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Levels-of-Growing-Stock Cooperative Study in Douglas-Fir: Report No. 14–Stampede Creek: 30-Year Results

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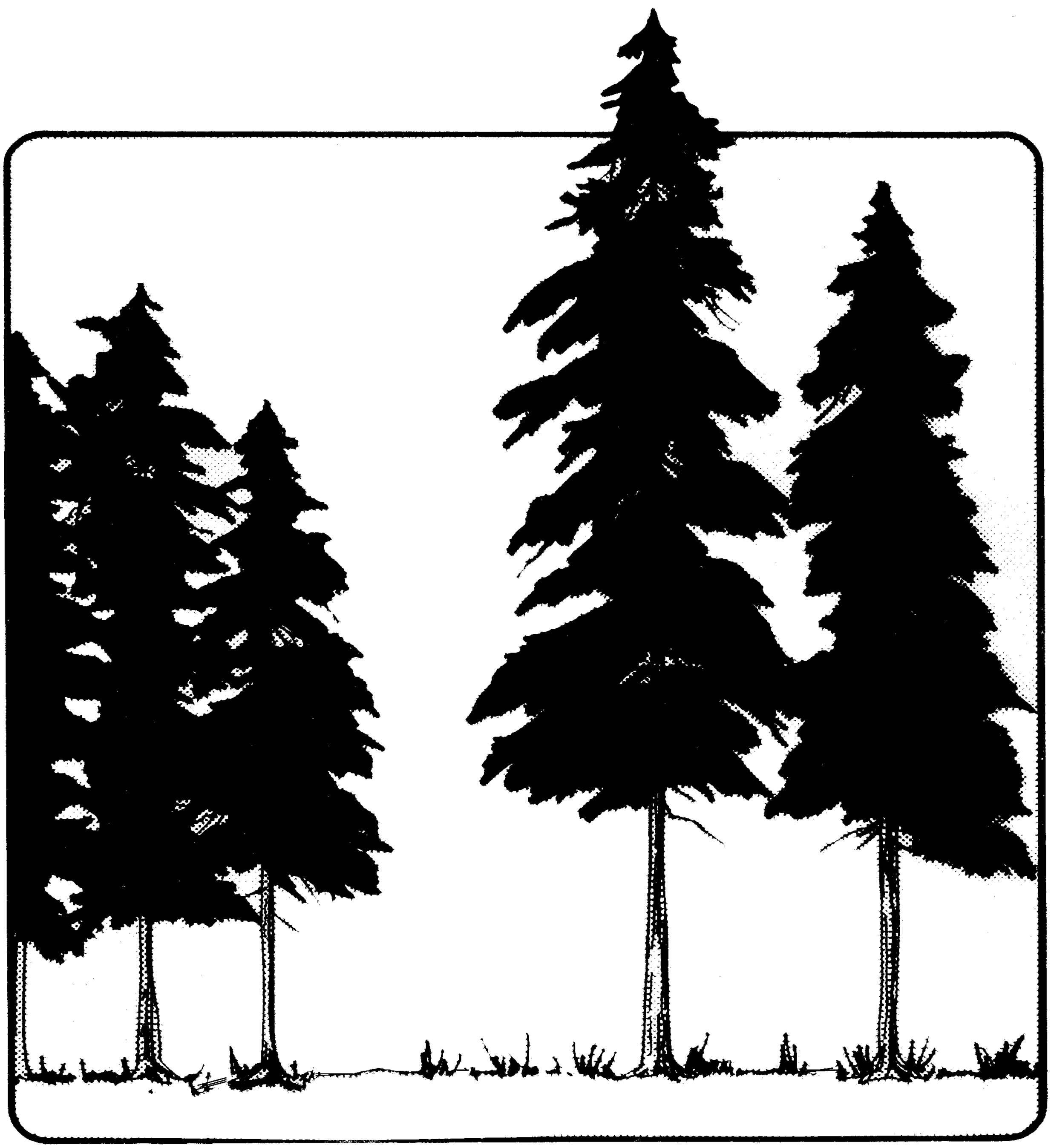

Levels-of-growing-stock cooperative study treatment schedule, showing percentage of gross basal area increment of control plot retained in growing stock.

	Treatment							
Thinning	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
				Percent				
First	10	10	30	30	50	50	70	70
Second	10	20	30	40	50	40	70	60
Third	10	30	30	50	50	30	70	50
Fourth	10	40	30	60	50	20	70	40
Fifth	10	50	30	70	50	10	70	30

Background

Public and private agencies are cooperating in a study of eight thinning regimes in young Douglas-fir stands. Regimes differ in the amount of basal area allowed to accrue in growing stock at each successive thinning. All regimes started with a common level of growing stock established by a conditioning thinning.

Thinning interval is controlled by height growth of crop trees, and a single type of thinning is prescribed.

Nine study areas, each involving three completely random replications of each thinning regime and an unthinned control, have been established in western Oregon and Washington, U.S.A., and Vancouver Island, British Columbia, Canada. Site quality of these areas ranges from I to IV.

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Abstract

Curtis, Robert O.; Marshall, **David D. 2002**. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 14—Stampede Creek: 30-year results. Res. Pap. PNW-RP-543. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 77 p.

Results of the Stampede Creek installation of the levels-of-growing-stock (LOGS) study in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) are summarized. To age 63 (planned completion of 60 feet of height growth), volume growth on the site III natural stand has been strongly related to level of growing stock, but basal area growth-growing stock relations were considerably weaker. Marked differences in tree size distributions have resulted from thinning. Periodic annual volume increments at age 63 are two to three times greater than mean annual increment; this stand is still far from culmination. Results for this southwest Oregon installation are generally similar to those reported from other LOGS installations, although development has been slower than on the site II installations that make up the majority of the series.

Keywords: Thinning, growing stock, growth and yield, stand density, Douglas-fir, *Pseudotsuga menziesii*, series—Douglas-fir LOGS.

Summary

Results of the Stampede Creek installation of the cooperative Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) levels-of-growing-stock (LOGS) study, located in the Tiller Ranger District of the Umpqua National Forest in southwest Oregon, are summarized through age 63 (completion of 60 feet of height growth, comprising the planned course of the experiment).

Estimated site index (50-year breast height [b.h.] base) of this naturally seeded stand is 111 (site III). The height growth trend differs substantially from widely used older regional curves, and site estimates have increased by about one full site class during the period of observation. Volume growth has been strongly related to growing stock; basal area growth somewhat less so. There is a substantial tradeoff between increased individual tree size and value and total volume production. Different growing stock levels have produced marked differences in tree size distributions and crown dimensions. Periodic annual volume increments are two to three times greater than mean annual increments at age 63, with the differences being greatest for board-foot volumes. The stand is still far from culmination. Results are generally comparable to those reported from other LOGS installations, except for the slower development on this medium site compared to the good sites that make up the majority of LOGS installations.

Other LOGS (Levels-of-Growing Stock) Reports

Williamson, Richard L.; Staebler, George R. 1965. A cooperative level-of-growing-stock study in Douglas-fir. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

Describes purpose and scope of a cooperative study investigating the relative merits of eight different thinning regimes. Main features of six study areas installed since 1961 also are summarized.

Williamson, Richard L.; Staebler, George R. 1971. Levels-of-growing-stock cooperative study on Douglas-fir: report no. 1—description of study and existing study areas. Res. Pap. PNW-111. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

Thinning regimes in young Douglas-fir stands are described. Some characteristics of individual study areas established by cooperating public and private agencies are discussed.

Bell, John F.; Berg, Alan B. 1972. Levels-of-growing-stock cooperative study on Douglas-fir: report no. 2—the Hoskins study, 1963-70. Res. Pap. PNW-130. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 19 p.

A calibration thinning and the first treatment thinning in a 20-year-old Douglas-fir stand at Hoskins, Oregon, are described. Growth for the first 7 years after thinning was greater than expected.

Diggle, P.K. 1972. Levels-of-growing-stock cooperative study in Douglas-fir in British Columbia (report no. 3, cooperative L.O.G.S. study series). Inf. Rep. BC-X-66: Victoria, BC: Canadian Forestry Service, Pacific Forest Research Centre. 46 p.

Describes the establishment and installation of the two LOGS studies established on Vancouver Island at Shawnigan Lake and Sayward Forest.

Williamson, Richard L. 1976. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 4—Rocky Brook, Stampede Creek, and Iron Creek. Res. Pap. PNW-210. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 39 p.

The USDA Forest Service maintains three of nine installations in a regional cooperative study of influences of levels of growth stock (LOGS) on stand growth. The effects of calibration thinnings are described for the three areas. Results of first treatment thinning are described for one area.

Berg, Alan B.; Bell, John F. 1979. Levels-of-growing-stock cooperative study on Douglas-fir: report no. 5—the Hoskins study, 1963-75. Res. Pap. PNW-257. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 29 p.

Growth data are presented for the first 12 years of management of young Douglas-fir growing at eight levels of growing stock. The second and third treatment periods are described.

Young Douglas-fir stands transfer growth from many to few trees. Some of the treatments have the potential to equal the gross cubic-foot volume of the controls during the next treatment periods.

Arnott, J.T.; Beddows, D. 1981. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 6—Sayward Forest, Shawnigan Lake. Inf. Rep. BC-X-223, Victoria, BC: Canadian Forestry Service, Pacific Forest Research Centre. 54 p.

Data are presented for the first 8 and 6 years at Sayward Forest and Shawnigan Lake, respectively. The effects of the calibration thinnings are described for these two installations on Vancouver Island, British Columbia. Results of the first treatment thinning at Sayward Forest for a 4-year response period also are included.

Tappeiner, John C.; Bell, John F.; Brodie, J. Douglas. 1982. Response of young Douglas-fir to 16 years of intensive thinning. Res. Bull. 38. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University. 17 p.

Williamson, Richard L.; Curtis, Robert O. 1984. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 7—preliminary results: Stampede Creek, and some comparisons with Iron Creek and Hoskins. Res. Pap. PNW-323. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 42 p.

Results of the Stampede Creek LOGS study in southwest Oregon are summarized through the first treatment period, and results are compared with two more advanced LOGS studies and are generally similar.

Curtis, Robert O.; Marshall, David D. 1986. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 8—the LOGS study: twenty-year results. Res. Pap. PNW-356. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 113 p.

Reviews history and status of LOGS study and provides new analyses of data, primarily from the site II installations. Growth is strongly related to growing stock. Thinning treatments have produced marked differences in volume distribution by tree size. At the fourth treatment period, current annual increment is still about double the mean annual increment. Differences among treatments are increasing rapidly. There are considerable differences in productivity among installations, beyond those accounted for by site differences. The LOGS study design is evaluated.

Curtis, Robert O. 1987. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 9—some comparisons of DFSIM estimates with growth in the levels-of-growing-stock study. Res. Pap. PNW-RP-376. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 34 p.

Initial stand statistics for the LOGS study installations were projected by the DFSIM simulation program over the available periods of observation. Estimates were compared with observed volume and basal area growth, diameter change, and mortality. Overall agreement was reasonably good, although results indicate some biases and a need for revisions in the DFSIM program.

Marshall, David D.; Bell, John E.; Tappeiner, John C. 1992. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 10—the Hoskins study, 1963-83. Res. Pap. PNW-RP-448. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 65 p.

Results of the Hoskins LOGS study in western Oregon are summarized and management implications discussed through the fifth and final planned treatment period. To age 40, thinnings in this low site I Douglas-fir stand resulted in large increases in diameter growth with reductions in basal area and volume growth and yield. Growth was strongly related to level of growing stock. Culmination of cubic-foot mean annual increment does not appear to be near for any of the treatments.

Curtis, Robert O. 1992. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 11—Stampede Creek: a 20-year progress report. Res. Pap. PNW-RP-442. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 47 p.

Results of the first 20 years of the Stampede Creek study in southwest Oregon are summarized. To age 53, growth on this site III Douglas-fir stand has been strongly related to level of growing stock. Marked differences in volume distribution by tree sizes are developing as a result of thinning. Periodic annual increment is about twice mean annual increment in all treatments, indicating that the stand is still far from culmination.

Curtis, Robert O.; Clendenden, Gary W. 1994. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 12—the Iron Creek study: 1966-89. Res. Pap. PNW-RP-475. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 67 p.

Results of the Iron Creek study in the Gifford Pinchot National Forest, southern Washington, are summarized through age 42 (completion of the 60 feet of height growth comprising the planned course of the experiment). Volume growth of this mid-site II plantation has been strongly related to growing stock; basal area growth much less so. Different growing-stock levels have produced marked differences in the size distribution and in crown dimensions. Periodic annual volume increment at age 42 is two to three times mean annual increment in all treatments.

Hoyer, Gerald E.; Andersen, Norman A.; Marshall, David. 1996. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 13—the Francis study: 1963-90. Res. Pap. PNW-RP-488. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 91 p.

