuth and distance information is used in each analysis to plot planimetric stem maps.

Additional plot information obtained during the initial inventory in 1984 includes the following: slope (percent), aspect, elevation, soil type, site age and site index. Plots were identified by quad name, taken from USGS 7.5 ft topographic maps, by aerial photographs, planimetric stem maps (showing tree location and its relative size) and by plot access information consisting of a detailed plot location narrative, sketch and ownership information for each site.

Development of Stand, Basal Area and Stock Tables

Basic mensurational data were compiled for each plot before and after thinning and extrapolated to a per acre stand basis. A stand table consisting of the number of trees of a given species per diameter class per acre was developed. Trees were grouped into two-inch diameter classes. Basal area tables were also developed by species and diameter class on a per acre basis. Stock tables, the cubic foot volume of trees of a given species per diameter class per acre, were also developed.

Tree volumes for hardwoods were computed according to three utilization standards, total volume, wood volume, and sawlog volume. Total volume is the total outside bark volume including the stump. Wood volume is inside bark volume from stump height (1 foot) to a 4-inch top (inside bark) for all stems. Sawlog volume is the inside bark volume found in trees having an 11-inch or greater dbh and have straight, sound segments 8 feet or greater in length, from stump height to a 9-inch top diameter inside bark (Pillsbury and Kirkley 1984). Only total volumes were computed for non-hardwood species.

Using a computer application (Future Basic II),[4] a series of computer subprograms were written to develop the 90 stand, basal area and stock tables plus a number of other tables needed to summarize the data. From this array of information we were able to begin to chart the course of stand growth and change in the coast live oak thinning plots. Standard mensuration formulae were used to calculate basal area, number of trees per acre and tree volume.

Results of 1996 Re-measurement of Stands

Only the results of the primary long-term goals of the study are presented here. Analysis and results for the following subtopics: wood volume, sawlog volume, tree movement by diameter class, economics, predicting incomes and rates from sustained thinning, economic considerations based on forage, wildlife and aesthetics, and changes in the forage layer in the thinned plots, can be found in Pillsbury and others (1998).

Twelve-year Results of Thinning Treatments

Coast live oak plot data were analyzed for change in stand density and growth volume. The effects of the thinning treatments after twelve years on stand characteristics including number of stems, basal area, and total volume is discussed.

Number of Stems per Acre

In the control plots, a decline in the number of trees per acre is seen primarily due to mortality *(fig. 2)*. The thinned plots saw little change since the initial thinning.

[4] Mention of trade names or products is for information only and does not imply endorsement by the U.S. Department of Agriculture.

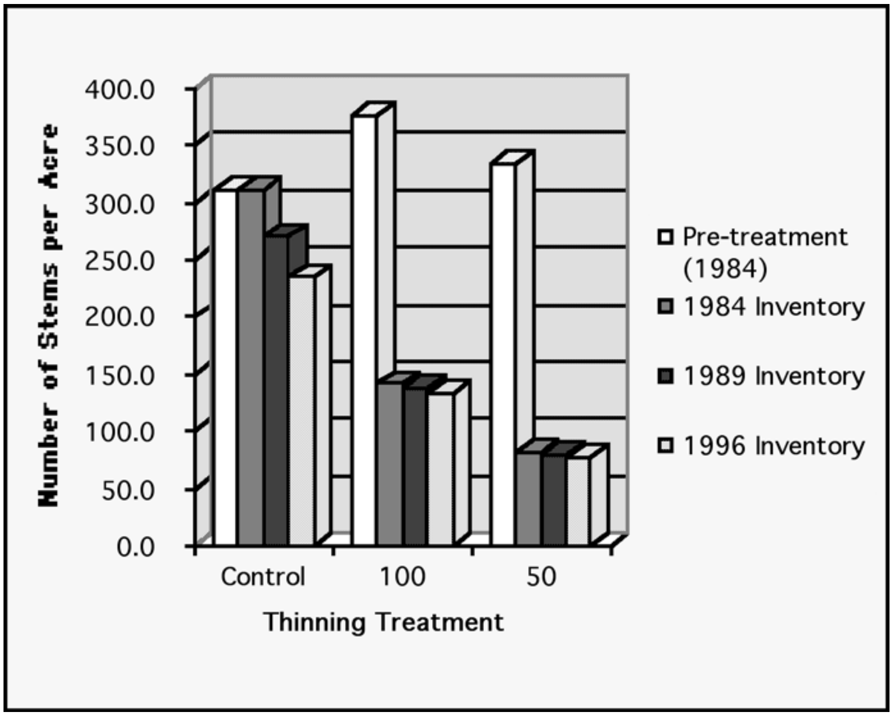


Figure 2—Number of stems per acre by treatment type.

