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# Long-Term Growth of Coast Live Oak in Three California Counties—17-Year Results<sup>1</sup>

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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 in 1984. Information about diameter, number of stems per acre, 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, 1996, and 2001.

Both basal area and total volume growth percentages were significantly greater in the thinned plots compared to the control plots. Average basal area per acre growth rates were 22 percent for the treatment plots and one percent for control plots. In general, total volume growth rates were nearly three times as great in the treatment plots compared to the growth plots. Mortality in unmanaged stands can substantially reduce the growth potential. Proper care and management of the woodland forest can reduce losses from fire and, in general, protect the value of the resource.

*Keywords:* Basal area, coast live oak, management, thinning, volume growth rate.

## Introduction

Thinnings are normally conducted to stimulate the growth of the trees that remain and to increase the merchantable net yield of 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). A potential secondary benefit of thinning is to reduce mortality caused by accidental fire, since fire intensity may be lower in thinned versus unthinned stands.

Currently, little is known about site productivity, regeneration, tree growth, and the potential effects of harvesting, including intermediate thinnings, on coast live oak woodlands. The goal of this study was 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. Previously published papers described the methodology and rationale for the thinning regime and provide preliminary findings about the effects of thinning on coast live oak stands (Pillsbury and others 1987; Pillsbury and Joseph 1990; Pillsbury and others 1998). This paper extends our knowledge about the effects of thinning in coast live oak stands to a 17-year period.

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<sup>1</sup> An abbreviated version of this paper was presented at the Sixth California Oak Symposium: Today's Challenges, Tomorrow's Opportunities, October 9-12, 2006, Rohnert Park, California.

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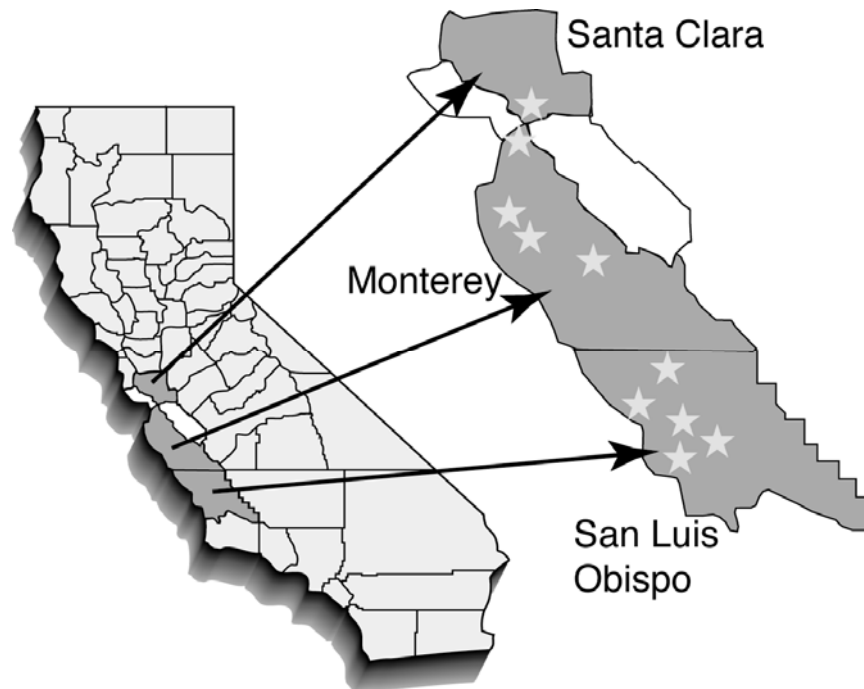
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The findings of this study should prove useful to foresters and land managers concerned with the management of coast live oak woodlands. It also will be helpful to landowners seeking information on strategies for managing their coast live oak woodlands.