Results of the Francis LOGS study, begun at age 15, are summarized together with results from additional first-thinning treatments started at age 25. To age 42, total cubic volume growth on this mid-site II plantation has been strongly related to level of growing stock. Close dollar values among several alternatives suggest that diverse stand structure objectives can be attained at age 42 with little difference in wood product-value per acre.

Curtis, Robert O.; Marshall, David D.; Bell, John F. 1997. LOGS: a pioneering example of silvicultural research in coast Douglas-fir. Journal of Forestry. 95(7): 19-25.

Reviews history of LOGS including the reasoning involved in its design and the principal results of the study to date.

Marshall, David D.; Curtis, Robert O. 2002. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 15—Hoskins: 35-year results. Res. Pap. PNW-RP-537. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 80 p.

King, James E.; Marshall, David D.; Bell, John F. [In press]. Levels-of-growing-stock cooperative studies in Douglas-fir: report no. 17—the Skykomish study, 1961-93; the Clemons study, 1963-94. Res. Pap. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Contents

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Introduction

The Stampede Creek levels-of-growing-stock (LOGS) installation is one of nine in a regional study established in young even-aged Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands according to a common work plan[1] (Williamson and Staebler 1971). This study is a cooperative effort involving the USDA Forest Service, Weyerhaeuser Company, Oregon State University, Washington Department of Natural Resources, Canadian Forest Service, and British Columbia Ministry of Forests. The objective is to compare cumulative wood production, tree size development, and growth-growing stock relations under eight different thinning regimes that were begun before the onset of severe competition. The original study plan was developed at Weyerhaeuser Company, Centralia, Washington. Procedural details to ensure consistency among cooperators were developed by the Pacific Northwest Research Station, USDA Forest Service, Portland, Oregon.

Descriptions of the program and detailed progress reports on individual installations are contained in the series of LOGS publications listed. Curtis and Marshall (1986) give an overall analysis of results for the first 20 years, primarily for the higher site installations, which then were at or near the end of the planned experiment.

Installations on poorer sites developed more slowly than those on good sites, and the poorer site installations are only now reaching a point where they can be expected to show substantial differences among treatments and possible differences in response compared to stands on good sites.

The Stampede Creek installation was established in 1968 by the Pacific Northwest Research Station and the Pacific Northwest Region (Region 6) of the USDA Forest Service. The installation differs from others in the LOGS series in that it was (1) somewhat taller and older at time of establishment, (2) on a poorer site than the majority of installations (initially classed as IV but now classed as III), and (3) in an area (southwest Oregon) that is considerably different ecologically from the other installations.

Some preliminary data are given in report no. 4 (Williamson 1976), report no. 7 (Williamson and Curtis 1984), and report no. 11 (Curtis 1992).

This report on the Stampede Creek installation presents summary data and interpretations of results from establishment (1968) through completion of the experiment as originally planned (1998). It is essentially an update of report no. 11 (Curtis 1992) but incorporates an additional 10 years of growth and some minor differences in analyses.

Objectives

The LOGS cooperative study evolved from work in the late 1950s by George Staebler (1959, 1960). Staebler argued that thinning would transfer increment to the remaining faster growing trees and increase growth percentage through reduction in growing stock, while largely eliminating mortality losses. He also recognized that the implied assumption of near-constant gross increment over a wide range of stocking had not at that time been tested. The objectives of the LOGS study, as stated in the 1962 plan, were “to determine how the amount of growing stock retained in repeatedly thinned stands of Douglas-fir affects cumulative wood production, tree size, and growth-growing stock ratios.” Treatments were designed to include a wide range of growing stock so that results would show “how to produce any combination of factors deemed optimum from a management standpoint.” The study was intended to define the quantitative relations between growth and growing stock for a closely controlled initial stand condition and kind of thinning.

[1] Staebler, George R.; Williamson, Richard L. 1962. Plan for a level-of-growing-stock study in Douglas-fir. Unpublished study plan. On file with: Forestry Sciences Laboratory, 3625 93rd Avenue SW., Olympia, WA 98512.

This report:

- Presents revised data summaries showing development of the Stampede Creek LOGS installation through age 63 (end of fifth and final treatment period). These tables replace those in previous publications. They are expected to form part of the basis for one or more future publications generalizing the overall results of the LOGS installations.

- Compares results of the different treatments.

- Makes some interpretations of these results in relation to results from the higher site LOGS installations and possible operational stand management regimes.

Methods

Description of Study Area

The Stampede Creek installation is in the Tiller Ranger District, Umpqua National Forest, near Tiller in southwest Oregon (fig. 1) in sec. 10, T. 31 S., R. 1 W., Willamette Meridian. It is the only LOGS installation in southwest Oregon (an area often considered ecologically distinct from the Douglas-fir type as found further north) and is within the mixed-conifer (*Pinus-Pseudotsuga-Libocedrus-Abies*) zone of Franklin and Dyrness (1973).

The predominantly Douglas-fir stand originated by natural seeding after a 1929 wildfire. When the study was established in 1968, the stand was older (age as estimated from borings was 33 years total, 25 years b.h. [breast height]) and taller than the initial conditions of other stands included in the LOGS study. Estimated total ages of dominant and codominant trees ranged from 29 to 36 years. Field notes indicated delayed stand establishment after the fire, presence of well-developed madrone *(Arbutus menziesii* Pursh*)*, chinkapin (*Castanopsis chrysophylla* (Dougl.) A.DC.), and brush species, and fairly uniform spacing. Numbers of trees and basal areas before thinning were about 83 percent of normal for the quadratic mean diameter (QMD) according to table 25 in McArdle and others (1961). This suggests relatively low early competition and is consistent with the observation that live crowns extended nearly to breast height at the time of study establishment.

The installation is on a broad minor ridge, at an elevation of 2,700 feet, with an average slope of about 25 percent and a generally north to east aspect. Soils are loam over clay loam and clay derived from well-weathered volcanic tuffs and breccias.[2] Soil and parent material in the eastern group of plots (fig. 2) contains somewhat more clay and has higher moisture-holding capacity.[3] Average (1972-78) growing season (May to September) temperature and precipitation were 54.9 ºF and 7.71 inches, as determined from weather instruments located at the installation. Present ground cover is mainly salal (*Gaultheria shallon*).

The plant association is classified as ABCO/GASH-BENE *(Abies concolor/Gaultheria shallon-Berberis nervosa)* except for a small area at the western end of the installation (plots 21, 32) classified as TSHE/GASH-BENE-SWO *(Tsuga heterophylla/Gaultheria shallon-Berberis nervosa)* (Atzet and others 1996).

The area was classified as site IV at time of establishment, but subsequent development has led to a current site index estimate (50 years b.h.) of about 111 feet (site III).

Before study establishment in 1968, about 100 large snags present on the area were felled.

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[2] Herman, Loren D. 1968. Detailed soil survey of LOGS study area on Stampede Creek, Umpqua N.F. Unpublished report. On file with: Forestry Sciences Laboratory, 3625 93rd Avenue SW., Olympia, WA 98512.

[3] Miller, Richard E. Personal communication. Soil scientist (retired), Pacific Northwest Research Station, 3625 93rd Ave. SW., Olympia, WA 98512-9193.

Figure 1—Locations of the nine installations of the levels-of-growing-stock cooperative study in Douglas-fir.

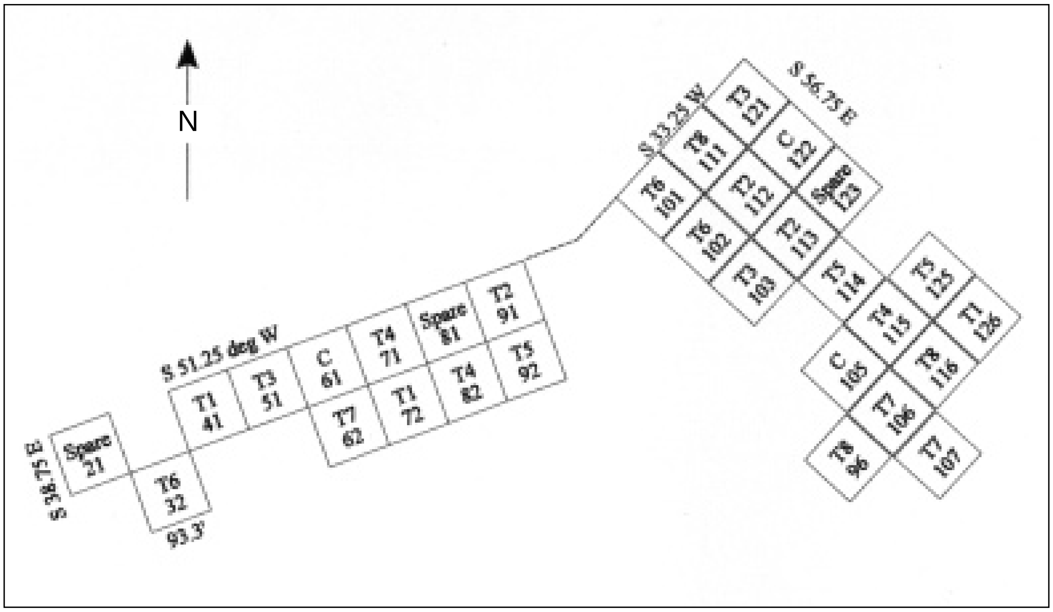

Figure 2—Arrangement of plots in the Stampede Creek LOGS installation.

Experimental Design

The experiment is a completely randomized design having three replications of eight thinning treatments, plus control (treatment 9). The 27 plots are one-fifth of an acre, square, without buffers except that a 30-foot isolation strip was provided around the outer margins of the experimental area. Physical arrangement is shown in figure 2. Detailed criteria given in the study plan for area and plot selection provided a high degree of uniformity in initial conditions.

Thirty-nine plots were laid out in the stand. Of these, 5 were rejected as unsuitable and the 27 judged most comparable were selected for use in the study. Of the remaining seven, two were allocated as spare controls and five as spare thinning plots for use if major damage to other plots made substitution necessary. The spare plots were measured in 1968 and 1973 only. In 1988, three of the thinned spare plots were remeasured and the other spares were abandoned. These three plots, not provided for in the original study plan, are designated as treatment 10 and were remeasured in 1988, 1993, and 1998; the intention was to provide a supplementary comparison with the effects of a precommercial thinning without subsequent treatment.

Stand Treatments

Treatments were closely controlled to provide compatibility with installations at other locations.

Selection of crop trees—Crop trees were selected, before thinning, at the rate of 16 per plot (80 per acre), and distributed to provide three to five well-spaced crop trees in each quarter of a plot. Crop trees were identified with white paint bands.

Calibration thinning––An initial calibration thinning was made in 1968 (at age 33) on the 24 plots assigned to thinning treatments plus the spare thinned plots. This was intended to reduce all plots to as nearly comparable condition as possible. All trees less than one-half the initial stand QMD were cut. Additional noncrop trees were cut as needed to meet the study plan specifications, which called for the stand to be thinned to an initial spacing based on the equation,

$$S = 0.6167 \times QMD + 8 ,$$

where S is the average spacing in feet and QMD is the quadratic mean diameter of the leave trees. Marking was controlled by the specifications that QMD of the leave trees on any plot should be within 15 percent of the installation mean and leave tree basal areas should be within 3 percent. All leave trees on thinned plots were identified with permanent numbered tags. Trees 1.6 inches in diameter at breast height (d.b.h.) and larger were tagged on the control plots.

Treatment thinnings––The eight thinning treatments differ in the amount of basal area allowed to accumulate in the growing stock. The increase in basal area retained in any thinning is a predetermined percentage of the gross increase found in the unthinned plots since the last thinning (inside front cover; table 1). The average residual basal area for all thinned plots after the calibration thinning is the starting point for calculating future growing stock accumulation. Growth of controls was assumed to represent the productive potential of the site at full stocking and can be thought of as providing a local gross yield table for the study area.

Following the initial calibration thinning, treatment thinnings were made at intervals of about 10 feet of growth in crop tree height (approximated in later years by H40, mean height of the largest 40 stems per acre [8 per plot]).[4] Treatment thinnings were made in 1973, 1978, 1983, 1988, and 1993 (ages 38, 43, 48, 53, and 58, respectively). Basal areas to be left after thinning were calculated from the equation,

$$BA_n = BA_{(n-1)} + p \times GBAG ,$$

where
BA_n = basal area retained after thinning,
$BA_{(n-1)}$ = basal area at beginning of preceding treatment period,
p = prespecified percentage of gross basal area growth to be retained, and
GBAG = average gross basal area growth on controls.

The expected trends in basal area created by these specifications are shown schematically in figure 3. Treatments 1, 3, 5, and 7 are hereafter referred to as the “fixed” treatments and 2, 4, 6, and 8 as the “variable” treatments.