Any change in the number of stems per acre that would occur would be due to either in-growth or mortality. In-growth, when trees finally reach 4.5 feet in height and 1.0 inches in dbh and then would be included in the sample, only resulted in six trees for the 10 sites. On a number of sites it was observed that sprouts were nearly tall enough to be classified as trees and it is expected that the next inventory will show the first substantial ingrowth. Stump sprouting and the growth and development of sprouts are examined in a later section.

Mortality, however, did occur and had a definite impact on the study, especially for the control plots *(fig. 3)*. The wildfires that occurred during the summers of 1985 and 1994 produced very intense conditions and were responsible for the majority of tree death that occurred. A total of three of the 10 control plots were affected by fire between inventory dates of 1984 and 1989 and one control plot between inventory dates of 1989 and 1996. An average of 76 trees per acre was lost during the 12-year interval. The majority of trees lost in the first inventory were in plot 1-2, which lost an average of 215 trees per acre. The 1996 inventory showed a serious loss again in plot 1-2 of 110 more trees per acre. In effect, plot 1-2 lost 325 of its 400 trees per acre from 1984 to 1996 due to fire, or 42 percent of the total lost in all control plots.

During the 1984-1989 period, both fire and snow significantly affected site 3. While only 30 trees/acre that were damaged by one or both of these events died during the first 5-year period, an additional 160 trees per acre died during the next seven years.

By contrast only an average of 31 trees/acre died from other causes in the other eight control plots, and only an average of 8.5 and 4.0 trees per acre died in the 100 and 50-ft^2/acre plots, respectively. The greater density of trees in the unthinned control plots certainly contributed to the fire intensity and subsequent loss. The effect of repeated fire in unthinned stands cannot be ignored.

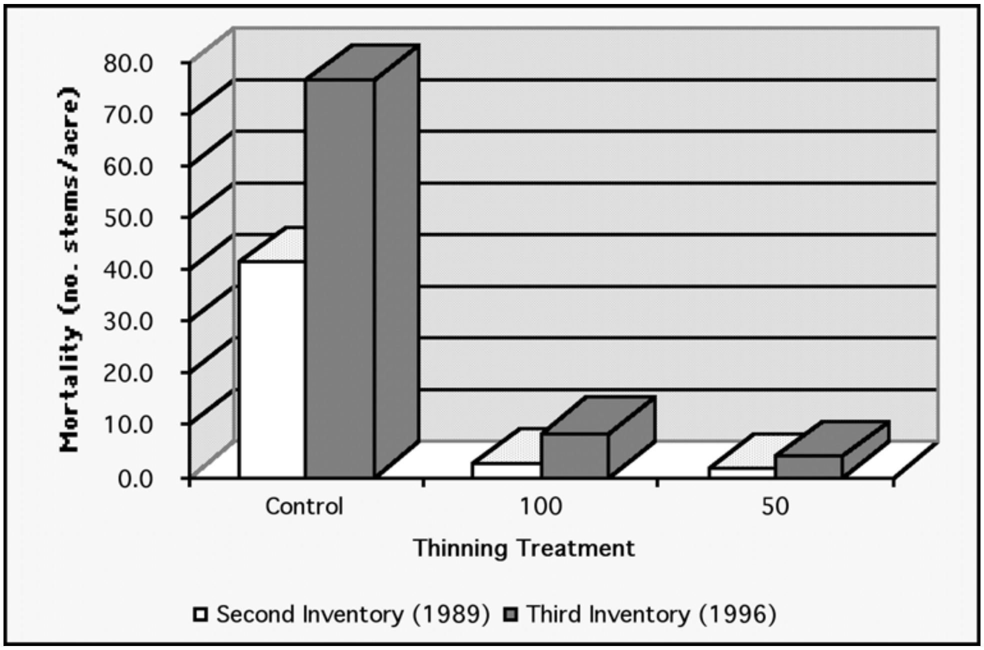
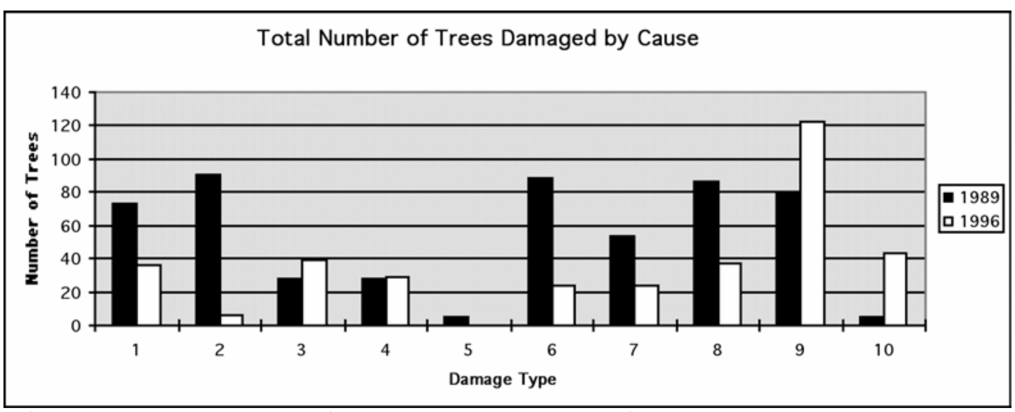


