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Thinning Decreases Mortality and Increases Growth of Ponderosa Pine in Northeastern California

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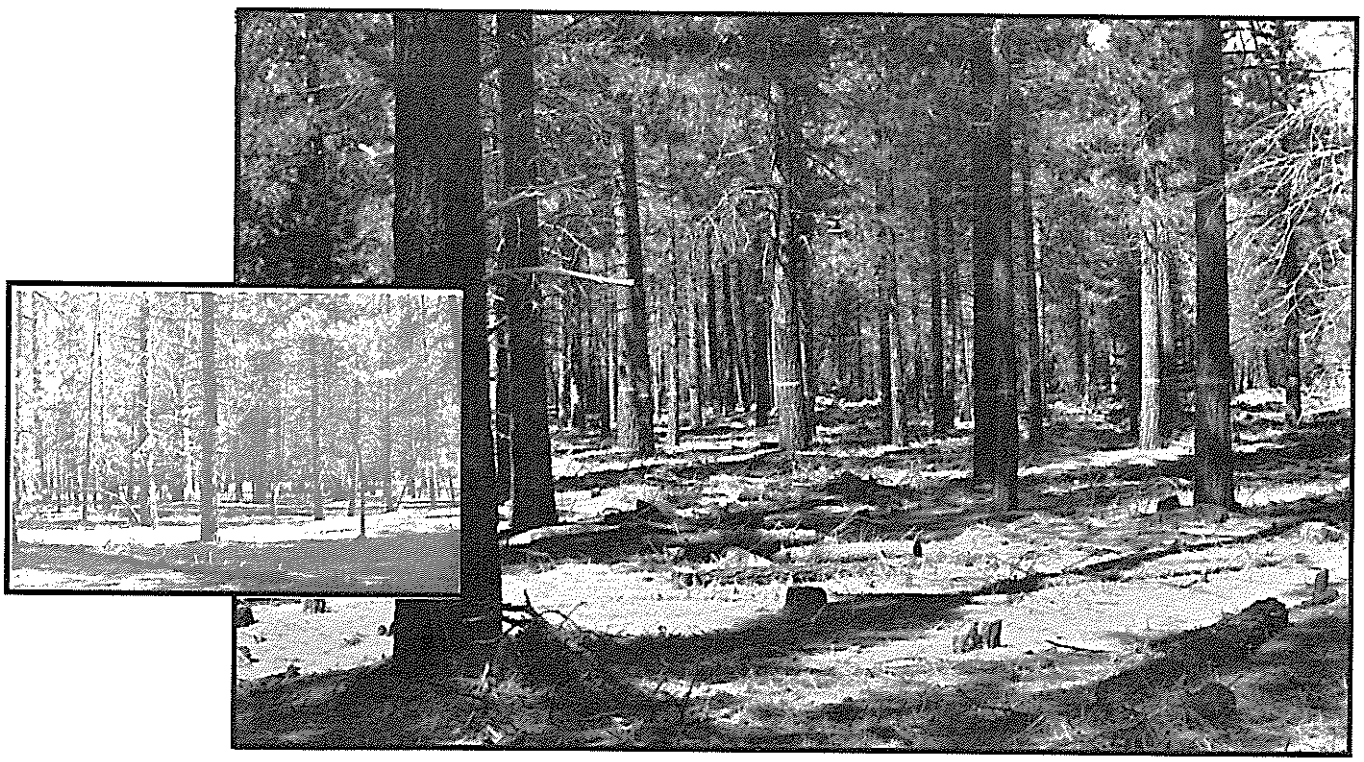

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Overstocked 70- to 90-year-old stands of ponderosa pine on medium- to low-quality sites were thinned in 1980 to 40, 55, and 70 percent of normal basal area and compared to an unthinned control. Mortality, diameter, and height in these northern California stands were measured annually from 1980 to 1987. After 8 years, mortality, primarily from mountain pine beetle *(Dendroctonus ponderosae)* and annosus root disease (*Heterobasidion annosum*), was reduced 100, 95, and 86 percent relative to increasing amounts of reserve basal area. Thinned stands averaged five times more cubic-foot volume growth than unthinned stands. More growth and less mortality could result from treating similar stands elsewhere.