Kind of thinning was further specified by the following requirements:

1. No crop trees were to be cut until all noncrop trees had been removed.

2. The QMD of trees removed in thinning should approximate the QMD of trees available for thinning (that is, of noncrop trees only until all noncrop trees had been removed). This results in a d/D ratio (ratio of diameter of trees cut to diameter of stand before thinning) of less than 1.0.

[4] The original intent was that the initially selected crop trees would be retained and would form the final stand; however, damage and decline in vigor of some initially selected trees made numerous substitutions necessary. In effect, the crop tree list was revised at each thinning prior to marking of trees to be cut.

Table 1—Treatments defined by percentage of gross basal area increment of control retained after thinning (calibration thinning excluded)

	Thinning				
Treatment	**First**	**Second**	**Third**	**Fourth**	**Fifth**
	Percent retention				
Fixed:					
1	10	10	10	10	10
3	30	30	30	30	30
5	50	50	50	50	50
7	70	70	70	70	70
Increasing:					
2	10	20	30	40	50
4	30	40	50	60	70
Decreasing:					
6	50	40	30	20	10
8	70	60	50	40	30
Unthinned:					
C	–	–	–	–	–

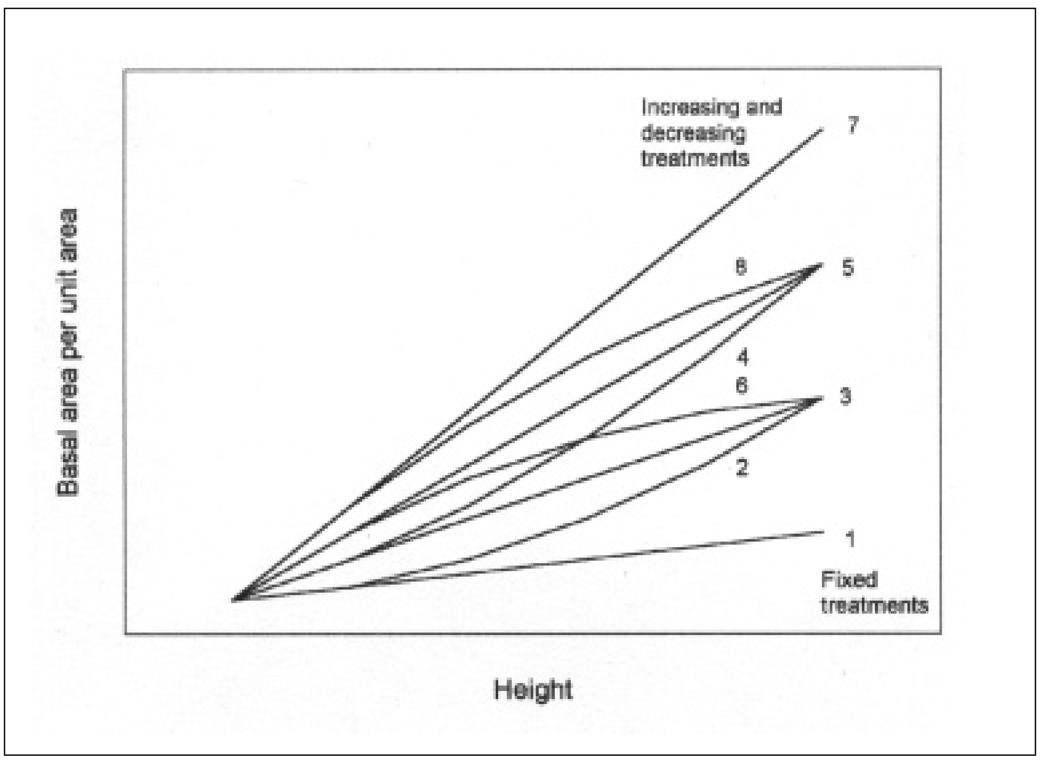

Figure 3—Idealized trends in basal area for the eight thinning regimes in the LOGS study.

3. Trees removed in thinning were to be distributed across the range of diameters of trees available for thinning.

Data Collection and Summarization

Immediately after the calibration thinning, and at all subsequent measurement dates, diameters of all tagged trees were measured to the nearest 0.1 inch. Ingrowth was tagged and measured on the control plots only. Heights were measured on a sample of trees at each occasion, beginning in 1968; sample size differed at different measurement dates but was never less than 12 trees per plot, and usually more, distributed across the range of diameters. Heights to base of live crown also were measured, beginning in 1973.

Constrained height-diameter curves were fit to each measurement on each plot (Flewelling and de Jong 1994). Tree volumes in total cubic feet inside bark (CVTS) were calculated by the Bruce and DeMars (1974) equation, from actual measured heights when available and from predicted heights for trees not having measured heights. These were converted to merchantable cubic volumes to a 6-inch top (CV6) by using equations from Brackett (1973). Scribner volumes for 32-foot logs (SV6) (Chambers and Foltz 1979), with a minimum top log of 16 feet, were calculated by using diameter estimates from Flewelling's (unpublished)[5] taper equations.

Stand heights were characterized as H40, the mean height of the 40 stems per acre with the largest diameters (largest 8 per plot); and as Hcrop, the mean height of designated crop trees. Although Hcrop was originally envisioned as the primary measure, some initially designated crop trees did not remain reasonable selections as the stand developed, and substitutions were necessary. H40 is not much different, provides consistent values, and is the principal measure used in this report.

Analyses

The original study plan specified analysis of variance (ANOVA) as the primary method of analysis, and ANOVA results are given in many of the other publications listed. A similar analysis is included here for consistency with the other work. Many aspects of the experiment are more meaningfully presented and interpreted, however, through simple graphics and comparisons of treatment means. We devote most of our attention in subsequent sections to these.

Results

Analysis of Variance

Differences among treatments in periodic gross volume (total stem) growth, gross basal area growth, survivor QMD growth, and volume growth percentage were tested by an analysis of variance ANOVA, as specified in the original study plan (see footnote 1) and as shown in table 2. Only the thinned treatments, which were controlled to achieve a range in growing stock, were included. (Note that for the thinned plots, there is in most cases little difference between gross and net growth). The results for these four ANOVAs are summarized in table 3 and discussed below. The specific trends discussed here will be shown graphically in later sections. These results are generally consistent with those from other LOGS installations at the end of the five treatment periods (Curtis and Clendenen 1994, Hoyer and others 1996, Marshall and others 1992).

[5] Using the methodology of Flewelling and Raynes 1993.

Table 2–Analysis of variance

Source of variation	Degrees of freedom (5 treatment periods)
Treatments:	
(1) Fixed vs. variable percentage treatments	1
(2) Among levels of fixed percentage treatments –	
Linear effects	1
Quadratic effects	1
Cubic effects	1
(3) Increasing vs. decreasing percentage treatments	1
(4) Between levels of increasing percentage treatments	1
(5) Between levels of decreasing percentage treatments	1
Error (a) for testing treatments	16
Periods (P)	4
Treatment × period interactions:	
P × A	4
P × B linear effects	4
P × B quadratic effects	4
P × B cubic effects	4
P × C	4
P × D	4
P × E	4
Error (b) for testing interactions	64
Total	119

All treatments—Over the five treatment periods, growing stock accumulated differently among the fixed percentage treatments (1, 3, 5, and 7) and among the variable percentage treatments (2, 4, 6, and 8). However, the mean growing stock (average of initial values over the five treatment periods) was nearly the same for the four fixed as for the mean of four variable treatments (105.9 and 105.5 square feet per acre respectively). This resulted in no significant difference in overall average growth of fixed versus variable treatments.

Fixed treatments—The ANOVA tested the fixed percentage treatments (1, 3, 5, and 7) for linear, quadratic, and cubic trends across the range of growing stock found. In all cases, growth could be adequately described as linearly related to growing stock (that is, the squared and cubic terms were not significant) for the five treatment periods. Basal area and volume growth increased linearly with growing stock, while diameter growth and volume growth percentage decreased with growing stock. This linear relation also changed significantly between periods (with slope generally decreasing with age) for all but the volume growth percentage, which stayed similar. One would not expect these trends to be linear over a wider range of growing stock; growth would necessarily be zero for zero growing stock, and the ANOVA does not include the much higher densities of the controls.

Table 3–Analysis of variance results for periodic annual gross volume increment, periodic annual gross basal area increment, survivor quadratic mean diameter periodic annual increment, and volume growth percentage

	P-values and mean square errors [a]			
	Volume (CVTS)		Basal area	Diameter
Source of variation	PAI	Growth percent	PAI	PAI
(A) Fixed vs. variable	0.545	0.288	0.259	0.513
(B) Fixed (linear)	0.000**	0.001**	0.010**	0.000**
(B) Fixed (quadratic)	0.491	0.481	0.741	0.675
(B) Fixed (cubic)	0.356	0.398	0.650	0.787
(C) Increasing vs. decreasing	0.001**	0.962	0.031*	0.715
(D) Between increasing	0.004**	0.863	0.016*	0.235
(E) Between decreasing	0.365	0.003**	0.165	0.060
Error (a) mean square	1,394.126	0.005	0.799	0.465
Periods (P)	0.000**	0.000**	0.000**	0.000**
P × A	0.189	0.671	0.714	0.980
P × B (linear)	0.000**	0.726	0.027*	0.000**
P × B (quadratic)	0.523	0.414	0.835	0.715
P × B (cubic)	0.982	0.675	0.960	0.428
P × C	0.031*	0.776	0.092	0.002**
P × D	0.085	0.721	0.060	0.020*
P × E	0.029*	0.203	0.066	0.003**
Error (b) mean square	183.600	0.095	0.071	0.0002

[a] P-value is the probability of a larger F-value, given that the null hypothesis of no difference among means is true. Significance levels: * = 0.01 < p ≤ 0.05 and ** = p ≤ 0.01.

Variable treatments—The increasing treatments (2 and 4) accumulated more basal area in the later treatment periods, and the decreasing treatments (6 and 8) accumulated more basal area in the earlier treatment periods, which resulted in mean growing stocks (average of initial values of both treatments over the five treatment periods) of 97.8 and 113.1 square feet per acre, respectively. Mean periodic volume growth (over five treatment periods) was 221.6 for the increasing treatments and 259.8 cubic feet • acre^{-1} • year^{-1} for the decreasing treatments. The corresponding basal area growth was 4.6 and 5.2 square feet • acre^{-1} • year^{-1}. Both volume and basal area growth were significantly greater for the decreasing treatments. There was no significant difference among treatments in percentage of diameter growth or volume growth.

For the increasing treatments (2 and 4), with average gross periodic annual increments in volume of 198.5 and 244.7 cubic feet • acre^{-1} • year^{-1}, and average gross basal area periodic annual increments of 4.2 and 5.1 square feet • acre^{-1} • year^{-1} respectively, growth was different between the two levels, with the higher level of growing stock (4) having greater growth. The differences in average volume and basal area growth between the decreasing treatment (6 and 8) have generally been significant in the other LOGS installations, but they were not significantly different here even though

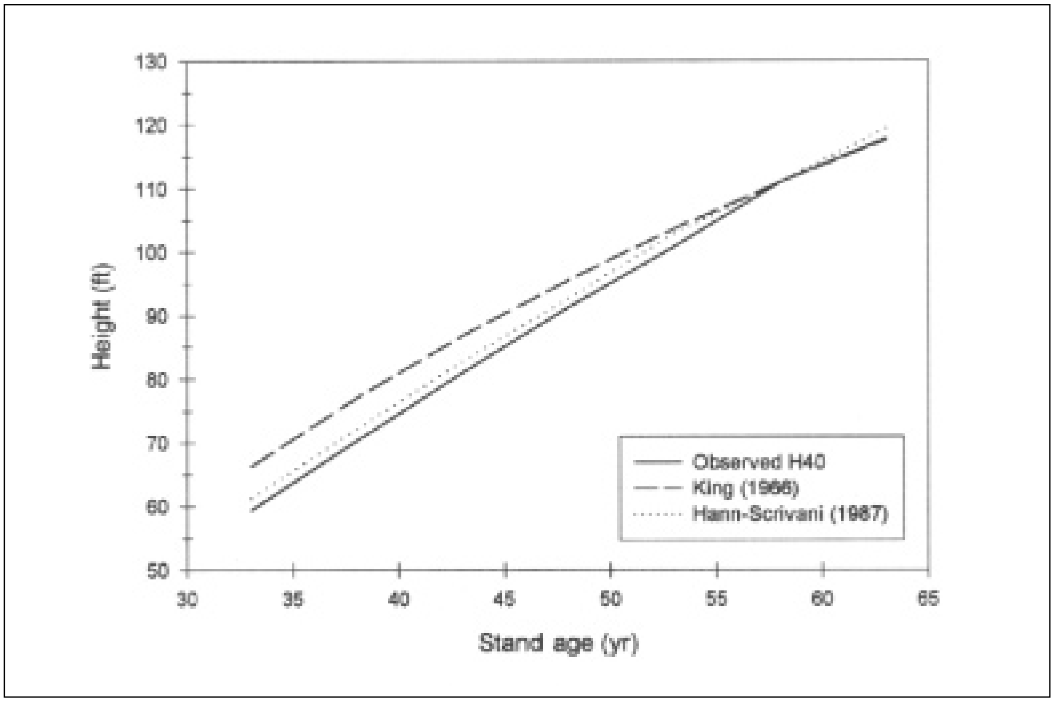

Figure 4—Observed H40 trend (mean of eight thinning treatments and control) compared with trends predicted by King (1966) and Hann and Scrivani (1987).

treatment 8 had, on average, nearly 17 percent more growing stock at the start of the growth periods. Only the volume growth percentage differed significantly between the two decreasing treatments, with the lower level of growing stock treatment (6) having a higher growth percentage (6.6 compared to 5.7 percent).