## Methods

### *Site and Plot Selection*

Initially, 10 sites were selected for this study in Monterey, San Luis Obispo, and Santa Clara counties (*fig. 1, table 1*). Three plots were established at each site, consisting of one control plot (no thinning) and two plots that were thinned to 50-square-feet per acre (heavily thinned plots) and 100-square-feet per acre (lightly thinned plots), respectively. Plots were established in stands ranging in age from 40 to 85 years old.



**Figure 1**—Map of coast live oak thinning plots.

A change in ownership at one site required it to be dropped from the analysis in this paper. The analyses for all previous years were redone so that comparisons could be made for this paper. However, results presented in previous papers, based on all 10 sites, should not be compared to the results presented here in this paper.

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 and monumented for re-measure.

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**Table 1**—Location and treatment (control, lightly thinned, or heaving thinned), of study plots.

<u>Location/USGS Quad./County</u>	<u>Treatment by site and plot number<sup>1</sup></u>		
	<u>Control</u>	<u>100 sf/ac</u>	<u>50 sf/ac</u>
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
Rana Creek Ranch/Rana Creek/Monterey	7-3	7-1	7-2
Pesenti Winery/Templeton/San Luis Obispo	8-3	8-1	8-2
Prefumo Canyon/Morro Bay South/San Luis Obispo	9-3	9-1	9-2
<u>Lopez Lake/Lopez/San Luis Obispo</u>	<u>10-2</u>	<u>10-3</u>	<u>10-1</u>

<sup>1</sup> Site and plot, for example, 1-2 means Site 1, Plot 2.

### **Data Collection**

The following information was obtained for each tree at least 1 inch in diameter at breast height in each plot in 1984, 1989, 1997, and 2001: tree number, species, diameter at breast height (inches), total height (feet), tree vigor code, and crown class. Additional tree information obtained during the initial inventory in 1984 included a 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.

Plot level information included: 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 plot information obtained during the initial inventory in 1984 included slope (percent), aspect, elevation, soil type, stand age, and site index. Plots locations were identified on USGS 7.5 minute topographic maps and on aerial photographs.

### **Development of Stand, Basal Area and Stock Tables**

Standard mensurative data were compiled for each plot before and after thinning and extrapolated to a per-acre basis. Tree volumes for all hardwoods growing in the plots were expressed as total volume, wood volume, and sawlog volume. Total volume is the total outside bark volume including the stump. Wood volume is defined as the 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 diameter at breast height (dbh) and 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.

### **Results**

Coast live oak plot data were analyzed for changes in stand density, growth volume, and mortality 17 years following the application of thinning treatments. The effects of thinning after 17 years on stand characteristics, including number of stems, basal

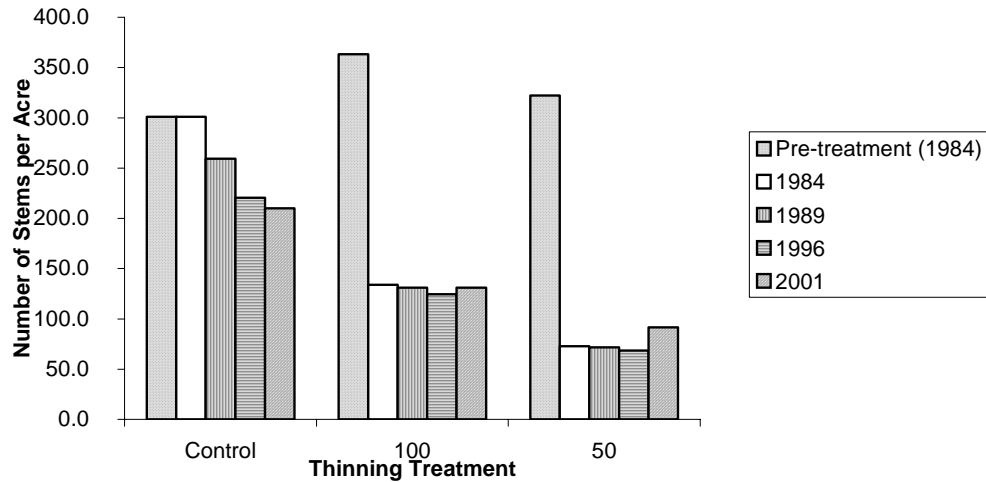
area, and total volume, are discussed below. Analysis and results for wood volume, sawlog volume, tree movement by diameter class, analysis of understory data, clump analysis, sprout analysis, natural regeneration, the forage layer in the thinned plots, and woody shrubs can be found in Pillsbury and others (2004).