Figure 3—Mortality for control and treatment plots.

In addition to the outright death of trees from fire, a number of factors contributed to tree damage during this period *(fig. 4)*. Again, wildfire played an important role. Many trees had scorched trunks, burned crowns and cracked or swollen bark making diameter measurement difficult. Trees, which were defoliated by the flames often, produced sprouts along the stem and branches. Although they were classified as a living tree, their rate of growth will be greatly reduced.



Code	Damage Type	Code	Damage Type	Code	Damage Type
1	DT=Dead Top	5	SB=Sprouts-basal	8	YD=Fire Damage-effects diameter
2	S=Snow Damage	6	SP=Sprouts-other	9	CB=Cracked Bark
3	BT=Broken Top	7	Y=Fire Damage-no diameter effects	10	BI=Basal Injury
4	SS=Sprouts-stem				

Figure 4—Mortality by damage type. Note the incidence of damage types appears to have decreased. This is because most of the trees that were affected in the 1989 inventory died by the 1996 inventory.

Basal Area Per Acre

Basal area was the variable used to design the thinning treatments in 1984. The changes that occurred in basal area are shown in *figure 5*.

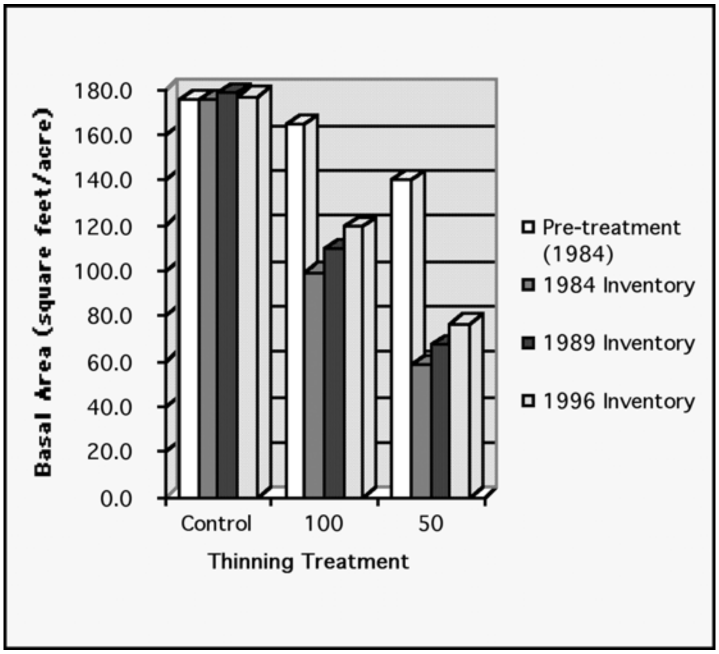


Figure 5—Basal area per acre for control and thinned plots.

