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Early Lessons From Commercial Thinning in a 30-Year-Old Sitka Spruce-Western Hemlock Forest

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Abstract

A commercial thinning study was undertaken in a 30-year-old stand, precommercially thinned at 15 years of age, at Cascade Head Experimental Forest on the Oregon coast. Measurements obtained after three different thinning treatments are presented and include stand volume, basal area, current growth rate, scar damage, crown ratio, and sapwood radius. Method of establishing plots is given, and stand conditions before and after thinning are described.

Keywords: Thinning effects, commercial thinning, Sitka spruce, western hemlock, Oregon (Cascade Head Exp. For.), Cascade Head Exp. For.—Oregon.

Introduction

The Sitka spruce *(Picea sitchensis* (Bong.) Carr.) zone is a narrow strip stretching from Prince William Sound, Alaska, to as far south as Coos Bay, Oregon (fig. 1). In most areas in Oregon, the zone is no more than 1-2 miles wide, except where it extends inland along river valleys (Franklin and Dyrness 1973). The Sitka spruce zone is one of the most productive forest zones in the world (Fujimori and others 1976). Mature coniferous forest stands are dense and tall and are dominated by Sitka spruce, western hemlock *(Tsuga heterophylla* (Raf.) Sarg.), and Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco), with lush understories of ferns, herbs, shrubs, and cryptogams. Red alder *(Alnus rubra* Bong.) is abundant on disturbed sites and in riparian zones.^

Climate in this zone is wet and mild. Precipitation, averaging 100 in per year, occurs primarily during the winter months. There is no pronounced summer drought, and summer fog is common.

Soils in this zone are deep, relatively rich, and fine textured. Inceptisols and ultisols are the most common soils (Ruth and Harris 1979). The surface layers of the soil are high in organic matter and total nitrogen and low in base saturation.

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[1/] Scientific names follow Garrison and others (1976)

Much of the Sitka spruce zone along the Oregon coast has been burned or clearcut in the last 100 years. Many acres of naturally regenerated stands of western hemlock and Sitka spruce are found on USDA Forest Service, on Bureau of Land Management (U.S. Department of the Interior), and on private industrial lands. Though most clearcuts are now planted, natural regeneration is so successful that many stands are overstocked. Young stands with over 1,000 trees per acre are common.

Precommercial thinning of stands is a prevalent practice. Most stands are scheduled for precommercial thinning when they are 10 to 15 years old. Residual stocking of 200 to 300 trees per acre is common. At these densities, commercial size—10 to 12 in in diameter at breast height (d.b.h.)—is reached at 25 to 30 years. Under conventional (conservative) thinning methods, the first commercial entry is not particularly profitable because of either the small volume removed or the expense of cable logging systems on steep slopes.

In the Hebo and Waldport Districts of the Siuslaw National Forest, about 2,000 acres of stands enter the 25-year age class annually. Many of these stands are dominated by western hemlock, now recognized as the number two timber-producing species in Oregon and Washington. Few of these precommercially thinned stands have been commercially thinned.