**Number of Stems per Acre**

**Ingrowth**

Changes in the number of stems per acre over the 17-year period would be due to either ingrowth or mortality. Trees were counted as ingrowth and included in the sample when they were at least 1 inch in diameter at breast height (4.5 ft). The first ingrowth was observed in the 1996 inventory with six trees, among the nine sites, being counted as ingrowth. Most changes in the number of stems per acre during the first 12 years were the result of mortality.

Ingrowth increased over time in the treated plots (fig. 2). The heavily thinned plots (50 ft<sup>2</sup> per acre) averaged 24.4 trees per acre ingrowth, while the lightly thinned plots (100 ft<sup>2</sup> per acre) averaged 11.1 trees per acre, and the control plots only 1.7 trees per acre. The largest amount of ingrowth was seen in Site 2. The heavily thinned plot had approximately 220 trees per acre of coast live oak ingrowth. The lightly thinned plot had 50 trees per acre of coast live oak ingrowth, and the control plot had no ingrowth. Seventeen years after thinning, three sites had ingrowth, including Sites 1, 2, and 4. Within these sites, ingrowth occurred in one heavily thinned plot, two lightly thinned plots, and two control plots.



**Figure 2**—Number of stems per acre by treatment type. Treatments include control, lightly thinned (100), and heavily thinned (50) plots.

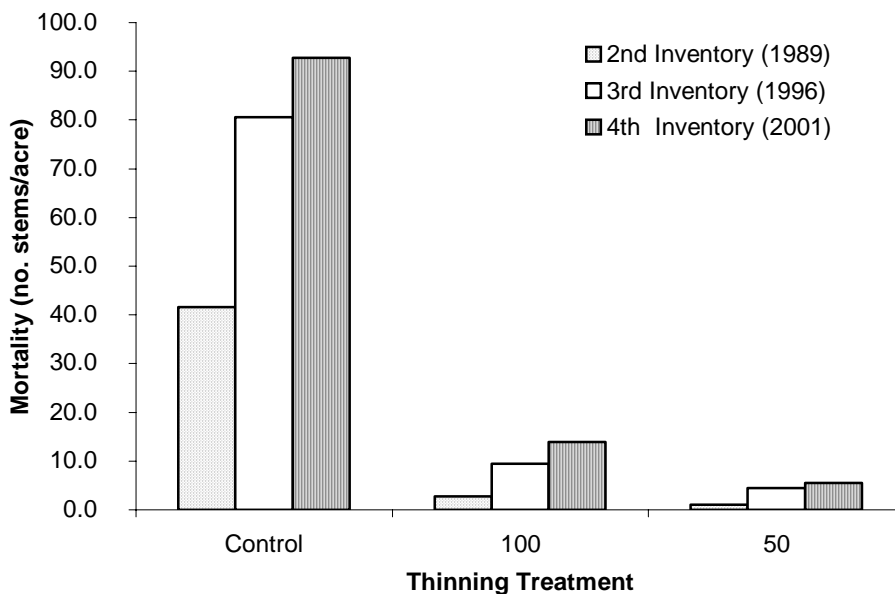
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After 17 years, ingrowth was found in only three of the nine sites. Based on the analysis of clumps and sprouts found by Pillsbury and others (2004), the rate of ingrowth could be accelerated if some method of stump protection from browsing such as screens or piling brush on the stump was provided. Stump protection was not included as a part of this study.