The twelve-year average increase for all control plots is 1.5 ft^2/acre or about 0.85 percent for the 5-year period. The more heavily thinned (50 ft^2/acre) plots increased by about 17.9 ft^2/acre (30.5 percent) while the 100-ft^2/acre plots increased by 20.0 ft^2/acre (20.1 percent) during the same period.

Further, these data show that the 50-ft^2/acre plots averaged 21 times the basal area growth when compared to the control plots *(fig. 6)* and the 100-ft^2/acre plots averaged 23 times the growth compared to the control plots.

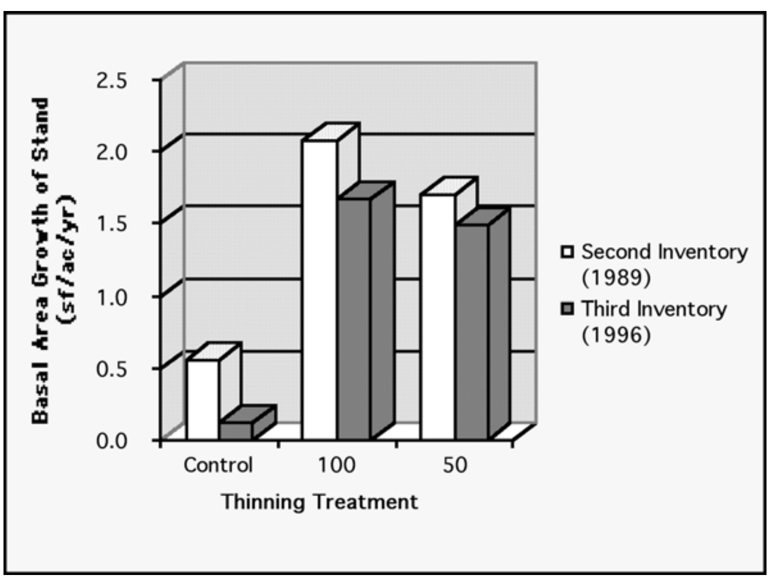


Figure 6—Basal area growth of stand for control and thinned plots.

It could be argued that these ratios and data might be somewhat misleading because of the high rates of mortality in the control plots. On the other hand, one of the reasons for thinning a stand is to reduce the density quickly i.e., speed up the rate of natural mortality, and to improve the vigor and growth rates of the remaining trees. Dense stands will typically have higher rates of natural mortality as well as higher death rates during catastrophic events such as wildfire and extreme snowstorms. In an effort to provide a comparison of how surviving trees responded relative to the control plots, the analysis from this point on is only conducted on living trees.

Because of the mortality caused by fire and snow, these data show not only the positive results of thinning but also the loss of growth that can occur when stands are not properly managed.

Total Volume in Cubic Feet per Acre

During the twelve-year period, total volume increased by 799 ft^3/acre (16.2 percent) for control plots *(fig. 7)*. Thinned plots incremented by 914 ft^3/acre (32.0 percent) for the 100-ft^2/acre plots and by 701 ft^3/acre (40.4 percent) for the 50-ft^2/acre plots.