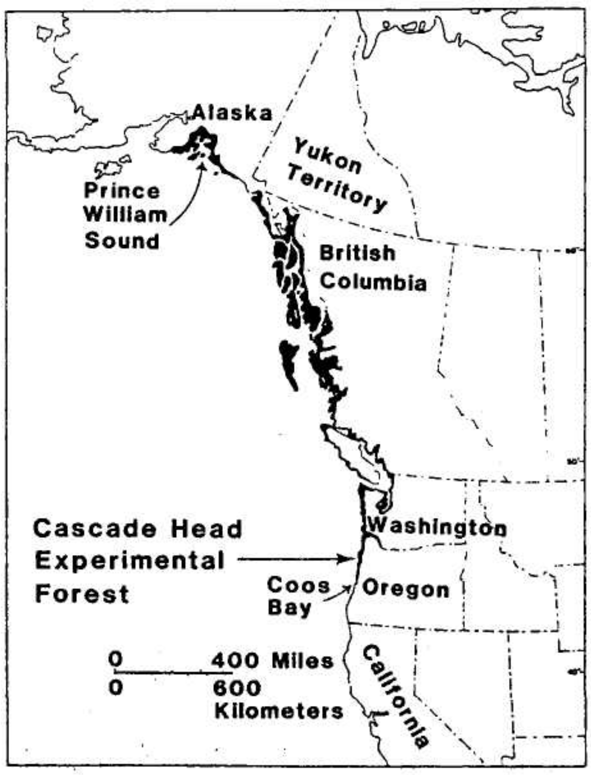

Figure 1 .—Sitka spruce zone along the Pacific coast and location of Cascade Head Experimental Forest along the northern Oregon coast.

Trees in stands that reach harvestable size without thinning are more variable than trees in stands that have been thinned. Though basal area and cubic volume may be greater in unthinned stands, board-foot volumes are larger in thinned stands. Precommercial and commercial thinning can provide an early return on capital invested in growing stock, while growth is concentrated on fewer trees.

Little research has been done to determine the best spacings for different management objectives for these precommercially thinned western hemlock-Sitka spruce stands. Questions that should be answered are:

1. How intensively can these stands be managed?
2. What will the yields be under various treatments?
3. What level of damage to trees is acceptable under different levels of intensive management?
4. What kinds of logging systems are most economical and best adapted to these types of stands?

A long-term study has been established at the Cascade Head Experimental Forest, Siuslaw National Forest, north of Lincoln City (fig. 1) to focus on commercial thinning treatments and logging systems for these stands. The purpose of this report is to discuss the commercial thinning portion of the study. Intensive studies on logging cost and on the specific causes of damage (Kellogg and Hargrave in press) were initiated by the Forest Engineering Department, College of Forestry, Oregon State University, Corvallis, and are not discussed here.

The three objectives of this study are:

1. To determine the effects of three different commercial thinning treatments on diameter and height growth.
2. To determine the amount of damage and subsequent decay to the leave trees following logging.
3. To determine the relationship between leaf area and volume production by observing development in the three different treatments and in the control.

Information generated from this study will be used to determine the efficacy of different thinning regimes, spacings, and number of thinnings during rotation; the information may be appropriate for economic analysis. Initial stand descriptions and stand conditions after thinning are reported here.

Methods

Two 30-year-old stands were selected for the study at Cascade Head Experimental Forest. Each stand was part of a naturally regenerated clearcut (units 1A and 1C) that was precommercially thinned to an average spacing of about 13 ft at age 15. The stands were divided into sixteen 3- to 5-acre compartments that could be logged independently (fig. 2). Unit 1A contained compartments 1 to 12, and unit 1C contained compartments 13 to 16. Compartments in unit 1A were set out by contiguity and similarity of topographic surface. Compartments 1 to 4 were on a north slope, 5 to 8 on west and southwest slopes, and 9 to 12 on gentle to level slopes. Compartments in unit 1C were established in the same block, two on south-facing and two on north-facing slopes.

The experiment involved three treatments and a control, each with four replicates:

1. Narrow spacing, 18- by 18-ft target.
2. Wide spacing, 24- by 24-ft target.
3. Herringbone strip (see fig. 3).
4. Control (no thinning).

The narrow- and wide-spacing compartments were marked with the idea of removing thinned material by cable logging. Cleared corridors were arranged in a herringbone pattern in the third thinning treatment (see fig. 3A). Corridors were 15 ft wide, leave strips 30 ft wide. Cable removal of thinned material occurred here as well.

The narrow- and strip-thinning treatments were designed to yield adequate volumes for a profitable thinning operation and to leave sufficient trees for a second commercial thinning. The wide spacing was intended to leave only enough trees for a final removal of larger saw logs.

Before the thinning, one permanent sample plot was established in each compartment. A circular plot with a radius of 83 ft and an area of 0.5 acre was laid out in the geometric center of each compartment. A 25- to 30-ft buffer was maintained around the circumference of each plot. Plots were permanently marked in the field.