### Mortality

Mortality was most evident in the control plots (*fig. 3*). Wildfires that occurred during the summers of 1985 and 1994 were responsible for the majority of tree death that occurred. Three of the nine sites were affected by fire between 1984 and 1989 and one burned again between 1989 and 1996. An average of 81 trees per acre in the control plots was lost during the 12-year interval, and this impact was still evident in the 17-year analysis. Site 1 burned twice during this period with the control plot losing 325 of its 400 trees per acre due to fire. This plot represented 45 percent of the total mortality in all control plots. The control plot in Site 3 lost 235 of its 610 trees per acre due to snow damage and fire. The greater density of trees in the unthinned control plots certainly contributed to stand altering fire intensity and subsequent loss.

No fires occurred in the nine sites between the 1996 and 2001 inventories. The number of stems per acre in the control plots continued to decline slightly but at a much lower rate than measured in previous inventories. In total, an average of 92.8 trees per acre was lost in the control plots over the 17-year period. Eighty-seven percent of these trees were lost in the first 12 years due primarily to fire. The current mortality rate, based on the 2001 measurement year, still exceeds ingrowth in the control plots.



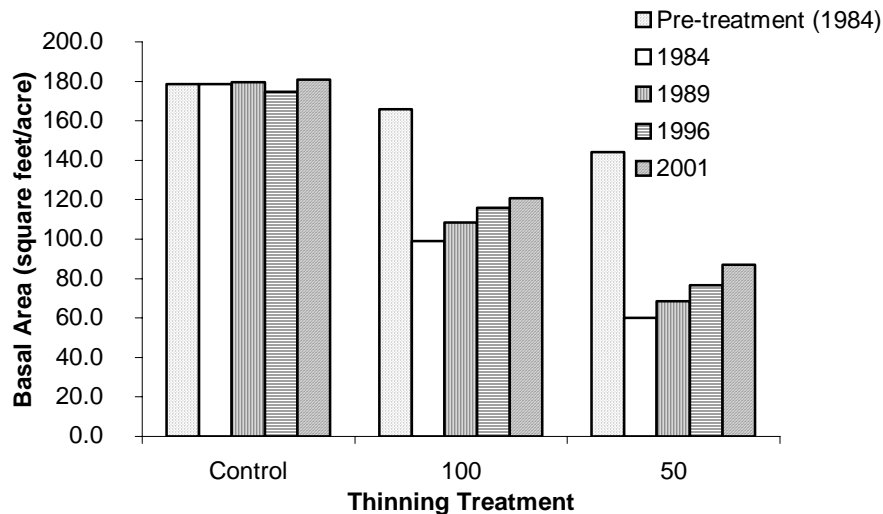
**Figure 3**—Mortality for control and treatment plots.

For the lightly thinned plots, mortality also exceeded ingrowth. Three of the lightly-thinned plots were burned at the same three sites yet a total of only 13.9 trees per acre were lost over the 17-year period, with an average of 9.4 trees per acre lost in the first 12 years. When an ingrowth rate of 11.1 trees per acre between the 1996 and 2001 measurement periods is factored into this picture, the number of stems per acre is now within 2.8 trees of the original number after thinning.

Unlike the control and lightly thinned plots, ingrowth now exceeds mortality in the heavily thinned plots. Even with fire burning three of the heavily thinned plots at the same sites as the control and lightly thinned plots, a total of only 5.6 trees per acre was lost over the 17-year period. With an ingrowth rate of 24.4 trees per acre between the 1996 and 2001 measurement periods, the result was an increase of approximately 18.9 trees per acre above the amount after thinning. Seventeen years after thinning, the heavily thinned plots had begun to show an increase in the number of trees per acre (*fig. 2*).

### **Basal Area per Acre**

The thinning treatments were designed on the basis of reducing basal area. Changes that occurred between 1984 and 2001 are shown in figure 4.