Trends in Live Stand Statistics

Height of largest 40 trees per acre (H40)—H40, defined as the mean height of the largest (by d.b.h.) 40 trees per acre (8 per 1/5-acre plot), is a useful measure of height development. This can be calculated objectively for all plots from the data available, is little affected by thinning, and is now quite commonly used in the region as the basis for site estimates.

The range in 1998 (age 63) values of the treatment means of H40 for thinned plots was from 114 to 124 feet, with a mean of 118 feet. The data suggest slightly greater heights for the thinning treatments in higher stocking levels. Mean H40 of the control plots was 116 feet (table 4).

Figure 4 compares development of H40 over the life of the installation with values predicted by King (1966) and by Hann and Scrivani (1987) for site index 111. The observed trend is best approximated by the Hann and Scrivani curves, which were specifically developed for southwestern Oregon. Over the 25 years from establishment to attainment of age 50 b.h., estimated site index using Kings curves has changed from 98 to 111, whereas the Hann-Scrivani estimates changed only from 108 to 111.

Table 4–Heights of the 40 largest trees per acre, 1968-98, by treatment, plot, measurement date, and age (in parentheses)

		Heights of the 40 largest trees per acre at start of period											
		Calibration period		Treatment period 1		Treatment period 2		Treatment period 3		Treatment period 4		Measurement period 5	
Treatment	Plot	1968 (33)	1973 (38)	1973 (38)	1978 (43)	1978 (43)	1983 (48)	1983 (48)	1988 (53)	1988 (53)	1993 (58)	1993 (58)	1998 (63)
		Feet											
Fixed:													
1	41	56.5	67.9	67.9	78.0	78.0	89.0	89.0	97.1	97.1	104.8	105.6	114.3
	72	58.8	69.5	68.9	80.5	80.5	89.6	89.6	99.0	99.1	110.5	108.3	116.1
	126	57.9	70.1	70.1	80.6	80.6	89.0	89.0	101.2	101.2	112.4	112.4	119.1
Avg.		57.7	69.2	69.0	79.7	79.7	89.2	89.2	99.1	99.2	109.2	108.8	116.5
3	51	59.5	69.6	69.6	81.4	81.4	91.1	91.1	99.6	99.6	108.0	108.4	114.9
	103	57.6	68.2	68.2	77.9	77.9	88.2	88.2	95.9	95.9	105.9	105.9	111.1
	121	59.0	68.1	68.1	80.5	80.5	91.8	91.8	101.7	101.0	112.0	112.0	116.5
Avg.		58.7	68.6	68.6	79.9	79.9	90.4	90.4	99.1	98.8	108.6	108.8	114.2
5	92	62.4	74.5	74.5	85.3	85.3	94.4	94.4	104.1	104.1	114.0	114.0	120.6
	114	62.8	74.8	74.8	83.5	83.9	92.6	92.6	101.8	101.8	112.1	112.1	118.8
	125	61.7	73.4	73.4	82.8	82.9	93.6	93.6	100.9	100.9	111.0	111.0	115.9
Avg.		62.3	74.2	74.2	83.8	84.0	93.5	93.5	102.3	102.3	112.4	112.4	118.4
7	62	61.3	72.0	72.0	81.9	81.9	92.5	92.5	102.1	102.1	110.9	110.9	120.1
	106	61.4	72.0	72.0	84.2	84.2	96.1	96.1	106.7	106.7	118.0	118.0	124.7
	107	60.9	70.1	70.1	79.8	79.8	92.8	92.8	102.3	102.3	113.8	113.8	120.9
Avg.		61.2	71.4	71.4	82.0	82.0	93.8	93.8	103.7	103.7	114.2	114.2	121.9
Increasing:													
2	91	58.2	69.5	68.3	78.9	78.9	88.6	88.6	95.1	95.1	104.3	104.3	111.1
	112	58.3	70.1	69.6	79.5	79.4	89.3	89.3	97.1	97.1	108.0	108.0	116.0
	113	61.3	73.9	73.6	84.8	84.8	96.0	96.0	103.0	103.0	112.5	112.5	119.8
Avg.		59.3	71.2	70.5	81.0	81.0	91.3	91.3	98.4	98.4	108.3	108.3	115.6
4	71	57.2	69.7	69.7	78.0	78.0	91.0	91.0	101.4	101.4	111.9	111.9	120.0
	82	56.8	67.8	67.5	79.0	79.0	89.9	89.6	99.3	99.3	110.1	110.1	116.8
	115	58.6	70.2	70.2	81.1	81.1	89.2	89.2	102.3	102.3	113.1	113.1	116.2
Avg.		57.5	69.3	69.2	79.4	79.4	90.0	90.0	101.0	101.0	111.7	111.7	117.7
Decreasing:													
6	32	56.8	66.6	66.6	78.8	78.8	89.9	89.9	99.7	99.7	108.0	108.0	115.9
	101	61.0	69.4	69.4	81.7	81.7	92.0	92.0	102.1	102.1	114.0	113.3	119.5
	102	56.5	67.0	67.0	76.7	75.8	87.1	88.1	96.1	96.1	105.6	105.6	112.4
Avg.		58.1	67.7	67.7	79.1	78.8	89.7	90.0	99.3	99.3	109.2	109.0	115.9
8	96	60.8	73.0	73.0	83.9	83.9	98.0	98.0	107.9	107.9	120.4	120.4	127.7
	111	61.2	74.2	74.2	84.3	84.3	95.0	95.0	105.2	105.2	116.0	116.0	123.8
	116	59.8	71.7	71.7	80.6	80.6	93.4	93.4	103.7	103.7	115.4	115.4	121.0
Avg.		60.6	73.0	73.0	82.9	82.9	95.4	95.4	105.6	105.6	117.3	117.3	124.2
Unthinned:													
C	61	59.5	70.1	70.1	81.0	81.0	90.2	90.2	100.4	100.4	109.5	109.5	117.3
	105	60.6	70.8	70.8	81.1	81.1	90.8	90.8	99.6	99.6	109.3	109.3	115.8
	122	58.0	69.6	69.6	79.6	79.6	86.8	86.8	99.5	99.5	108.3	108.3	114.8
Avg.		59.4	70.2	70.2	80.6	80.6	89.3	89.3	99.8	99.8	109.0	109.0	116.0

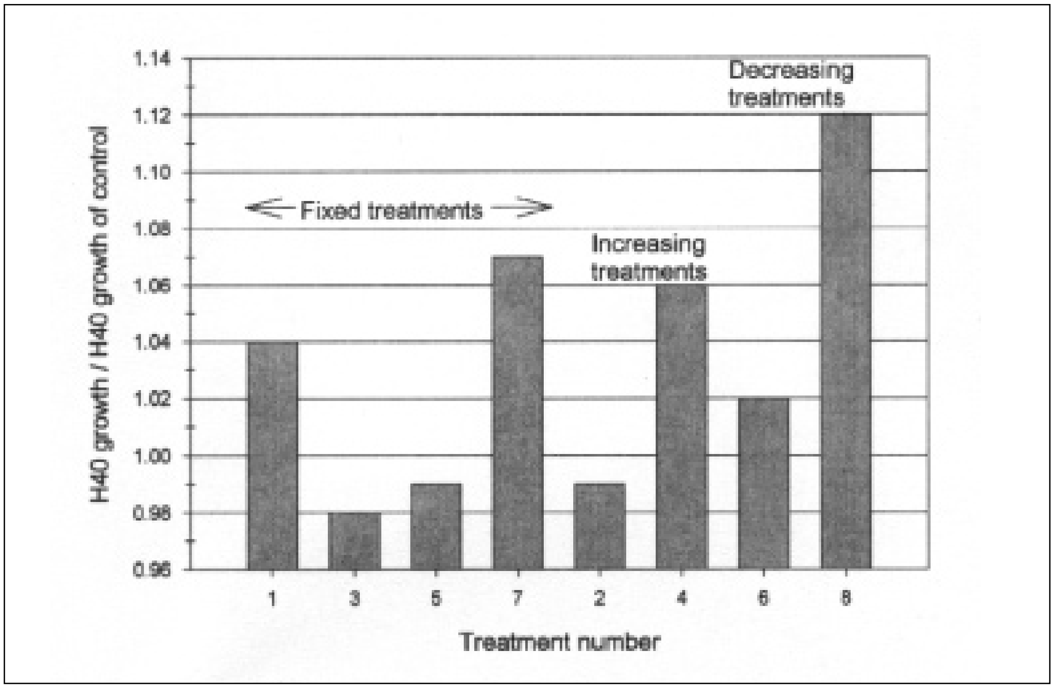

Figure 5—Thirty-year increment in H40 expressed as ratios to H40 increment of control, by treatments.

Figure 5 compares H40 increment over the 30-year period by treatments. There is some suggestion that H40 increments on the thinned treatments were slightly greater than on the control, and that the treatments with higher stocking levels (4, 7, 8) had slightly better height growth. Treatment 1 is inconsistent with this interpretation, but the differences could reflect slight differences in site.

Number of trees—Trends over time of trees per acre by treatment are given in table 5. Distributions by 1-inch diameter classes after calibration (1968) and in 1998 are shown in table 6 and figure 6.

Basal area—Corresponding values of basal area per acre, by treatments, are shown in figure 7 and table 7.

Quadratic mean diameter—Trends in QMD by treatment are shown in figure 8 and table 8. Changes in QMD from 1968 through 1998, by treatments and expressed as ratios to the corresponding change on control, are shown in figure 9.

Thinnings have had a strong effect on the 30-year change; the effect has been greatest at the lowest stockings. A considerable part of this change, however, is the result of the progressive removal of trees of slightly smaller average diameter than that of the stand as a whole (that is, d/D<1.0). A better expression of the actual effect of treatments on tree development is survivor diameter growth (Curtis and Marshall 1989), shown in figure 10.

Other diameter measures—Other average diameters are sometimes also used to express stand attributes. D40, average diameter of the 40 largest (by d.b.h.) trees per

Table 5–Trees per acre, 1968-98, by treatment, plot, measurement date, and age (in parentheses)

		Trees per acre											
		Calibration period		Treatment period 1		Treatment period 2		Treatment period 3		Treatment period 4		Measurement period 5	
Treatment	Plot	1968 (33)	1973 (38)	1973 (38)	1978 (43)	1978 (43)	1983 (48)	1983 (48)	1988 (53)	1988 (53)	1993 (58)	1993 (58)	1998 (63)
		Number per acre											
Fixed:													
1	41	300	295	200	195	125	125	75	75	60	60	50	50
	72	285	285	175	175	120	120	70	70	55	55	45	40
	126	300	300	205	205	150	150	100	100	70	70	55	55
Avg.		295	293	193	192	132	132	82	82	62	62	50	48
3	51	300	300	195	195	150	150	115	115	85	85	75	75
	103	295	290	200	200	150	150	125	125	95	95	85	85
	121	275	275	200	200	155	150	125	125	105	105	85	85
Avg.		290	288	198	198	152	150	122	122	95	95	82	82
5	92	280	275	210	210	175	175	135	135	95	95	80	80
	114	280	280	250	250	225	225	205	205	175	170	135	125
	125	295	295	250	250	215	215	185	185	175	175	145	140
Avg.		285	283	237	237	205	205	175	175	148	147	120	115
7	62	275	270	250	245	220	215	190	190	175	175	160	150
	106	290	290	255	240	225	225	210	210	205	195	185	170
	107	275	275	275	270	250	250	235	235	215	210	195	195
Avg.		280	278	260	252	232	230	212	212	198	193	180	172
Increasing:													
2	91	285	280	195	185	125	125	100	90	90	85	85	75
	112	300	300	220	220	140	140	80	80	70	70	65	65
	113	275	270	155	150	105	105	65	60	60	60	60	55
Avg.		287	283	190	185	123	123	82	77	73	72	70	65
4	71	295	290	175	175	140	135	115	115	100	100	90	90
	82	320	315	245	240	175	175	145	145	125	125	125	125
	115	275	270	205	200	160	160	145	145	135	135	130	130
Avg.		297	292	208	205	158	157	135	135	120	120	115	115
Decreasing:													
6	32	340	335	295	295	220	220	170	170	110	110	85	85
	101	290	290	235	235	185	185	130	130	90	90	75	75
	102	330	325	305	295	250	250	190	185	130	125	100	95
Avg.		320	317	278	275	218	218	163	162	110	108	87	85
8	96	230	230	210	210	175	175	155	150	135	135	110	110
	111	280	280	245	245	240	240	205	200	170	170	130	120
	116	255	255	250	245	210	210	185	185	155	155	125	125
Avg.		255	255	235	233	208	208	182	178	153	153	122	118
Unthinned:													
C	61	1,035	965	965	860	860	675	675	495	495	400	400	345
	105	845	830	830	745	745	620	620	470	470	360	360	335
	122	1,345	1,235	1,235	1,065	1,065	760	760	580	580	470	470	420
Avg.		1,075	1,010	1,010	890	890	685	685	515	515	410	410	367