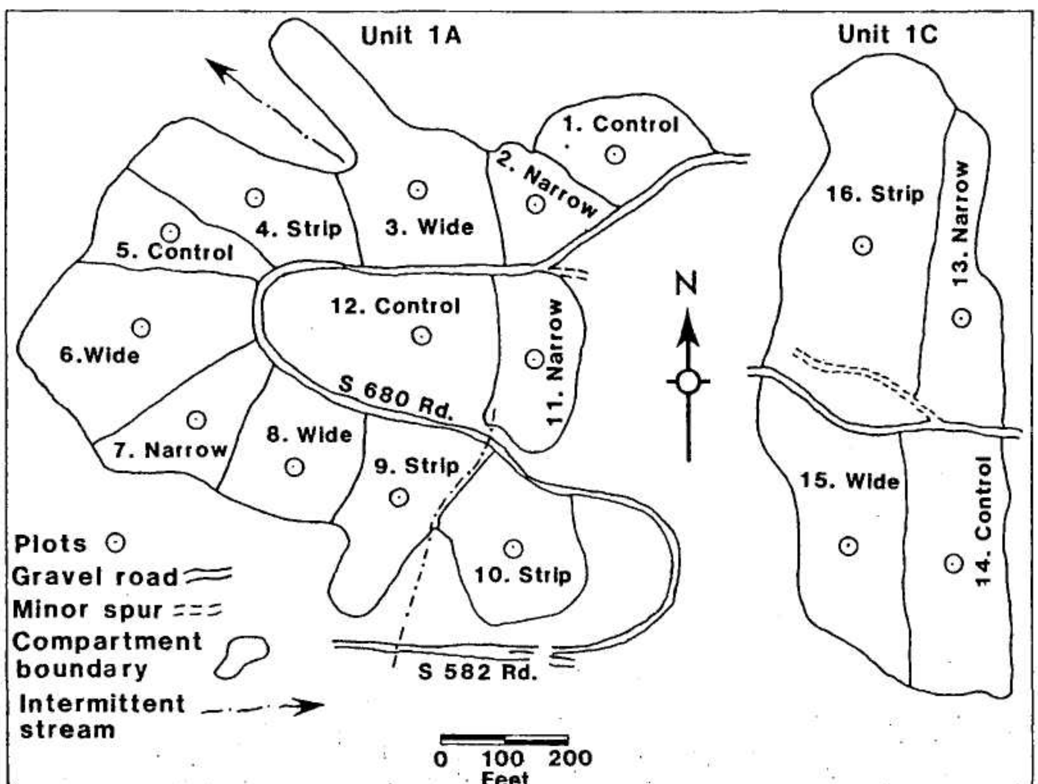

Figure 2.—Compartments, treatments, and plots for commercial thinning, Cascade Head Experimental Forest.

Prior to logging in all plots, trees with diameters 2 in or greater at breast height were tagged and measured for diameter at breast height. Crown class and scar condition (location, length, width, and height) were recorded for each tree.

Sapwood basal area and sapwood radial growth increments for 5 and 10 years were taken on 10 percent of the trees. Two cores were taken from the sample trees at right angles at breast height. The sapwood thickness was measured in the field for most samples. A few were brought in and stained with Bromcresol Green to increase confidence in the field determination. The mean of the two sapwood measurements was entered as the value for that tree. Sapwood basal area was determined because it is highly correlated to leaf area (Grier and Waring 1974).