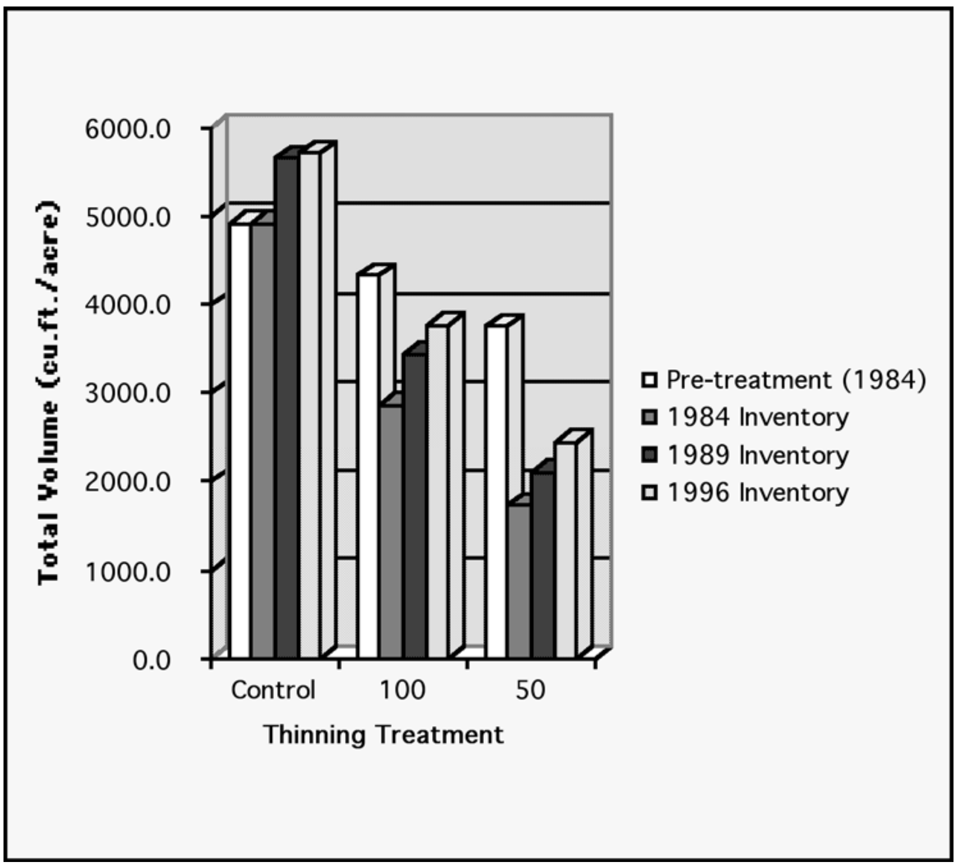


Figure 7—Total volume for control and treatment plots.

Further it must be understood that control plots contain many more trees than the thinned plots and that the total volume growth could be greater simply due to the total number of trees. In total they could produce more volume even though their growth rates might be slower. For this reason, a more realistic comparison of growth is to calculate growth per tree.

The data show that the thinned plots out grew the control plots by substantial margins *(fig. 8)*. The 100 ft^2/acre plots incremented 50 percent more total volume and the 50 ft^2/acre plots incremented 91 percent more total volume than did the control plots.

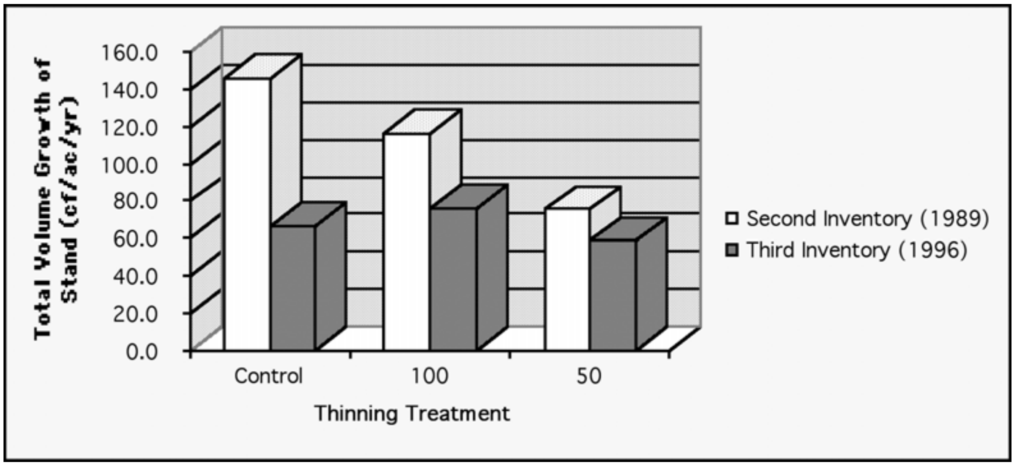


Figure 8—Total volume growth per tree for control and treatment plots.