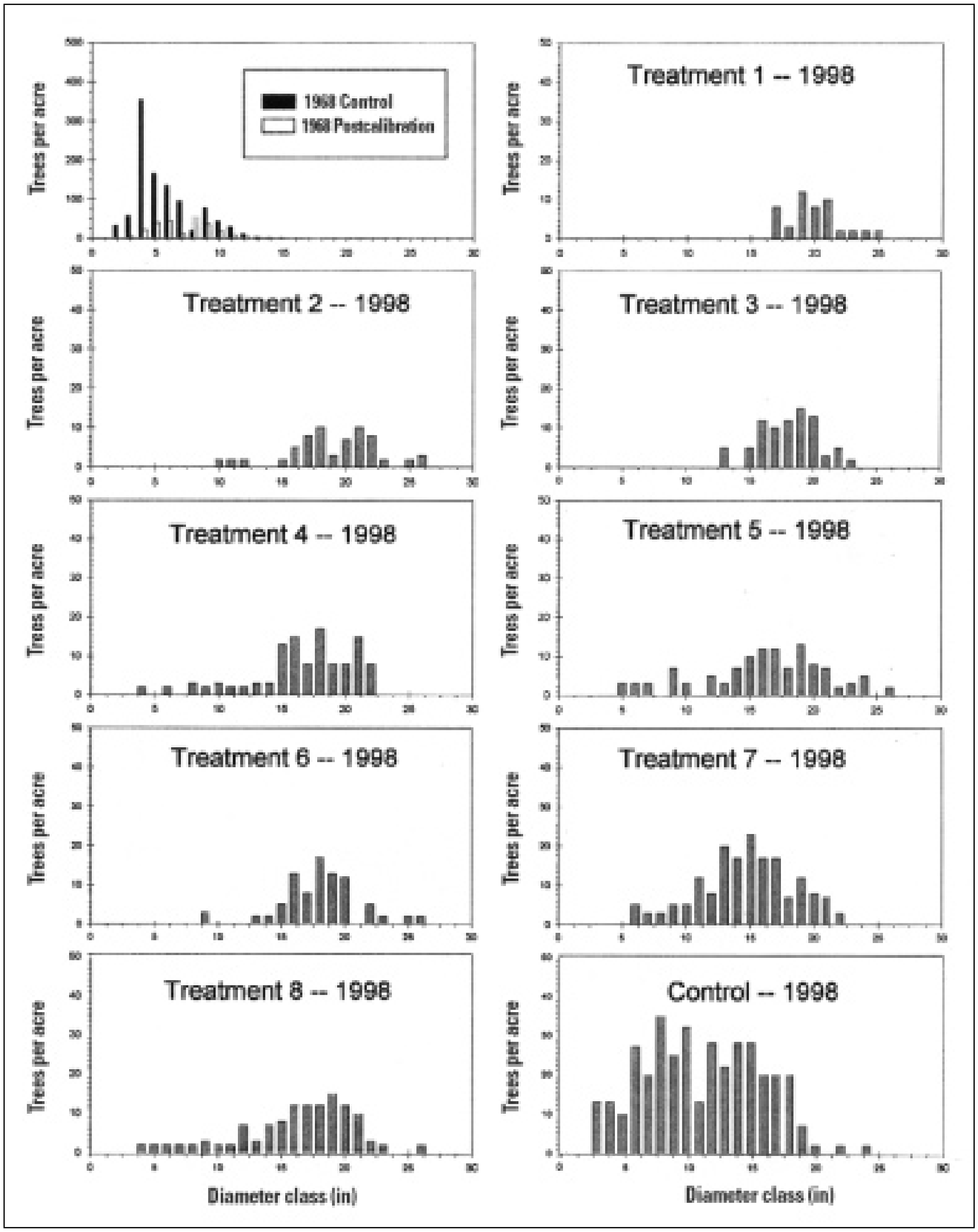

Figure 6—Frequency distribution of trees per acre, by 1-inch d.b.h. classes for control and combined thinned plots in 1968 and by treatment in 1998.

acre, corresponds to H40 and is useful for expressing effect of treatment on diameter growth of leading dominant trees. Unlike QMD, this is only slightly influenced by removal of trees through thinning or mortality, because few trees in this category were cut in the thinning regimes, and suppression mortality was negligible.

The D40 values in 1998 were substantially greater for thinned plots than for the control, but seem only loosely related to thinning treatment. Thinning treatments have had less effect on D40 than on QMD.

Table 6––Numbers of trees, by 1-inch class, after calibration and in 1998, by treatment (age in parentheses)

	Fixed treatments								Increasing treatments				Decreasing treatments				Unthinned	
	1		3		5		7		2		4		6		8		C	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
D.b.h.	1968	1998	1968	1998	1968	1998	1968	1998	1968	1998	1968	1998	1968	1998	1968	1998	1968	1998
class	(33)	(63)	(33)	(63)	(33)	(63)	(33)	(63)	(33)	(63)	(33)	(63)	(33)	(63)	(33)	(63)	(33)	(63)
Inches	- -								*Number of trees* -									
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	58	0
3	2	0	0	0	7	0	3	0	2	0	5	0	0	0	5	0	355	13
4	18	0	13	0	18	0	12	0	35	0	20	2	33	0	30	2	168	13
5	40	0	40	0	50	3	25	0	52	0	28	0	67	0	13	2	135	10
6	48	0	43	0	53	3	45	5	42	0	48	2	52	0	32	2	95	27
7	48	0	50	0	40	3	57	3	43	0	62	0	62	0	40	2	92	20
8	65	0	73	0	45	0	63	3	42	0	53	3	48	0	57	2	78	35
9	42	0	32	0	28	7	40	5	27	0	48	2	38	3	33	3	45	25
10	23	0	28	0	15	3	18	5	18	2	23	3	10	0	20	2	30	32
11	5	0	8	0	10	0	8	12	13	2	8	2	5	0	13	2	12	13
12	2	0	0	0	13	5	8	8	5	2	0	2	2	0	8	7	3	28
13	2	0	2	5	3	3	0	20	5	0	0	3	3	2	3	3	2	22
14	0	0	0	0	2	7	0	17	2	0	0	3	0	2	0	7	2	28
15	0	0	0	5	0	10	0	23	2	2	0	13	0	5	0	8	0	28
16	0	0	0	12	0	12	0	17	0	5	0	15	0	13	0	12	0	20
17	0	8	0	10	0	12	0	17	0	8	0	8	0	8	0	12	0	20
18	0	3	0	12	0	7	0	7	0	10	0	17	0	17	0	12	0	20
19	0	12	0	15	0	13	0	12	0	3	0	8	0	13	0	15	0	7
20	0	8	0	13	0	8	0	8	0	7	0	8	0	12	0	12	0	2
21	0	10	0	3	0	7	0	7	0	10	0	15	0	0	0	10	0	0
22	0	2	0	5	0	2	0	3	0	8	0	8	0	5	0	3	0	2
23	0	2	0	2	0	3	0	0	0	2	0	0	0	2	0	2	0	0
24	0	2	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	2
25	0	2	0	2	0	0	0	0	0	2	0	0	0	2	0	0	0	0
26	0	0	0	3	0	2	0	0	0	3	0	0	0	2	0	2	0	0
Total	295	48	290	82	285	115	280	172	287	65	297	115	320	85	255	118	1,075	367

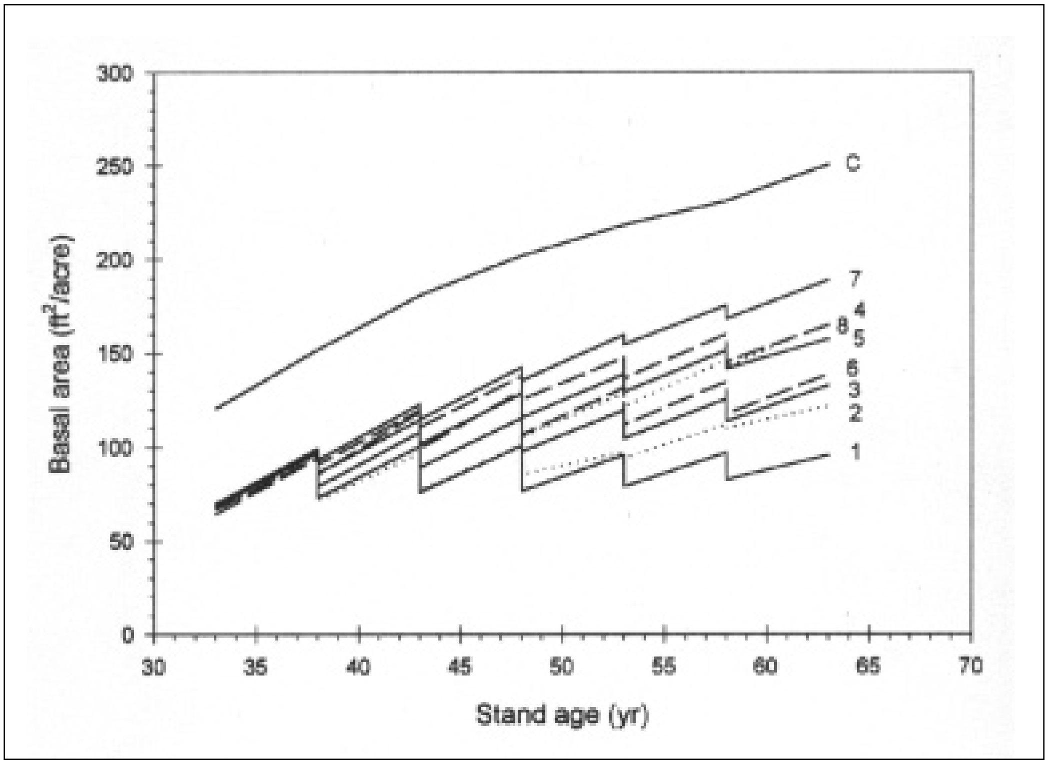

Figure 7—Trends of live basal area over time, by treatment.

Differences in 30-year change in D40, which take into account differences among treatments in initial D40s, are much more pronounced than differences among 1998 D40s. Relatively few trees among the largest 40 per acre have been removed in thinning, and D40 change primarily represents growth even though a few trees were cut. Omitting treatment 2, which we know was severely impacted by root disease, the changes in relation to treatment are similar in direction to those for QMD although much smaller in magnitude.

An alternative measure of diameter development is Dcrop, QMD of designated crop trees. The original study plan envisioned an initial selection of 80 crop trees per acre, based on a combination of vigor and spacing, with these trees to be favored during thinning and retained (in some treatments) to the end of the experiment. Interpretation of Dcrop is obscured by subsequent substitution of new crop trees for damaged and low-vigor trees, and we use the closely related value of D40 in preference to Dcrop. D40 and Dcrop become identical in later years in those treatments where number of stems was reduced below 80 per acre.