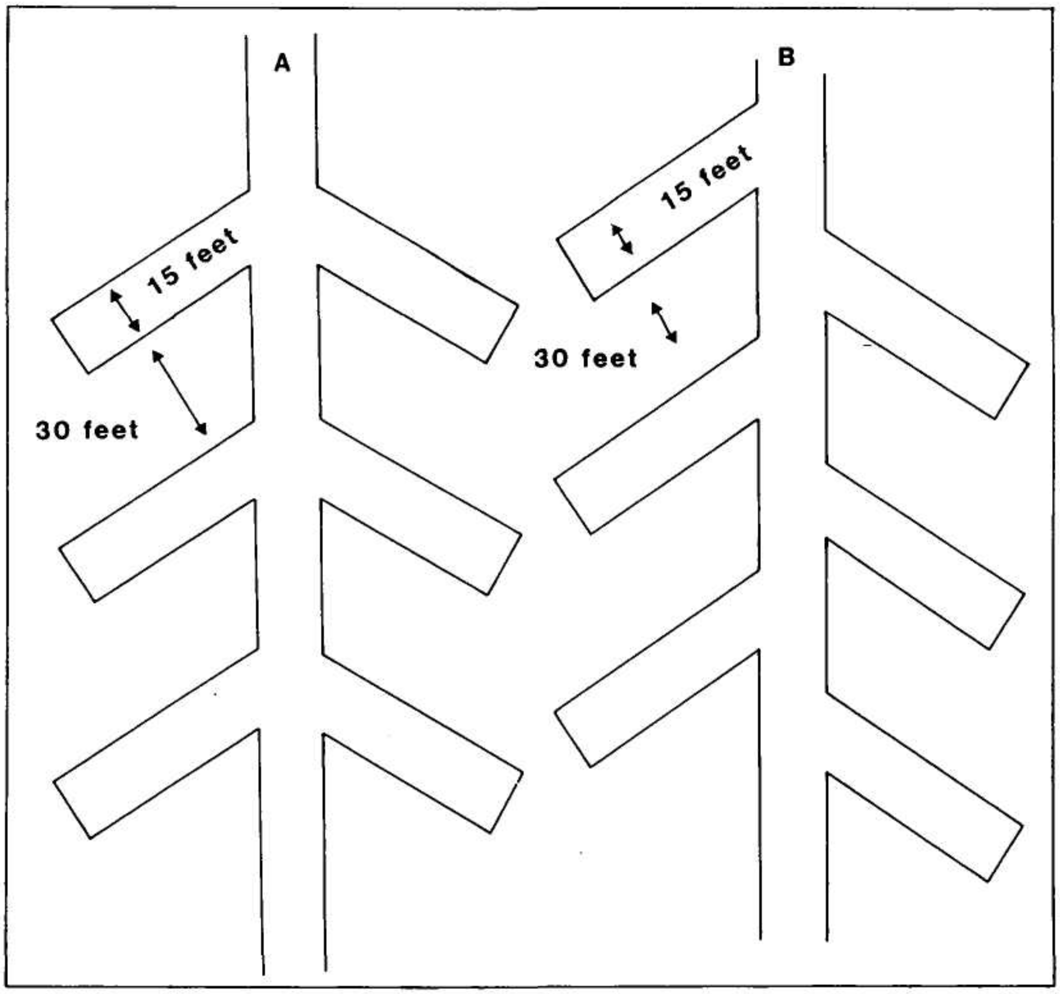

Figure 3.—The herringbone thinning was laid out in the pattern shown in A with the side corridors in opposite positions. A bet ter arrangement would have the side corridors in alternating positions, as in B.

Crown length on the same 10-percent sample was estimated visually as a percentage of total height of the tree. Heights taken for the 10-percent sample were used to access tarif tables (Hoyer 1966, Turnbull and others 1980). The tarif equations derived were used later to estimate tree volumes. Average heights by crown class for western hemlock, Douglas-fir, and Sitka spruce are shown in table 1.

Vegetation data were gathered for each plot. Visual estimates of percentage of cover for shrubs, herbs, and mosses were taken. Visual estimates were also made for downed wood in two categories—that greater than 4 in in diameter and that less than 4 in in diameter.

After logging, each plot was revisited. All remaining trees were tallied on the data sheets. New scars were measured for location, length, width, and height. Control plots were not revisited. Plots will be remeasured every 5 years.