The U.S. Department of Agriculture-Forest Service (1977) uses the following definition for Productive Forest Land: "Land which is physically capable of producing crops of industrial wood in excess of 20 cubic feet/acre/year." While the wood products from coast live oak are mostly in the form of firewood, it is interesting to note that the rate of growth of coast live oak exceeded 20 cubic feet/acre/year for all plots.

The results of this study were compared with a stem analysis study conducted on 25 plots in 1985 (Pillsbury and De Lasaux) with similar results. All plots in the 1985 study exceeded 20 cubic feet/acre/year based on the mean annual increment (MAI), and all except one exceeded this value for the coast live oak study.

A similar MAI analysis was conducted for this study. It shows that the MAI of control plots has peaked and is now declining while the MAI of the thinned plots is still increasing. Thus the overall productivity of non-thinned plots will likely continue their decline, however, cutting treatments of the thinned plots appears to have prolonged stand productivity.

Analysis of Plot Regeneration

The revegetation of live oaks through the sprouting of cut stumps, otherwise known as coppice management, is widely used in a variety of forestry and woodlot situations. California coast live oak is well known as a vigorous sprouter. This is especially true when damage is created by fire, wind or harvesting. Most common are sprouts from the cambial layer which form a ring on top of the stump.

In this study sprouts took on two distinct forms: 1) mound or "clump" form, and, 2) sprouting form. Clumps occurred when the succulent sprouts were browsed by wildlife and domestic animals. These sprouts become rounded into a dome or mound shape. The mounds continue to expand outward, growing mostly in diameter rather than height, until an animal can no longer reach the sprouts in the center or until a growing season passes when browsing fails to occur. The center sprouts then will "escape" and grow into a new tree. This process could take anywhere from two or three years up to 15 or 20 years. If the stump had one or more dominant leaders it was classified as a sprout (as opposed to a clump).

In order to better understand the process of tree development from clumps, they were grouped into three size categories. For the 100-sf/ac lightly thinned plots, 34 percent of all clumps were less than two ft. in diameter, with 53 percent two ft. to three ft. in diameter, and 13 percent greater than three ft. in diameter.

For the 50-sf/ac heavily thinned plots, 35 percent of all clumps were less than two ft. in diameter, with 41 percent two ft. to three ft. in diameter, and 24 percent greater than three ft. in diameter.

By our definition, a mound ceases to be classified as a mound when at least one sprout attains a height of least three inches and is unbrowsed. Therefore, over time it would be expected that as mounds begin to produce sprouts, the number of mounds surveyed would decrease and the number of stumps that were classified as sprouts would increase.

In the 100-sf/ac plots there was a large decrease in the number of mounds *(fig. 9a)*, however it is not clear that this decrease resulted in a corresponding increase in sprouts *(fig. 9c)*. In the 50-sf/ac plots a closer correlation can be seen as three of the four sprout height classes showed an increase *(fig. 9d)* likely due to the decrease in the number of mounds *(fig. 9b)*.