Table 7–Basal area of all live trees per acre, 1968-98, by treatment, plot, measurement date, and age (in parentheses)

		Basal area											
		Calibration period		Treatment period 1		Treatment period 2		Treatment period 3		Treatment period 4		Measurement period 5	
		1968	1973	1973	1978	1978	1983	1983	1988	1988	1993	1993	1998
Treatment	Plot	(33)	(38)	(38)	(43)	(43)	(48)	(48)	(53)	(53)	(58)	(58)	(63)
		Square feet per acre											
Fixed:													
1	41	67.6	98.5	72.6	101.8	75.2	102.7	75.5	95.3	78.5	96.5	82.1	98.4
	72	71.8	103.8	75.5	104.3	78.0	102.9	76.7	95.6	79.3	97.8	81.5	87.8
	126	67.2	93.6	72.1	96.4	76.2	97.1	78.8	97.6	79.8	98.0	84.9	101.3
Avg.		68.9	98.6	73.4	100.8	76.5	100.9	77.0	96.2	79.2	97.4	82.9	95.8
3	51	72.8	103.7	80.8	111.2	90.9	120.5	100.6	122.5	105.0	127.3	114.6	134.4
	103	69.6	98.0	79.3	108.8	90.2	113.8	96.6	117.9	104.8	125.3	114.1	132.8
	121	68.3	96.9	78.1	104.1	87.5	112.5	96.8	119.0	104.4	125.2	112.7	131.4
Avg.		70.2	99.5	79.4	108.0	89.6	115.6	98.0	119.8	104.7	126.0	113.8	132.9
5	92	72.2	104.1	85.8	117.1	102.5	135.4	117.1	145.6	129.1	155.0	141.5	164.6
	114	64.9	92.3	86.1	113.3	103.4	128.1	116.0	137.2	129.7	148.5	141.9	146.5
	125	69.7	96.6	87.7	114.0	99.8	122.8	114.6	134.2	129.6	151.0	142.6	161.6
Avg.		68.9	97.7	86.5	114.8	101.9	128.8	115.9	139.0	129.5	151.5	142.0	157.6
7	62	68.9	98.7	92.8	123.4	113.5	143.3	134.4	159.1	154.3	179.7	172.1	194.9
	106	70.5	100.1	92.2	121.0	114.0	140.7	133.7	157.7	154.8	169.7	159.8	177.2
	107	68.7	96.1	96.1	124.5	117.9	144.3	138.9	162.3	154.7	177.1	172.9	194.5
Avg.		69.4	98.3	93.7	123.0	115.1	142.8	135.7	159.7	154.6	175.5	168.3	188.9
Increasing:													
2	91	67.9	92.8	72.0	93.8	73.7	94.7	86.9	94.3	94.3	110.8	110.8	118.5
	112	64.6	94.6	72.0	101.3	77.7	103.4	85.7	107.1	97.2	117.0	110.7	130.1
	113	70.1	100.5	71.4	95.8	81.6	105.1	84.3	91.1	91.1	109.1	109.1	116.6
Avg.		67.5	96.0	71.8	97.0	77.6	101.0	85.6	97.5	94.2	112.3	110.2	121.7
4	71	70.8	102.4	78.5	109.5	90.6	117.5	105.3	130.6	121.8	147.8	139.9	162.6
	82	67.1	97.5	80.9	109.9	90.7	120.3	106.3	129.8	121.4	148.1	148.1	174.2
	115	71.2	97.8	80.6	103.3	87.3	109.6	105.1	125.8	121.6	143.1	140.2	160.6
Avg.		69.7	99.2	80.0	107.6	89.5	115.8	105.6	128.7	121.6	146.3	142.7	165.8
Decreasing:													
6	32	66.7	95.3	86.5	119.4	98.9	130.8	106.8	132.5	112.2	138.1	116.7	139.6
	101	66.6	98.4	85.3	120.3	99.1	128.7	106.5	131.8	112.3	135.7	120.7	142.2
	102	60.7	89.7	85.7	117.3	100.6	130.4	106.8	130.8	111.7	130.7	115.6	135.1
Avg.		64.7	94.4	85.8	119.0	99.6	129.9	106.7	131.7	112.0	134.8	117.7	138.9
8	96	68.6	96.4	91.8	120.3	109.9	136.6	123.6	143.6	134.7	156.4	145.8	166.8
	111	62.3	90.9	85.4	114.8	111.4	138.3	126.1	149.6	137.9	160.7	144.5	158.7
	116	70.5	98.1	96.8	124.1	110.9	138.9	126.2	150.5	137.6	162.8	146.1	169.5
Avg.		67.1	95.1	91.3	119.7	110.8	137.9	125.3	147.9	136.7	160.0	145.4	165.0
Unthinned:													
C	61	121.7	153.6	153.6	186.2	186.2	212.0	212.0	232.1	232.1	247.0	247.0	271.0
	105	107.7	138.3	138.3	165.9	165.9	187.3	187.3	200.0	200.0	207.7	207.7	222.7
	122	133.0	164.1	164.1	191.1	191.1	207.2	207.2	224.1	224.1	239.3	239.3	258.4
Avg.		120.8	152.0	152.0	181.1	181.1	202.2	202.2	218.7	218.7	231.3	231.3	250.7

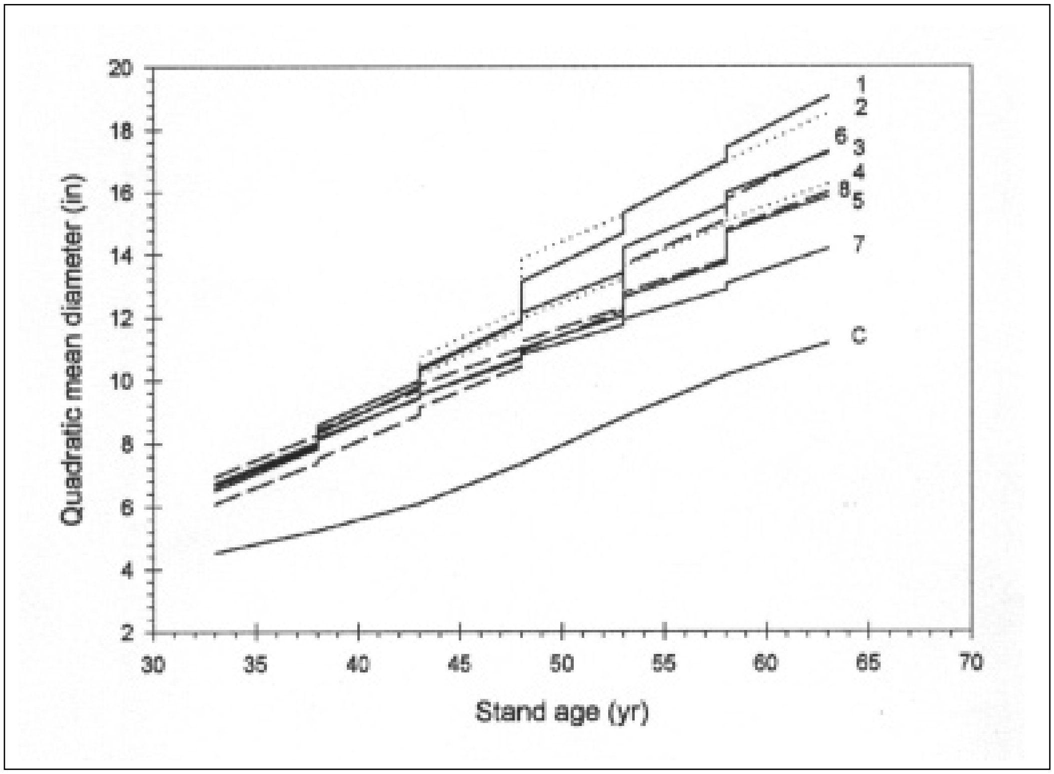

Figure 8—Trends of quadratic mean diameter over time, by treatment.

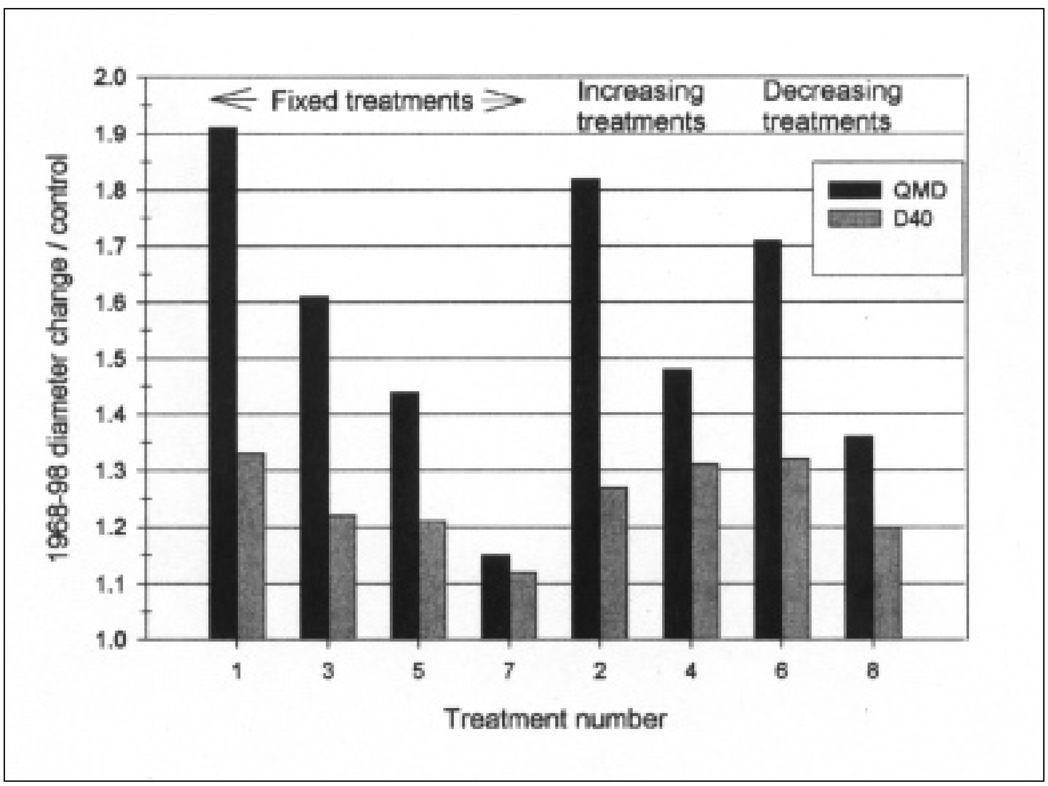

Figure 9—Thirty-year diameter increments (QMD and D40) by treatment, expressed as ratios to corresponding change on control.

Table 8–Quadratic mean diameter of all live trees, 1968-98, by treatment, plot, measurement date, and age (in parentheses)

		Quadratic mean diameter											
		Calibration period		Treatment period 1		Treatment period 2		Treatment period 3		Treatment period 4		Measurement period 5	
Treatment	Plot	1968 (33)	1973 (38)	1973 (38)	1978 (43)	1978 (43)	1983 (48)	1983 (48)	1988 (53)	1988 (53)	1993 (58)	1993 (58)	1998 (63)
		Inches											
Fixed:													
1	41	6.4	7.8	8.2	9.8	10.5	12.3	13.6	15.3	15.5	17.2	17.4	19.0
	72	6.8	8.2	8.9	10.5	10.9	12.5	14.2	15.8	16.3	18.1	18.2	20.1
	126	6.4	7.6	8.0	9.3	9.7	10.9	12.0	13.4	14.5	16.0	16.8	18.4
Avg.		6.5	7.9	8.4	9.8	10.4	11.9	13.3	14.8	15.4	17.1	17.5	19.1
3	51	6.7	8.0	8.7	10.2	10.5	12.1	12.7	14.0	15.0	16.6	16.7	18.1
	103	6.6	7.9	8.5	10.0	10.5	11.8	11.9	13.1	14.2	15.6	15.7	16.9
	121	6.7	8.0	8.5	9.8	10.2	11.7	11.9	13.2	13.5	14.8	15.6	16.8
Avg.		6.7	8.0	8.6	10.0	10.4	11.9	12.2	13.4	14.3	15.6	16.0	17.3
5	92	6.9	8.3	8.7	10.1	10.4	11.9	12.6	14.1	15.8	17.3	18.0	19.4
	114	6.5	7.8	7.9	9.1	9.2	10.2	10.2	11.1	11.7	12.7	13.9	14.7
	125	6.6	7.7	8.0	9.1	9.2	10.2	10.7	11.5	11.7	12.6	13.4	14.5
Avg.		6.7	8.0	8.2	9.5	9.6	10.8	11.1	12.2	13.0	14.2	15.1	16.2
7	62	6.8	8.2	8.3	9.6	9.7	11.1	11.4	12.4	12.7	13.7	14.0	15.4
	106	6.7	8.0	8.1	9.6	9.6	10.7	10.8	11.7	11.8	12.6	12.6	13.8
	107	6.8	8.0	8.0	9.2	9.3	10.3	10.4	11.3	11.5	12.4	12.8	13.5
Avg.		6.7	8.0	8.1	9.5	9.6	10.7	10.9	11.8	12.0	12.9	13.1	14.3
Increasing:													
2	91	6.6	7.8	8.2	9.6	10.4	11.8	12.6	13.9	13.9	15.5	15.5	17.0
	112	6.3	7.6	7.7	9.2	10.1	11.6	14.0	15.7	16.0	17.5	17.7	19.2
	113	6.8	8.3	9.2	10.8	11.9	13.5	15.4	16.7	16.7	18.3	18.3	19.7
Avg.		6.6	7.9	8.4	9.9	10.8	12.3	14.0	15.4	15.5	17.1	17.1	18.6
4	71	6.6	8.0	9.1	10.7	10.9	12.6	13.0	14.4	14.9	16.5	16.9	18.2
	82	6.2	7.5	7.8	9.2	9.8	11.2	11.6	12.8	13.3	14.7	14.7	16.0
	115	6.9	8.1	8.5	9.7	10.0	11.2	11.5	12.6	12.8	13.9	14.1	15.0
Avg.		6.6	7.9	8.4	9.9	10.2	11.7	12.0	13.3	13.7	15.0	15.2	16.4
Decreasing:													
6	32	6.0	7.2	7.3	8.6	9.1	10.4	10.7	12.0	13.7	15.2	15.9	17.4
	101	6.5	7.9	8.2	9.7	9.9	11.3	12.3	13.6	15.1	16.6	17.2	18.6
	102	5.8	7.1	7.2	8.5	8.6	9.8	10.1	11.4	12.5	13.8	14.6	16.1
Avg.		6.1	7.4	7.6	8.9	9.2	10.5	11.0	12.3	13.8	15.2	15.9	17.4
8	96	7.4	8.8	9.0	10.2	10.7	12.0	12.1	13.2	13.5	14.6	15.6	16.7
	111	6.4	7.7	8.0	9.3	9.2	10.3	10.6	11.7	12.2	13.2	14.3	15.6
	116	7.1	8.4	8.4	9.6	9.8	11.0	11.2	12.2	12.8	13.9	14.6	15.8
Avg.		7.0	8.3	8.5	9.7	9.9	11.1	11.3	12.4	12.8	13.9	14.8	16.0
Unthinned:													
C	61	4.6	5.4	5.4	6.3	6.3	7.6	7.6	9.3	9.3	10.6	10.6	12.0
	105	4.8	5.5	5.5	6.4	6.4	7.4	7.4	8.8	8.8	10.3	10.3	11.0
	122	4.3	4.9	4.9	5.7	5.7	7.1	7.1	8.4	8.4	9.7	9.7	10.6
Avg.		4.6	5.3	5.3	6.1	6.1	7.4	7.4	8.8	8.8	10.2	10.2	11.2