Volume growth was computed for the stand based on the measurement of 5- and 10-year diameter increments. To estimate growth for the two 5-year and the 10-year periods, regression equations were developed to predict average radial increment by diameter class. The relationship had the form: DIAMETER INCREMENT = a + b (d.b.h.). Then a 5- and i 0-year increment was assigned to each tree on all the plots. The diameter of each tree at ages 20 and 25 years was then estimated from the diameter at breast height measured at age 30 and the growth estimates. The cubic- and board-foot volumes were computed using tarif tables (Hoyer 1966).

Data were entered into the Department of Forest Science Data Bank, Oregon State University, Corvallis. Documentation and data are available to those interested with permission of the authors. Statistical analysis was carried out using SPSS (Nie and others 1975) and SAS (SAS Institute, Inc., 1982).

Table 1—Average height of trees by species and crown class 1y

Species	Average height by crown class			
	Dominant	Codominant	Intermediate	Suppressed
	Feet			
Western hemlock	2/ 73.3 (97)	69.8 (32)	50.2 (13)	40.0 (4)
Sitka spruce	70.5 (6)	54.7 (11)	47.3 (31)	40.3 (11)
Douglas-fir	68.7 (7)	67.6 (3)	57.3 (1)	

1/ Because the samples were taken systematically (every 10th tree), the numbers of trees sampled in each class are proportional to their abundance in the stand.

2/ Number of sample trees is in parentheses.

Results

The stand conditions before and after thinning by treatment, species, and crown class are described in table 2. An analysis of variance was run on number of trees, diameter at breast height, basal area, and volume by treatment for the original stand condition, and no significant differences were detected. We therefore feel that the 16 plots encompassed most of the variation within the stands and that selection of treatments was not biased.

Table 2—Stand description, by treatment, species, and crown class, before and after thinning

	Trees/acre		Diameter at breast height		Basal area		Volume (to 6-inch top)/acre			
	Before	After	Before	After	Before	After	Before	After	Before	After
	Number		Inches		Square feet/acre		Cubic feet		Board feet Scribner	
Treatment:										
Control	254	254	11.3	11.3	195.6	195.6	5,320.9	5,320.9	24,852.2	24,852.2
Narrow	274	108	11.4	12.3	212.0	99.5	5,733.3	2,806.8	26,696.6	13,374.3
Strip	273	143	11.7	11.8	216.6	114.6	5,875.3	3,155.2	27,315.2	14,689.8
Wide	270	60	11.5	12.6	206.6	55.4	5,720.2	1,609.7	26,391.0	7,663.6
Species: 1/										
Western hemlock	181	96	12.2	12.8	153.8	86.7	4,422.4	2,522.2	20,760.5	11,962.7
Sitka spruce	64	33	9.4	9.8	37.4	19.5	866.8	454.5	3,768.6	1,993.1
Douglas-fir	12	8	14.4	15.7	12.9	8.4	373.2	246.4	1,784.6	1,189.1
Red alder	11	6	10.0	7.7	3.6	1.7	--	--	--	--
Crown class:										
Dominant	135	80	13.9	14.2	143.0	88.7	4,264.3	2,641.1	20,331.6	12,652.8
Codominant	59	24	10.6	10.8	38.7	15.6	949.7	390.0	4,148.5	1,701.9
Intermediate	46	21	8.5	8.1	19.8	8.3	369.4	140.7	1,512.5	575.8
Suppressed	28	16	5.7	6.1	6.2	3.7	79.1	51.3	321.1	214.5

– d no data available.
1/ Species and crown class categories do not Include data from control plots.

Diameters

Average diameter at breast height among the four major species did differ (table 2). All were significantly different (p > 0.05)-?/ except Sitka spruce and red alder. It was not surprising that average diameter at breast height was largest for Douglas-fir (14.4 in), but it was surprising that the average diameter at breast height for Sitka spruce (9.4 in) was smaller than that for western hemlock (12.2 in). There are several possible explanations. First, western hemlock has a larger average sapwood radius and a larger average crown ratio; this indicates western hemlock has greater leaf area than Sitka spruce does. A larger photosynthetic surface would normally grow a bigger tree. Another explanation could be related to the spruce weevil *(Pissodes strobi),* which has been evident in the area for a number of years. Weevils kill the leader, which results in trees with forked tops. Of the 118 trees with forked tops, 83 percent were Sitka spruce. Recovery from weevil attack takes time, and height of the tree is reduced. These factors could force spruce into a suppressed crown position.