**Figure 4**—Basal area per acre for control and thinned plots.

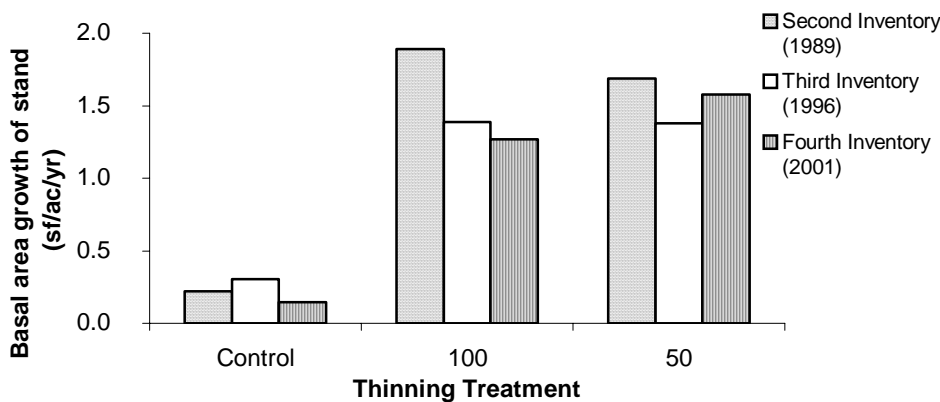
The 17-year average increase for all control plots is 2.5 ft<sup>2</sup> per acre, or about 1.4 percent. For the lightly thinned plots, the increase is about 21.6 ft<sup>2</sup> per acre (22 percent) while the heavily thinned plots increased by about 26.8 ft<sup>2</sup> per acre (45 percent) over the same time period.

Throughout the 17-year period, the heavily thinned plots have continually increased in growth rate (ft<sup>2</sup> per acre, per year) and have now surpassed the lightly thinned plots in basal area production. This may be an indication that the trees in the lightly thinned plots are beginning to more fully occupy the site, and as a result, their growth rates are beginning to slow. The trees in the heavily thinned plots continue to benefit from an increase in the amounts of water, soil nutrients, and sunlight available after thinning.

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Further, at the stand level, these data show that the heavily thinned plots averaged 11 times the basal area growth when compared to the control plots (*fig. 5*), and the lightly thinned plots averaged nine times the growth, compared to the control plots.

Because of the high rate of mortality in the control plots, it could be argued that these ratios and data might be somewhat misleading. But, one of the reasons for thinning a stand is to reduce the density quickly, speeding up the rate of natural mortality or mimicking a catastrophic event (fire), and to improve the vigor and growth rates of the residual stand. Dense stands will typically have higher rates of natural mortality in addition to higher death rates during catastrophic events, such as wildfire or extreme snowstorms. In an effort to provide a comparison of how surviving trees responded relative to control plots, the analysis of total volume was conducted only on living trees.



**Figure 5**—Basal area growth of stand for control and thinned plots.

Due to 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 17-year period, total volume increased by 984 ft<sup>3</sup> per acre (19.4 percent) for control plots (*fig. 6*). Total volume in thinned plots increased by 1,107 ft<sup>3</sup> per acre (38.1 percent) for the lightly thinned plots and by 1,174 ft<sup>3</sup> per acre (64.2 percent) for the heavily thinned plots.

As with basal area, the heavily thinned plots were beginning to out-produce both the control and lightly thinned plots in total volume growth after 17 years. After 12 years, the heavily thinned plots were the least productive and both the control and lightly thinned plots out-produced the heavily thinned plots (Pillsbury and others 2002). The shift in total volume production shows the ability of the heavily thinned plots to gain significant volume as a benefit from thinning. Even though the heavily thinned plots have fewer trees than the other plots, the growth is now being dispersed among these fewer but larger trees, resulting in an increase in growth and merchantable volume in the heavily thinned plots.