Retrieval Terms: vegetation management, thinning, ponderosa pine, mountain pine beetle, annosus root disease

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IN BRIEF . . .

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Should 80-year-old stands of ponderosa pine on sites of low to medium quality in the eastside pine type be thinned? To answer this question, demonstration areas were established on the Lassen National Forest, in northern California, to quantify the effect of thinning to reduce tree losses caused by insects and disease. One of these areas was established in 1980 at Poison Lake. Common to all areas were four levels of stocking density: 40, 55, and 70 percent of normal basal area (NBA) and an unthinned control. Results from such levels help to demonstrate the biological and economical alternatives available to forest managers.

Stand composition was mostly pole-size ponderosa pine with lesser amounts of incense-cedar. Virtually no understory vegetation was present. Stand age ranged from 70 to 90 years. Site quality ranged from medium to low with dominant and codominant trees expected to average from 40 to 100 feet (12 to 31 m) of height in 50 years.

In the untreated control, mortality of commercial trees averaged 2.1 trees per acre (5.2/ha) per year from 1980 through 1987. Thinning reduced this mortality by 86 to 100 percent with the reduction increasing as basal area of remaining trees decreased. Five years after thinning, stand growth of control trees averaged 16 ft^3 per acre (1 m^3/ha) per year and five times this amount in thinned areas.

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INTRODUCTION

Loss of trees to insect and disease pests is a serious problem in unmanaged, young-growth stands in the eastside pine type in northeastern California (McCambridge and Stevens 1982). In 1976 and 1977, the softwood volume of growing stock in California on all ownerships amounted to 45,975 million ft^3 (1,379 million m^3). During this same period, mortality of this growing stock resulted in a loss of 137,700,000 ft^3 (4,131,000 m^3) (U.S. Dept. Agric. Forest Serv. 1982). Insects and diseases caused about one-third of this mortality (California Department of Forestry 1979). These losses—both in tree growth and mortality—likely result from the stress placed on the trees from insects and diseases. In many instances, this stress is a direct consequence of overstocking. Stand density, therefore, has an important bearing on ambient temperature and moisture conditions and, when manipulated, can lead to improved growth rates and discourage the attack of certain insects—especially bark beetles. Research on bark beetles in the western United States indicates that silvicultural practice, particularly thinning, has significantly reduced the impact of these insects on forest stands (Hall and Davies 1968).

In young stands of eastside ponderosa pine (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*), thinning reduced competition to the extent that outbreaks of the mountain pine beetle were prevented (Sartwell and Stevens 1975, Sartwell and Dolph 1976). Barrett and Roth (1985) found that wide spacing after thinning ponderosa pine stands on average sites allowed the released trees to produce healthy crowns and an acceptable rate of growth, despite heavy dwarf-mistletoe infestation.

The Western Forest Insect Issues Study (U.S. Dept. Agric. Forest Serv. 1977) acknowledged the importance of silvicultural treatment to minimize losses caused by forest insects and recommended developing the technology required for forest management and protection through silvicultural treatments:

> The study team believes the most important action needed to prevent intolerable losses caused by insects, primarily bark beetles, in the future is to provide the necessary silvicultural treatment to young stands to minimize their susceptibility to attack. To do this, the Forest Service should accelerate its current effort to provide the necessary silvicultural treatment to the 1.9 million acres (800,000 ha) of pole-size lodgepole and ponderosa pine stands growing on sites which produce 85 ft^3 per acre or more (6 m^3/ha) per year.

This paper describes the effectiveness of three levels of thinning relative to an uncut control in an overstocked 70- to 90-year-old ponderosa pine stand in northern California.

STUDY LOCATION AND ENVIRONMENT

This study, at Poison Lake, is part of a Forest Service Regional Administrative Study on commercial thinning begun in 1974 on several National Forests in northern California. Poison Lake is located in northeastern California on the Eagle Lake District of the Lassen National Forest.