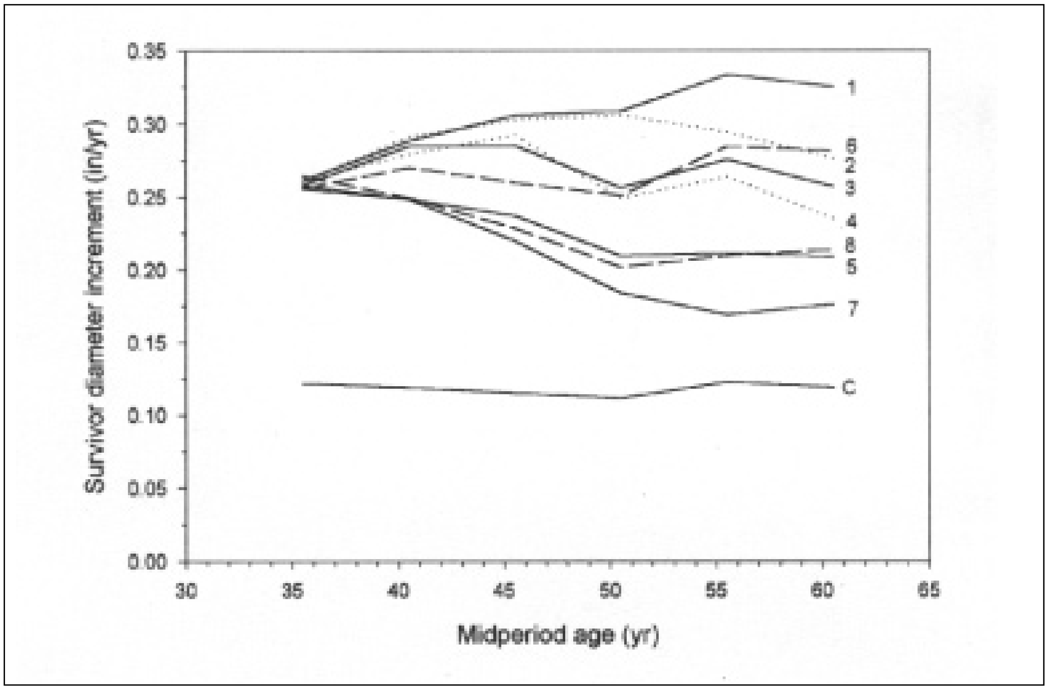

Figure 10—Survivor diameter growth by treatment and midperiod age.

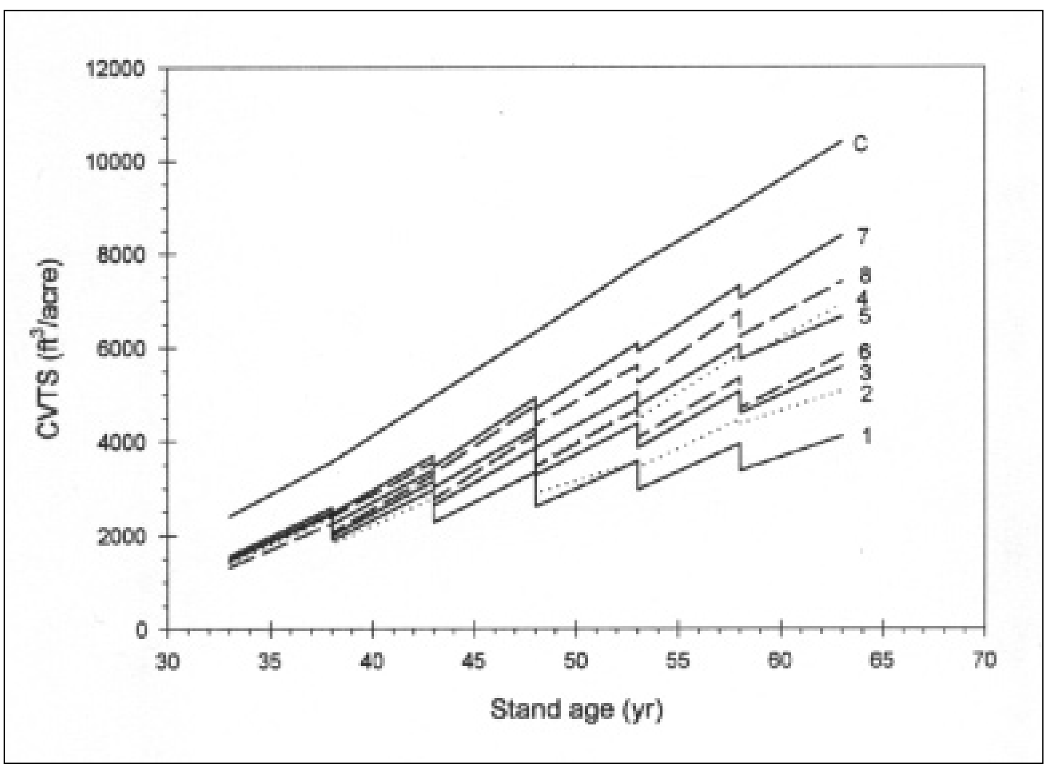

Figure 11—Trends of total cubic volume (CVTS) per acre over time, by treatments.

Table 9–Total cubic volume (CVTS) of all live trees per acre, 1968-98, by treatment, plot, measurement date, and age (in parentheses)

		Volume-total stem											
		Calibration period		Treatment period 1		Treatment period 2		Treatment period 3		Treatment period 4		Measurement period 5	
Treatment	Plot	1968 (33)	1973 (38)	1973 (38)	1978 (43)	1978 (43)	1983 (48)	1983 (48)	1988 (53)	1988 (53)	1993 (58)	1993 (58)	1998 (63)
		Cubic feet per acre											
Fixed:													
1	41	1,447	2,515	1,880	3,031	2,267	3,476	2,605	3,577	2,927	3,816	3,249	4,134
	72	1,572	2,661	1,978	3,122	2,361	3,453	2,617	3,527	2,958	3,953	3,293	3,763
	126	1,421	2,358	1,858	2,808	2,251	3,151	2,636	3,658	3,063	4,100	3,604	4,464
Avg.		1,480	2,511	1,905	2,987	2,293	3,360	2,619	3,588	2,983	3,956	3,382	4,120
3	51	1,544	2,578	2,075	3,337	2,753	4,084	3,440	4,558	3,955	5,141	4,633	5,732
	103	1,448	2,399	1,994	3,131	2,623	3,713	3,162	4,198	3,787	4,959	4,526	5,479
	121	1,452	2,402	1,974	3,043	2,599	3,785	3,271	4,422	3,900	5,116	4,658	5,583
Avg.		1,481	2,460	2,015	3,171	2,658	3,861	3,291	4,393	3,881	5,072	4,605	5,598
5	92	1,589	2,715	2,274	3,533	3,111	4,573	3,998	5,439	4,902	6,394	5,861	7,074
	114	1,406	2,361	2,222	3,314	3,031	4,188	3,776	4,882	4,675	5,808	5,647	6,130
	125	1,500	2,461	2,267	3,363	2,955	4,087	3,848	4,883	4,731	6,029	5,765	6,797
Avg.		1,498	2,512	2,254	3,403	3,032	4,282	3,874	5,068	4,770	6,077	5,758	6,667
7	62	1,559	2,619	2,471	3,722	3,428	4,938	4,662	6,047	5,880	7,432	7,138	8,645
	106	1,585	2,637	2,445	3,656	3,448	4,891	4,662	6,069	5,964	7,148	6,731	7,919
	107	1,577	2,544	2,544	3,741	3,555	5,001	4,829	6,181	5,926	7,424	7,291	8,653
Avg.		1,574	2,600	2,486	3,706	3,477	4,943	4,718	6,099	5,923	7,335	7,053	8,406
Increasing:													
2	91	1,400	2,267	1,786	2,633	2,102	3,035	2,829	3,336	3,336	4,259	4,259	4,791
	112	1,327	2,321	1,784	2,829	2,239	3,316	2,876	3,898	3,524	4,663	4,396	5,443
	113	1,513	2,598	1,918	2,933	2,549	3,641	3,013	3,465	3,465	4,488	4,488	5,012
Avg.		1,413	2,395	1,829	2,798	2,296	3,331	2,906	3,567	3,442	4,470	4,381	5,082
4	71	1,470	2,576	2,060	3,268	2,712	3,990	3,583	4,834	4,534	5,908	5,612	6,857
	82	1,363	2,387	1,992	3,126	2,633	3,959	3,523	4,705	4,431	5,913	5,913	7,273
	115	1,506	2,470	2,077	3,013	2,585	3,575	3,461	4,608	4,480	5,734	5,633	6,651
Avg.		1,446	2,477	2,043	3,136	2,643	3,841	3,522	4,716	4,482	5,852	5,719	6,927
Decreasing:													
6	32	1,343	2,257	2,066	3,290	2,784	4,222	3,492	4,749	4,128	5,462	4,655	5,879
	101	1,424	2,405	2,111	3,441	2,860	4,189	3,540	4,807	4,195	5,581	5,000	6,144
	102	1,213	2,120	2,036	3,182	2,718	4,076	3,377	4,518	3,930	5,040	4,480	5,527
Avg.		1,327	2,261	2,071	3,304	2,787	4,163	3,470	4,691	4,084	5,361	4,712	5,850
8	96	1,545	2,585	2,480	3,702	3,411	4,920	4,466	5,678	5,360	6,873	6,487	7,773
	111	1,352	2,347	2,231	3,372	3,267	4,609	4,245	5,520	5,148	6,579	6,011	6,954
	116	1,567	2,575	2,545	3,663	3,300	4,784	4,372	5,684	5,260	6,883	6,242	7,524
Avg.		1,488	2,502	2,419	3,579	3,326	4,771	4,361	5,627	5,256	6,778	6,247	7,417
Unthinned:													
C	61	2,455	3,654	3,654	5,175	5,175	6,780	6,780	8,415	8,415	9,823	9,823	11,493
	105	2,211	3,316	3,316	4,609	4,609	5,917	5,917	7,088	7,088	8,136	8,136	9,206
	122	2,587	3,774	3,774	5,099	5,099	6,301	6,301	7,835	7,835	9,205	9,205	10,555
Avg.		2,417	3,581	3,581	4,961	4,961	6,333	6,333	7,779	7,779	9,055	9,055	10,418