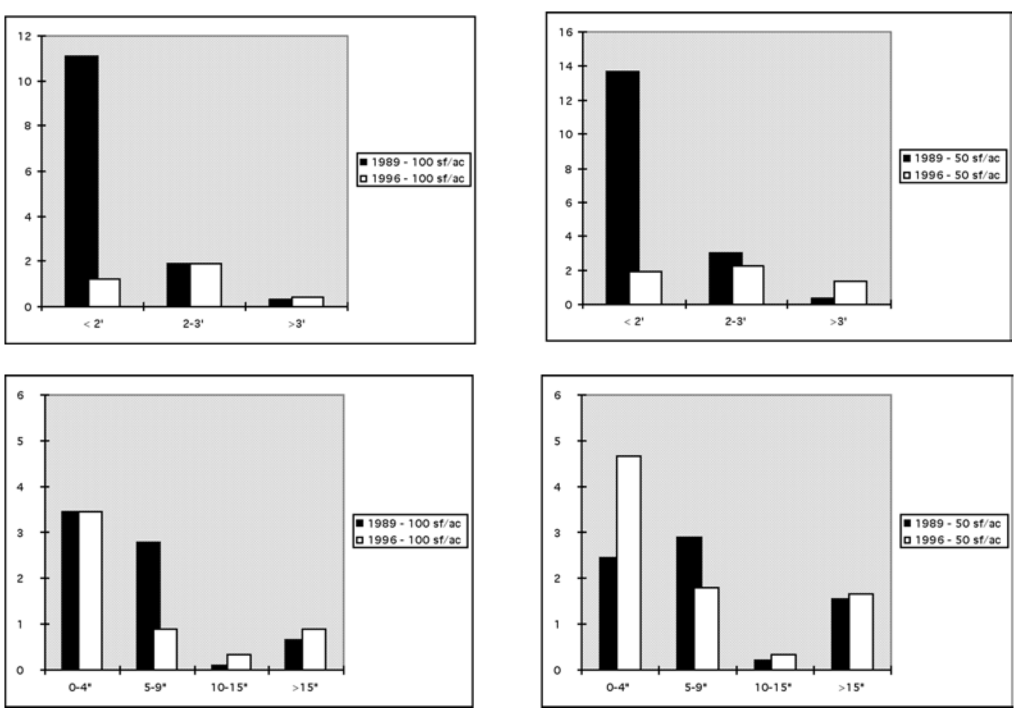


Figure 9—a) Clump data for 100-sf/ac plots. b) Clump data for 50-sf/ac plots. c) Sprout data for 100-sf/ac plots. d) Sprout data for 50-sf/ac plots.

Site 5 was the first to show signs of natural regeneration. The more heavily thinned 50-sf/ac plot (5-1) had 31 natural sprouts ranging from 4-19 inches in height while plot 5-3 had two natural sprouts ranging from 10-12 inches. Natural regeneration will be closely monitored in future inventories.

Conclusions and Recommendations

The first twelve years of growth information has been collected and analyzed for the coast live oak thinning study. The interpretation of this data is discussed below in the form of conclusions and recommendations.

1. Two major forest fires occurred during the 12-year interval, which affected the study. Our data shows that the more dense, unthinned plots sustained greater damage from fire than did the treatment plots. Proper care and management of the woodland forest can reduce losses from fire and, in general, protect the value of the resource.

   Many of the stands in the thinning study are thought to be near rotation age. Could they benefit from a thinning at this age? The answer to this question is "yes." The benefits were already apparent after the 5-year inventory, and that trend has strengthened after twelve years of growth.

2. Both basal area and total volume growth percentages were significantly greater in the thinned plots than the control plots. Average per acre growth rates for the 12-year interval ranged between 20 and 31 percent for treatment plots but only 1 percent for control plots. In general, total volume growth was approximately twice as great in the treated plots compared to control plots. Clearly coast live oak stands, even if they are older, respond in a positive manner to thinning.

3. Prior to thinning, all 30 plots in the study were measured and their growth rates were found to exceed the Forest Service definition for Productive Land (20 ft^3/acre/year). In fact they averaged about 70 ft^3/acre/year. An independent site, growth and yield study conducted on 25 plots in San Luis Obispo and Monterey counties in 1985 showed similar results. In that study, coast live oak plots averaged about 60 ft^3/acre/year. In both studies the researchers sampled only moderately dense to dense stands; the typical growth pattern for coast live oak.

   This information is significant as it relates to the potential for silvicultural practices and management for commercial products.

4. Cut stumps on thinned plots were evaluated for their ability to produce sprouts. Less than one-third of the stumps produced clumps (a dome-shaped mass of stems created by heavy browsing) by the end of the 12-year period, and only about 15 percent of the clumps were able to "escape" into the sprout stage.

   This means that regeneration by coppice methods is not going to occur rapidly following thinning by itself. Some method of protection, such as screens or piling brush on the stump, is necessary to encourage more rapid regeneration.

5. The condition of the soil was evaluated in 1984, 1989 and 1996. No type or amount of erosion was observed on any plot regardless of the land slope. Apparently the crown and root density left after thinning was sufficient to protect the site.

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