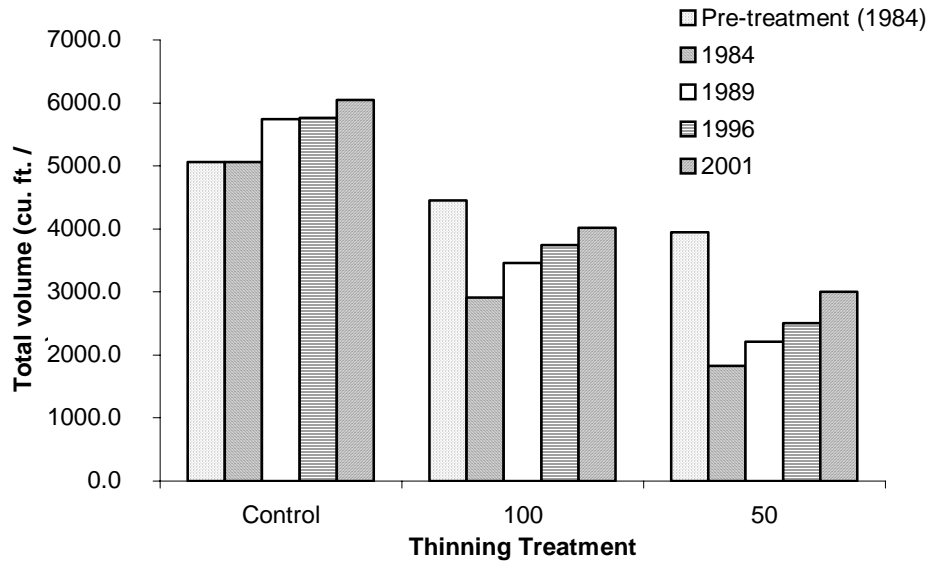


Figure 6—Total volume for control and treatment plots.

Volume growth per tree was greater in thinned plots than in control plots by substantial margins (*fig. 7*). Trees in the lightly thinned plots increased in volume by 56 percent compared to trees in the control plots, on average. Trees in the heavily thinned plots increased in volume by 147 percent more than trees in the control plots.

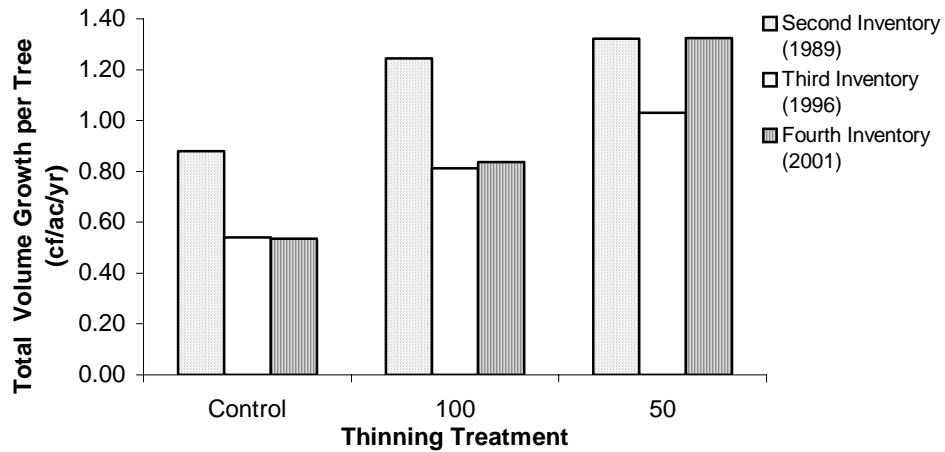
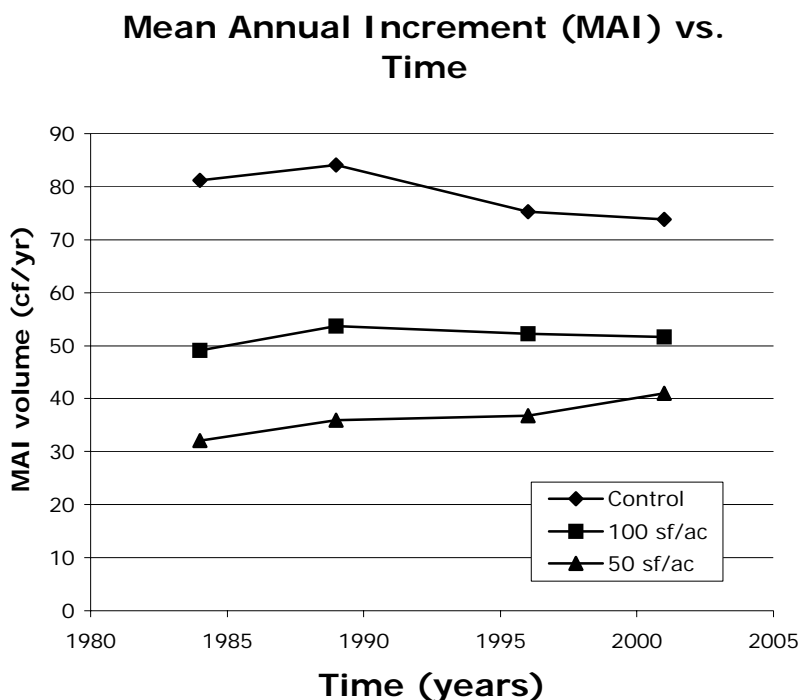