Average stand diameters were similar to those for industrial and Federal stands at age 30 to 35 for commercial thinning. As would be expected, diameters at breast height by crown class were significantly different with a range from 5.7 to 13.9 in. Similar average diameters at breast height after thinning indicated trees of all diameter classes were removed in proportion to their abundance in the stand.

[2/] Unless otherwise noted, all significances are at the $p < 0.05$ level.

Basal Area

Average basal areas per acre after thinning for the narrow (99.4 ft^2) and strip (114.6 ft^2) treatments were similar and both were significantly different from the wide (55.4 ft^2) treatment. The average number of trees per acre remaining on the thinned plots (60 to 143 trees per acre) indicated a relatively heavy thinning. Examination of the density management diagram of Flewelling and others (1980) showed that the narrow thinning produced a stand that is at crown closure line. The wide treatment created a stand considerably below the crown closure line. If the trees were evenly spaced in the strip thinning, the stand would be near 0.3 relative density, which is thought to be ideal postthinning spacing.

Volume

Volumes for the stands before thinning (about 5,700 ft^3/acre to a 6-in top) were higher than those published in standard volume tables (Barnes 1962). Barnes reports volumes of 4,050 ft^2/acre at site index 180 for 30-year-old western hemlock with trees over 6.5 in d.b.h. The yields for our stands clearly exceeded this at age 30 (table 2).

Volumes left in the narrow and strip treatments were 50 percent and 46 percent of original volumes, respectively, with no significant differences between the two. In the wide treatment, 29 percent of the volume remained. Kellogg and Hargrave (in press), in an independent estimate, report that 34 percent of the volume remained. Though the thinning was profitable, fewer trees were left than were marked in the narrow and wide treatments because of removal of heavily damaged leave trees. Both treatments should have relatively long growth periods before the stand closes and growth slows. The narrow treatment with 108 trees per acre could be commercially thinned again to produce a widely spaced stand capable of growing to old-growth proportions.

Periodic annual increments (PAI) for all species combined (by plot) decreased after age 25 (table 3). The decrease in growth between ages 20 to 25 and 25 to 30 was 102 ft^3/acre per year and 602.8 board feet per acre per year. Mean annual increment (MAI) calculated for age 30 was 188.7 ft^3/acre per year (table 3). Thus, PAI had clearly peaked and was declining rapidly.

Sapwood Radius and Increment Growth

Five- and 10-year increment growths and sapwood radii are given in table 4. There were significant differences in 5- and 10-year increment growths (number of inches grown per year) between species and crown class, but not between treatments. Sitka spruce had the largest decline, possibly the result of weevil attacks and loss of dominant crown position. The slowdown in radial growth rate indicated thinning was timely.

Sapwood radii (table 4) were significantly different among species. Measurements indicated that western hemlock, a more tolerant species than the others, had more leaf area, which resulted in better growth. Sapwood radii in intermediate and sup pressed crown classes were similar. Sapwood radii for the treatments were all similar.

Table 3—Periodic annual increment (PAI) at 5- and 10-year intervals and mean annual increment (MAI) at age 30 for all species combined

Age intervals	Volume (to 6-inch top) per acre per year	
Years	Cubic feet	Board feet Scribner
PAI:		
20-25	387.6	1,926.8
25-30	285.6	1,324.0
20-30	322.8	1,640.0
MAI:		
30	188.7	877.1

Table 4—Radial increment growth per year, by treatment, species, and crown class, for the last 5 and 10 years, sapwood radius, and crown ratio before thinning[1/]