The climate of the study area, which is located at an elevation of about 5600 feet (1702 m), is characterized by hot, dry summers and cold, moist winters. Temperatures range from as low as -30 °F to 110 °F (-34 °C to 43 °C) with a mean of 50 °F (10 °C). The growing season is about 120 days. Most precipitation is in the form of snow and averages about 20 inches (508 mm) per year.

The soils in the study area are part of the De Masters/Patio Families. These families consist of moderately deep to deep, well-drained soils formed from weathered rhyolite, basalt, and andesite. The area is relatively flat and uniform in terms of aspect, slope, and vegetation, which is primarily ponderosa pine, with an occasional incense-cedar (*Libocedrus decurrens* Torr.). Conifer age ranges from 70 to 90 years. Understory vegetation is sparse and composed of scattered greenleaf manzanita (*Arctostaphylos patula* Greene) and rabbitbrush (*Chrysothamnus* spp.).

METHODS

This study, begun in summer 1980, includes data recorded annually through the 1987 growing season. The total study length is at least 10 years.

The silvicultural prescription was commercial thinning. Stand characteristics before and after thinning for each thinning treatment and the control were recorded (*table 1*). Stands to be treated were thinned in summer and fall by removing obviously injured, diseased, and slow-growing trees as well as trees of poor form. In general, only the more vigorous dominant and codominant trees were considered as reserve trees. In a few instances, intermediate trees of good growth and form were marked as leave trees to prevent creating large holes in the treated stands. Trees that would not yield a commercial log (at least 8 feet long [244 cm] and 6 inches [15 cm] in diameter inside bark at the small end) were removed, as were trees with mechanical injury and damage from animals. All suppressed, most intermediate, and codominant and dominant trees with symptoms of pest damage were also removed. Healthy dominants and codomi-

Table 1—*Average number of ponderosa pine trees per acre, basal area, and cubic foot volume, before and after thinning, Poison Lake, California, 1987*

Treatments (Pct)	Trees				Basal area			Volume	
	Merch Before/After		Submerch[1] Before/After		Before	After	Normal	Before	After
	No./Acre				*Ft²*			*M ft³/acre*	
40	159	60	609	0	200	80	200	4.0	2.6
55	182	91	435	2	170	100	190	3.3	2.5
70	177	128	535	3	220	140	210	4.5	3.7
Control	171	171	558	558	190	190	200	4.6	4.6

[1]Trees that will not yield a commercial log at least 8 feet long and 6 inches in diameter inside bark at the small end.

nants were removed if necessary to attain the target basal areas. A general rule was that spacing was considered secondary to leaving vigorous crop trees.

The objective of this study was to create treated units thinned to 40, 55, and 70 percent of normal stocking and an unthinned control. Normal stocking indicates complete occupancy of a site by the trees. The normal values for the stands in this study were based on those reported by Meyer (1938). Each of these four treatments, including the control, had three replications.

Leave-tree marking and special logging methods were used to minimize injury to pines. Marking the leave trees results in less damage to the residual stand because the trees to be protected are identified with bands of paint, making them readily visible during the harvesting operation (Aho and others 1983a). Special logging considerations included directional felling, limited size and type of logging equipment, straight-line skid trails, endlining of logs, limited log lengths, and no tree-length logging. All harvested trees were scaled to determine the volume removed. To minimize insect buildup, logging slash was lopped to a 3-inch (8-cm) top and scattered to a maximum height of 18 inches (46 cm) above ground.

To determine the structure of the stands before and after treatment, all trees 1 inch (2.54 cm) in diameter at breast height (d.b.h.) and larger were measured for basal area, cubic foot volume, and crown class. Trees were also classified as merchantable or unmerchantable. Stocking of trees less than 1 inch d.b.h. was estimated from one-fortieth acre (0.01 ha) plots. Sampling intensity was ten randomly selected plots in each replication. One percent of the dominant and codominant trees were measured by dendrometer to determine stand volume, and then remeasured at the end of the fifth growing season to determine growth.

Mortality of all conifers in every replication was recorded annually and classified by d.b.h., crown class, and associated pests.