Figure 7—Total volume growth per tree for control and treatment plots.

An analysis of mean annual increment (MAI) showed that the MAI of the control plots peaked in 1985 and then declined while the MAI of the heavily thinned plots was still increasing in 2001. The MAI of the lightly thinned plots appeared to be leveling off (*fig. 8*). The next measurement should provide a clear indication of the MAI trend for these plots.



**Figure 8**—Mean Annual Increment over time.

## Conclusions and Recommendations

Two major forest fires occurred during the 17-year interval that affected the study. Our data show that the denser, unthinned plots at the three burned sites sustained greater damage from fire than did the treatment plots at those sites. Management of the woodland forest can reduce losses from fire and, in general, protect the value of the resource.

By 2001, the control plots, study wide, had an average mortality of 93 trees per acre, compared to 14 trees per acre lost in the lightly thinned plots and 6 trees per acre lost in the heavily thinned plots. This was more dramatically shown in Site 1, which was heavily burned as a result of two fires during the 17-year period. The control plot lost 83 percent of its trees compared to the treatment plots, which lost an average of 26 percent. 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.

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 apparent in the five-year inventory and have only strengthened after 17 years of regrowth. Both basal area and total volume growth percentages were significantly greater in the thinned plots than the control plots. Average basal area per acre growth rates for the 17-year interval were 22 percent for treatment plots and 1 percent for control plots. In general, total volume growth rates were nearly three times as great in the treated plots compared to control plots.

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<sup>3</sup> per acre, per year). In fact, they averaged about 70 ft<sup>3</sup> per acre, per year. As of 2001, only the heavily thinned plots were increasing in MAI. This result is somewhat surprising given that tree MAI is expected to slow considerably in later years. This is significant as it relates to the potential for silvicultural practices to positively influence production of middle to mature-aged stands, which is important for the management of forests for commercial products.

As predicted in the last inventory report (Pillsbury and others 1998), ingrowth is now being seen. It should be noted that it has taken 17 years for ingrowth to appear. For the control plots, less than one-tenth of one percent of the number of stems per acre is attributed to ingrowth. For the lightly thinned plots, approximately 8 percent of the current total number of stems per acre is ingrowth and in the heavily thinned plots, 27 percent of the current stand is new ingrowth. Stumps were not protected in this study; however, we recommend that protection measures be taken in similar silvicultural practices to accelerate regrowth.

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