	5-year average	10-year average	Sapwood radius	Crown ratio
	- - - - - - -	Inches	- - - - - - -	Percent
Treatment:				
Control	0.14[a]	0.18[a]	2.9[a]	41[a]
Narrow	.12[a]	.18[a]	2.7[a]	32[a]
Strip	.12[a]	.16[a]	2.8[a]	33[a]
Wide	.12[a]	.18[a]	2.8[a]	38[a]
Species:				
Western hemlock	.07[a]	.20[a]	3.5[a]	39[a]
Sitka spruce	.05[a,b]	.16[a,b]	1.5[b]	26[b]
Douglas-fir	.04[b]	.12[b]	1.7[b]	37[a]
Crown class:				
Dominant	.07[a]	.20[a]	3.5[a]	42[a]
Codominant	.05[b]	.16[b]	2.6[b]	32[b]
Intermediate	.04[b]	.14[b]	1.9[c]	29[b]
Suppressed	.05[b]	.12[b]	1.5[c]	18[c]

1/ Variables followed by the same letter are not significantly different, $p < 0.05$.

Crown Ratios

Average crown ratios for treatments before and after thinning were not significantly different (table 4). Before thinning, both western hemlock and Douglas-fir had significantly larger crown ratios than did Sitka spruce. After thinning, only western hemlock and Sitka spruce were different. Crown ratios for crown classes were all significantly different before thinning.

Relation Between Sapwood Basal Area, Crown Ratio, and 5- and 10-Year Increments

Five- and 10-year increments for hemlock were not highly correlated to crown ratio alone. Multiple correlation coefficients at the 0.1 significance level rose from 0.19 to 0.40 when correlations were computed between increment growth and the. combination of crown ratio and diameter at breast height. The correlation between increment growth and sapwood basal area was similar (0.42). On the other hand, sapwood basal area of hemlock was very well correlated with diameter at breast height (0.84) and diameter at breast height squared (0.88).

No significant correlations were found between sapwood basal area and crown ratio by species. The range of correlations was 0.33 to 0.57 for before and after thinning. Both small- and large-diameter trees had large crown ratios. The poor correlation probably resulted from including patches where small but open-grown trees had large crowns.

Scar Information

Before thinning, the number of scars per acre by treatment, species, and crown class was nominal (tables 5 and 6). Of the 2,154 trees sampled in the original stand, only 1.1 percent had scars. After thinning, 16 percent of the remaining 1,161 trees sustained scar damage (including controls). Excluding controls, scars per acre divided by trees per acre yielded higher percentages for the narrow (62 percent) and wide (81 percent) treatments than for the strip (16 percent) treatment.

All species of trees were scarred. Mean scar area per scarred tree, though extremely variable, was greater in the thin-barked spruce and hemlock than in the thick-barked Douglas-fir. Correlations of scar area, number of scars, and diameter at breast height showed no relation for any of the species.

Table 5—Scars per acre and scarred area per scarred tree, by treatment, species, and crown class, and percent of total number of scarred trees by treatment^

	Scars/acre		Scarred area/scarred tree	
	Before	After	Before	After
	- - - Number - - - -		Square inches	
Treatment:				
Control	5 (1.7)	5 (1.7)	32.87	32.87
Narrow	1 (.5)	67 (50)	26.66	254.60
Strip	5 (1.7)	23 (13)	109.32	193.61
Wide	2 (.3)	49 (39)	47.38	264.12
Species:				
Western hemlock	2	25	145.36	242.27
Sitka spruce	1	7	136.22	256.82
Douglas-fir	<1	2	46.50	71.91
Crown class:				
Dominant	1	24	58.97	224.8
Codominant	<1	5	43.51	315.13
Intermediate	1	4	105.69	220.02
Suppressed	1	2	14.43	80.46

[1/] Percentage of total trees scarred is in parentheses.