The experimental design was completely randomized with one-way treatment structure. Confidence intervals for the difference between any two treatments, designated by ($\bar{D} \pm$ w), where $\bar{D}$ equals the difference between treatment means, and w equals the half-width of the confidence interval, were calculated by the Tukey method based on the analysis of variance model (Steel and Torrie 1960). The confidence interval can be used to present the best information on the range of values within which the expected difference is estimated (with 95 percent confidence) to lie. Because information is gathered from permanent plots measured each year, the data are not truly independent. The type I errors given for various tests apply to each measurement and year separately. The overall error rate could increase by as much as the given amount for each measured variable each year.

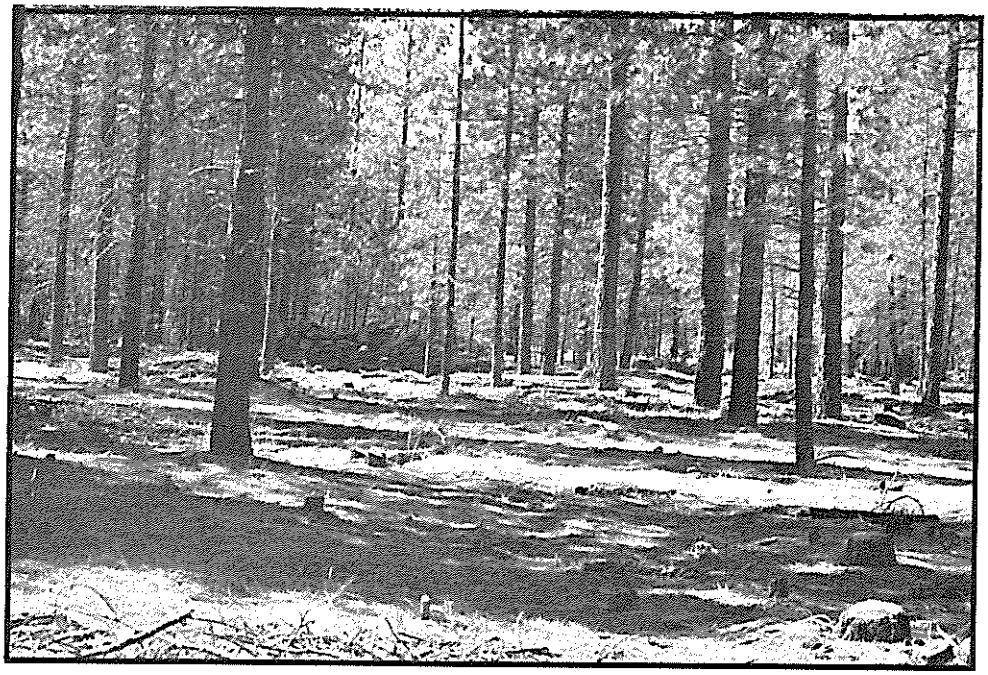
RESULTS

After treatment, the number of reserve trees differed among thinned levels and control *(fig. 1)*, and the amount of tree mortality after thinning was reduced from 86 to 100 percent as compared to the unthinned stands *(table 2)*. Mountain pine beetles and annosus root disease were the most common causes of tree mortality *(fig. 2)*. Most of the trees in the treated areas that died were in the intermediate crown class, of small diameter, and had been unsuccessfully attacked by bark beetles before treatment. As noted earlier, these trees were left because of spacing considerations and to prevent large unstocked holes in the stand. Most of the trees that died were diagnosed as having annosus root disease that was undetected before thinning.

Before treatment, analysis of variance indicated no significant difference in tree mortality ($p>0.05$). After treatment the thinned areas differed significantly in mortality ($p<0.01$) from the control regardless of thinning level *(table 3)*. No indication of a significant difference in tree mortality among thinning levels was found ($p>0.05$).

A factor that can cause pest-induced mortality to trees is injury from the thinning operation. The mortality and loss of tree volume that result from decay initiated by mechanical injuries during stand management activities can be substantial (Aho and others 1983b), particularly in the spring when the bark is easily dislodged. This was not the case at Poison Lake, however, as these losses were minimized through the use of improved logging methods.