Table 6—Percentage of total number of trees scarred, by crown class,

Crown class	Western hemlock		Sitka spruce		Douglas-fir	
	Before	After	Before	After	Before	After
			Percent			
Dominant	0.6	27.8	0	28.0	1.9	16.8
Codominant	.8	20.0	0	26.0	0	12.5
Intermediate	1.0	10.4	1.7	24.6	--	--
Suppressed	4.5	10.7	0	11.1	--	--

	Treatment							
	Control		Narrow		Strip		Wide	
	Before	After	Before	After	Before	After	Before	After
				Percent				
Dominant	1.3	1.3	0	43.0	0.8	15.0	0	52.0
Codominant	0	0	0	41.0	.5	11.0	1.4	43.0
Intermediate	1.0	1.0	1.1	33.0	5.1	12.1	.7	55.0
Suppressed	5.5	5.5	1.5	25.0	.8	8.5	0	13.0

— = no trees in these crown classes.

Discussion

Data from individual treatments indicated which treatments should produce the best growth for the amount of money invested. Strip thinning was the cheapest treatment overall (Kellogg and Hargrave in press) and resulted in fewer scars. Trees were not spaced uniformly, however. Some trees were exposed on two or more sides, while others were not released at all. Studies on strip-thinned Douglas-fir (McCreary and Perry 1983) indicated that trees more than 10 ft from an open corridor respond poorly to the thinning. The same tests will be made for western hemlock. Because the trees were in strips, it was difficult to compare den sity to the other two treatments.

The Siuslaw National Forest does not have strict commercial thinning standards; rather, they differ according to site characteristics. On the average, though, the Hebo and Waldport Districts commercially thin to an 18- by 18-ft spacing, leaving trees that average 12 in d.b.h. This is similar to our treatments where the average diameter at breast height was near 12 in. The Siuslaw National Forest typically tries to remove about 40 percent of the total basal area. All treatments in this study removed more than that—54, 48, and 74 percent for the narrow, strip, and wide treatments, respectively. Basal area removed for western hemlock was 44 percent, for Douglas-fir 40 percent, and for Sitka spruce 49 percent. As mentioned, the wide treatment left very few trees per acre. This may make the stands less resistant to wind throw, a serious problem on the Oregon coast. Barring any significant wind damage, a wide spacing may result in longer periods of growth between commercial thinnings.

Using the density management diagram for site class 2 western hemlock from Flewelling and others (1980) shows that trees could grow to ah average diameter of about 21 in in the narrow treatment and 26 in in the wide treatment before mortality from competition would occur. Predictions of this sort are impossible to make for the strip thinning because of the variability in spacing between leave trees.

Few data have been gathered on scar damage in commercially thinned stands **before** and after thinning. Most of the literature on decay resulting from logging scars is about stands that are more than 75 years old. Most of the literature is in general agreement that decay from scars may reduce growth, reduce volume, lower the quality of the stand, and sometimes even result in mortality. The size and locale of the logging scars affect the amount of decay. The higher up on the tree that scars occur, the lower is the incidence of infection. Depth of the scar is also important (Parker and Johnson 1960, Shea 1961, Wallis and Morrison 1975, Wallis and others 1971, Wright and Isaac 1956). This study is one of the first to look at scar damage before and after thinning on young stands.

In the future, crown ratio and sapwood basal area will be compared to scar damage and recovery to see if leaf area can affect a tree's ability to sustain injury. The data from the plots in this study will complement studies by the Forest Engineering Department, Oregon State University, Corvallis (Kellogg and Hargrave in press). This work involved a detailed study of logging costs and degree of scar damage.

The herringbone treatment could have yielded better results if an alternate system had been used. Large gaps were created at the intersection of two corridors with the skyline (fig. 3A). These gaps could have been reduced if the intersections of the corridors had alternated along the skyline (fig. 3B).

Plots will be monitored in the future. A detailed examination of scar damage and resultant decay will be carried out in 1993, 10 years after treatment. Remeasurement at 5-year intervals will give valuable information on growth and yield of coastal forest stands with different thinning treatments. The responses of different species and crown classes will be checked.

Acknowledgments

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Metric Equivalents

1 acre = 2.47 hectares
1 inch (in) = 2.5 centimeters
1 square inch (in^2) = 6.25 square centimeters
1 foot (ft) = 0.3 meter
1 square foot (ft^2) = 0.09 square meter
1 cubic foot (ft^3) = 0.27 cubic meter

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