Growth in the treated areas over the 5-year measurement period ranged from 54 ft^3 to 102 ft^3 per acre (4 m^3 to 7 m^3/ha) per year *(table 4)*. Growth in the control was only 16 ft^3 per acre (1 m^3/ha) per year. The thinning level that produced the most growth, an increase of 638 percent of control, was 70 percent of normal. The level that produced the least growth was 55 percent of normal (338 percent of control). The 40 percent level produced an intermediate amount of growth (475 percent). Taken together, growth of thinned stands increased an average of 500 percent over that in the control. Such a response was not expected. Thinned stands of this age usually do not show an increase in growth—maintenance of current growth is the norm.



A

B

Figure 1—Treatment levels at Poison Lake, Lassen National Forest, immediately after thinning in 1980: (A) 40 percent of normal basal area, (B) 55 percent of normal basal area, (C) 70 percent of normal basal area, and (D) untreated control.

Figure 1, continued

C

D

Table 2—*Commercial ponderosa pine mortality, Poison Lake, California, 1980-1987, by normal basal area*

Normal basal area	Tree mortality		
(Pct)	Average	Reduction	Range
	(No./acre/yr)	*(Pct)*	*(No./acre/yr)*
40	0	100.0	0
55	0.1	95.2	0-0.5
70	0.3	85.7	0-0.8
Control	2.1	—	0.6-4.1

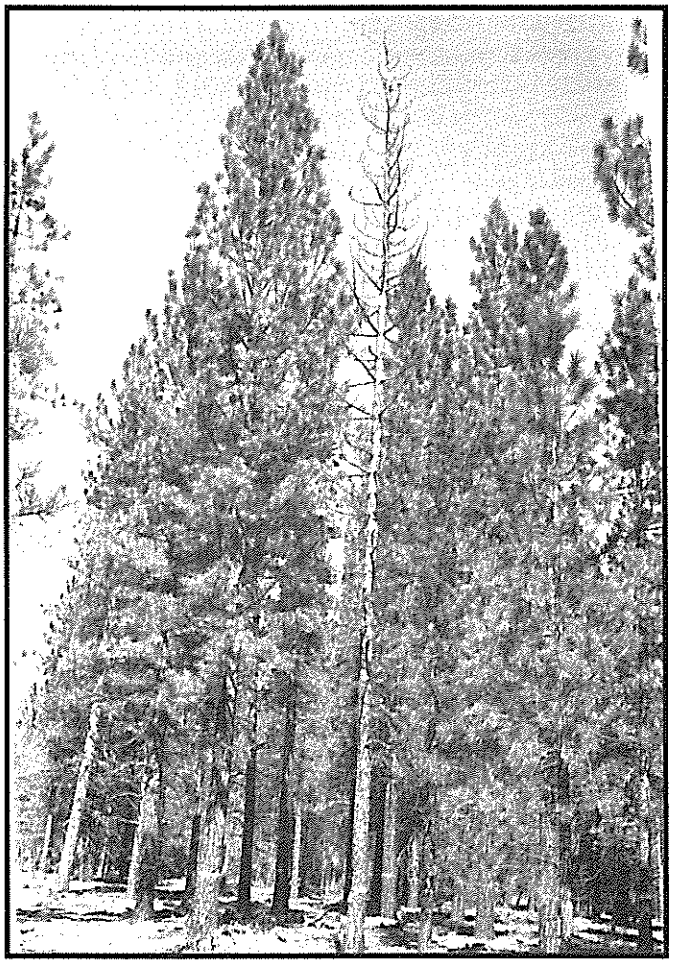


Figure 2—A dead reserve tree in the 55 percent level killed by annosus root rot and bark beetles, Poison Lake, Lassen National Forest, California.

Table 3—*Treatment means and differences between treatments for tree mortality, Poison Lake, California, 1987*

Treatments compared[1] *(Pct)*	Tree mortality	
	Treatment means compared	$\bar{D} \pm w^2$
	No. of trees/acre	*No. of trees/acre*
Control 40	2.1 0.0	2.1 1.1
Control 55	2.1 0.2	1.9 1.1
Control 70	2.1 0.3	1.8 1.1
55 40	0.2 0.0	0.2 1.1
70 40	0.3 0.0	0.3 1.1
70 55	0.3 0.2	0.1 1.1

[1]Percent values refer to percent of normal basal area.

[2]Difference between means plus or minus half-width of the confidence interval.

Table 4—*Growth of ponderosa pine, Poison Lake, California, 1980-1985*

Normal basal area *(Pct)*	Volume	Change relative to Control
	(Ft^3/acre/yr)	*(Pct)*
40	76	475
55	54	338
70	102	638
Control	16	—

DISCUSSION

Thinning significantly reduced ponderosa pine mortality in comparison to unthinned controls in a 70- to 90-year-old stand of eastside pine. Unthinned plots lost more than 2 commercial trees per acre (5/ha) per year. Thinned plots lost only 0.1 to 0.3 tree per acre (0.3 to 0.7/ha) per year. These trees were of the intermediate crown class. After they died, most were diagnosed as having annosus root disease. No tree mortality occurred at stand basal areas of less than 95 ft^2 (9 m^2) (a value that is slightly less than 55 percent of normal) per acre. This value agrees well with that from an earlier study by Oliver (1979) who showed that the optimum stocking level was about 110 ft^2 per acre (11 m^2), implying that mortality below this level of stocking was minimal.

The three levels of thinning tested in this study reduced mortality and affected growth of the ponderosa pines. Thinning the stand to 40 percent of normal resulted in no mortality, but harvesting some of the thrifty dominant and codominant trees in order to reach the desired basal area level probably caused this level to be intermediate in growth response. Stands cut to the 70 percent level experienced some mortality, which seemed to be a consequence of having to leave less-thrifty trees as crop trees in order to reach the required stocking level. No thrifty trees were removed in the stands left at the 70 percent level, and this full complement of rapidly growing trees contributed to volume growth—the reason for highest growth performance at this level. The 55 percent level experienced less mortality than the 70 percent level and more mortality than the 40 percent level, and ranked intermediate in volume growth.

Although overall tree mortality in the treated stands was low, a pattern between cause and timing was evident: If the causal agent was bark beetles, the trees died within 2 years of logging; if root disease followed by bark beetle attack was the cause, the trees died several years later.

Because of the low incidence of annosus root rot before thinning, no preventative measures were applied in thinned stands in this study. A manager contemplating thinning in stands in which this disease is prevalent should consider using borax as a means of preventing new infections.

Thinning not only reduces stand mortality and increases growth, but it also yields a positive return to the landowner. Timber sale budget data from the USDA Forest Service Pacific Southwest Region show that the average bid price for pine of this size and form class is $22 per cunit (1 cunit = 100 cubic feet or 3 m^3). Timber management costs for sale layout and administration are $11 per cunit. Consequently, net revenues realized from thinning stands similar to those in this study amount to $11 per cunit. Data from these plots indicate that a typical acre of well-stocked eastside pine thinned to 55 percent of normal basal area will yield 800 ft^3 (56 m^3/ha) (*fig. 3*). Fifty-five percent was selected for two reasons: (1) It is a thinning standard recommended for eastside pine by the Forest Service in California, and (2) it provides a conservative estimate of the gain from thinning. Multiplying 8 cunits times $11 equals $88 per acre ($217/ha)—the net yield per acre from thinning.

That average growth of thinned stands, 70 to 90 years old, was 500 percent of growth in the control has strong implications for managers. It could mean that the manager can apply an additional thinning which would increase the total yield of the stand

Figure 3—Yield of 800 cubic feet from one acre cut to 55 percent of normal basal area, Poison Lake, Lassen National Forest, California.

during the rotation. When applied to the tens of thousands of acres of stands of this age in California, the increase in yield could be substantial.

CONCLUSIONS

Results from this study provide land managers with three management options. They can thin to the 40 percent level and end up with fewer but larger trees at rotation age, thin to the 70 percent level and have more but smaller trees, or select the 55 percent level and have an intermediate number of trees and tree sizes. A variety of tree sizes provides a wider range of markets which often leads to higher realized prices. Regardless of the thinning level selected, mortality will be reduced significantly over the untreated stand.

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