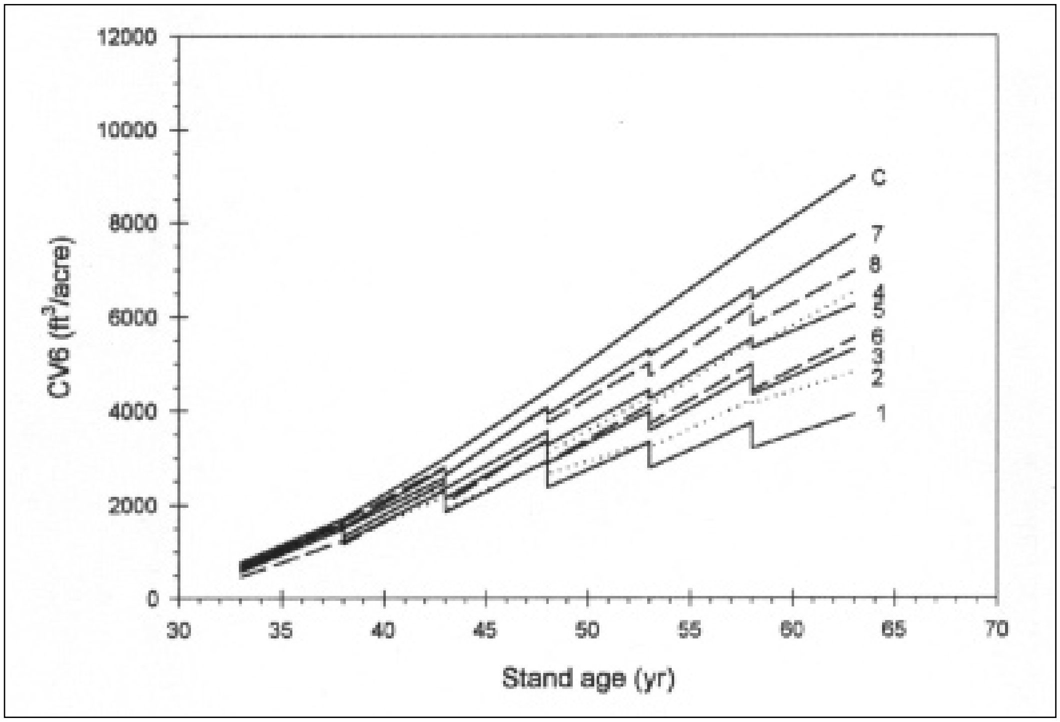

Figure 12—Trends of merchantable cubic volume to a 6-inch top (CV6) over time, by treatments.

Total cubic volume (CVTS)—Trends in standing cubic volume of total stem inside bark, by treatment, are shown in figure 11, with numerical values given in table 9.

Merchantable cubic volume—Trends in standing merchantable cubic volume (CV6) to a 6-inch top diameter inside bark (d.i.b.), by treatment, are shown in figure 12; numerical values are in table 10.

Board-foot volume (SV6)—General trends are more or less similar to those in CV6 (table 11), and we do not emphasize board feet in this report; we will later point out some comparisons of interest. Where shown, volumes are for 32-foot logs, with a minimum top log length of 16 feet, to a 6-inch top.

Table 10–Merchantable cubic volume (CV6) of all live trees per acre, 1968-98, by treatment, plot, measurement date, and age (in parentheses)

		Volume to a 6-inch top											
		Calibration period		Treatment period 1		Treatment period 2		Treatment period 3		Treatment period 4		Measurement period 5	
Treatment	Plot	1968 (33)	1973 (38)	1973 (38)	1978 (43)	1978 (43)	1983 (48)	1983 (48)	1988 (53)	1988 (53)	1993 (58)	1993 (58)	1998 (63)
		Cubic feet per acre											
Fixed:													
1	41	504	1,496	1,179	2,349	1,854	3,094	2,396	3,361	2,755	3,626	3,088	3,948
	72	746	1,758	1,414	2,564	1,995	3,084	2,430	3,329	2,801	3,768	3,140	3,600
	126	506	1,292	1,114	2,060	1,720	2,627	2,321	3,331	2,851	3,871	3,423	4,259
Avg.		586	1,515	1,236	2,325	1,856	2,935	2,382	3,340	2,802	3,755	3,217	3,935
3	51	627	1,561	1,396	2,660	2,254	3,601	3,074	4,186	3,703	4,868	4,392	5,460
	103	576	1,459	1,318	2,464	2,138	3,239	2,767	3,795	3,518	4,668	4,266	5,199
	121	608	1,484	1,294	2,363	2,086	3,282	2,860	4,007	3,559	4,756	4,382	5,292
Avg.		604	1,501	1,336	2,496	2,160	3,374	2,900	3,996	3,593	4,764	4,346	5,317
5	92	755	1,747	1,547	2,770	2,494	3,953	3,551	4,979	4,603	6,061	5,575	6,753
	114	740	1,573	1,525	2,540	2,361	3,465	3,129	4,187	4,115	5,237	5,184	5,677
	125	684	1,505	1,467	2,489	2,217	3,300	3,171	4,184	4,076	5,353	5,235	6,287
Avg.		726	1,608	1,513	2,600	2,357	3,572	3,284	4,450	4,265	5,550	5,332	6,239
7	62	656	1,635	1,560	2,836	2,647	4,152	3,985	5,362	5,254	6,784	6,563	8,089
	106	663	1,621	1,546	2,791	2,642	4,054	3,892	5,278	5,193	6,385	6,003	7,218
	107	626	1,532	1,532	2,736	2,629	4,052	3,942	5,292	5,135	6,633	6,555	7,903
Avg.		648	1,596	1,546	2,788	2,639	4,086	3,939	5,310	5,194	6,601	6,374	7,737
Increasing:													
2	91	624	1,358	1,124	1,977	1,687	2,616	2,522	3,049	3,049	3,976	3,976	4,521
	112	573	1,389	1,119	2,098	1,797	2,869	2,654	3,667	3,322	4,433	4,182	5,198
	113	861	1,830	1,485	2,509	2,259	3,336	2,834	3,287	3,287	4,279	4,279	4,791
Avg.		686	1,526	1,243	2,195	1,914	2,940	2,670	3,334	3,219	4,229	4,145	4,836
4	71	593	1,609	1,475	2,723	2,295	3,597	3,255	4,498	4,257	5,601	5,337	6,544
	82	500	1,392	1,171	2,294	2,042	3,379	3,070	4,258	4,044	5,511	5,511	6,849
	115	639	1,499	1,362	2,318	2,039	3,034	2,988	4,124	4,039	5,270	5,188	6,189
Avg.		577	1,500	1,336	2,445	2,125	3,337	3,104	4,293	4,113	5,461	5,345	6,528
Decreasing:													
6	32	380	1,109	1,053	2,218	2,011	3,434	2,906	4,154	3,787	5,111	4,390	5,588
	101	621	1,451	1,331	2,629	2,243	3,552	3,115	4,368	3,918	5,275	4,746	5,860
	102	423	1,169	1,144	2,210	1,908	3,199	2,703	3,860	3,490	4,604	4,151	5,203
Avg.		474	1,243	1,176	2,352	2,054	3,395	2,908	4,127	3,732	4,997	4,429	5,550
8	96	803	1,795	1,756	2,979	2,833	4,310	3,931	5,146	4,886	6,364	6,085	7,337
	111	693	1,590	1,557	2,654	2,565	3,852	3,585	4,853	4,607	6,002	5,578	6,517
	116	693	1,670	1,661	2,826	2,576	4,040	3,730	5,039	4,755	6,350	5,805	7,069
Avg.		729	1,685	1,658	2,820	2,658	4,067	3,749	5,013	4,750	6,239	5,823	6,974
Unthinned:													
C	61	688	1,687	1,687	3,122	3,122	4,863	4,863	6,651	6,651	8,386	8,386	10,195
	105	797	1,662	1,662	2,847	2,847	4,146	4,146	5,421	5,421	6,709	6,709	7,861
	122	856	1,790	1,790	3,005	3,005	4,280	4,280	5,903	5,903	7,470	7,470	8,952
Avg.		780	1,713	1,713	2,991	2,991	4,430	4,430	5,992	5,992	7,522	7,522	9,003

Table 11–Scribner board-foot volume (SV6) of all live trees per acre, 1968-98, by treatment, plot, measurement date, and age (in parentheses)

		Volume to a 6-inch top, 32-foot logs											
		Calibration period		Treatment period 1		Treatment period 2		Treatment period 3		Treatment period 4		Measurement period 5	
Treatment	Plot	1968 (33)	1973 (38)	1973 (38)	1978 (43)	1978 (43)	1983 (48)	1983 (48)	1988 (53)	1988 (53)	1993 (58)	1993 (58)	1998 (63)
		Scribner board feet per acre											
Fixed:													
1	41	838	5,880	4,656	8,626	6,533	12,485	9,652	13,765	11,180	14,903	12,759	17,861
	72	2,131	6,453	5,159	9,255	7,130	12,246	9,551	13,744	11,539	15,600	13,328	16,670
	126	1,424	4,293	3,712	7,608	6,307	10,608	9,199	13,544	11,591	17,042	15,173	19,240
Avg.		1,464	5,542	4,509	8,496	6,657	11,780	9,467	13,684	11,437	15,848	13,753	17,924
3	51	1,794	5,277	4,903	10,166	8,542	14,303	12,265	16,981	14,950	20,469	18,681	24,922
	103	1,511	5,270	4,826	8,672	7,506	12,175	10,443	15,410	14,328	19,633	17,910	22,520
	121	1,474	5,456	4,751	9,094	7,896	13,139	11,578	16,645	14,728	20,927	19,180	23,863
Avg.		1,593	5,334	4,826	9,311	7,981	13,206	11,429	16,345	14,669	20,343	18,590	23,768
5	92	1,997	5,799	5,056	10,194	9,217	15,406	13,703	21,134	19,416	26,589	24,444	31,592
	114	2,302	5,381	5,238	9,118	8,472	13,418	12,025	16,670	16,370	22,841	22,598	25,744
	125	1,995	5,005	5,005	9,600	8,428	13,115	12,612	17,378	16,877	22,999	22,496	27,967
Avg.		2,098	5,395	5,100	9,637	8,706	13,979	12,780	18,394	17,554	24,143	23,179	28,434
7	62	1,720	5,835	5,505	10,603	9,850	17,464	16,774	22,857	22,355	29,197	28,231	37,208
	106	1,670	5,919	5,607	10,817	10,315	16,788	16,074	23,440	23,040	29,554	27,879	34,037
	107	1,339	5,904	5,904	10,977	10,445	16,693	16,299	23,266	22,590	29,587	29,229	36,452
Avg.		1,576	5,886	5,672	10,799	10,203	16,982	16,382	23,188	22,661	29,446	28,446	35,899
Increasing:													
2	91	1,753	4,480	3,772	6,982	5,785	10,077	9,759	12,074	12,074	16,822	16,822	19,619
	112	1,507	4,988	4,037	7,174	6,197	10,891	10,121	14,607	13,113	19,435	18,364	23,898
	113	2,602	6,419	5,311	9,208	8,241	13,158	11,404	13,501	13,501	18,996	18,996	22,094
Avg.		1,954	5,296	4,374	7,788	6,741	11,375	10,428	13,394	12,896	18,418	18,061	21,870
4	71	1,724	5,048	4,936	9,570	8,044	14,075	12,785	17,986	16,946	24,034	22,993	29,527
	82	1,199	5,104	4,235	8,357	7,411	13,027	11,716	17,306	16,409	24,189	24,189	30,430
	115	1,905	5,340	4,865	8,604	7,458	12,108	11,896	16,875	16,462	22,477	22,189	27,467
Avg.		1,609	5,164	4,679	8,844	7,638	13,070	12,132	17,389	16,606	23,567	23,124	29,141
Decreasing:													
6	32	1,076	3,711	3,593	7,941	7,335	13,125	11,104	17,790	16,285	22,014	18,854	24,994
	101	1,694	4,793	4,469	9,410	7,920	13,814	12,136	18,445	16,640	22,907	20,663	26,918
	102	1,244	3,833	3,833	7,788	6,784	12,405	10,437	15,553	13,937	19,617	17,507	22,523
Avg.		1,338	4,112	3,965	8,379	7,346	13,115	11,225	17,263	15,621	21,513	19,008	24,812
8	96	2,538	5,999	5,874	11,493	10,974	17,891	16,380	21,703	20,674	28,978	27,722	34,186
	111	2,003	5,729	5,579	9,788	9,500	15,193	14,125	20,662	19,716	26,957	25,033	30,353
	116	1,844	6,048	6,048	10,976	9,842	17,179	15,815	21,596	20,204	28,037	25,707	32,760
Avg.		2,128	5,925	5,833	10,753	10,105	16,754	15,440	21,321	20,198	27,990	26,154	32,433
Unthinned:													
C	61	1,874	6,385	6,385	11,974	11,974	20,266	20,266	28,682	28,682	37,400	37,400	45,825
	105	2,388	5,141	5,141	10,754	10,754	16,661	16,661	23,353	23,353	30,330	30,330	35,735
	122	2,730	6,296	6,296	10,880	10,880	17,173	17,173	25,796	25,796	33,404	33,404	40,300
Avg.		2,331	5,941	5,941	11,203	11,203	18,033	18,033	25,943	25,943	33,711	33,711	40,620

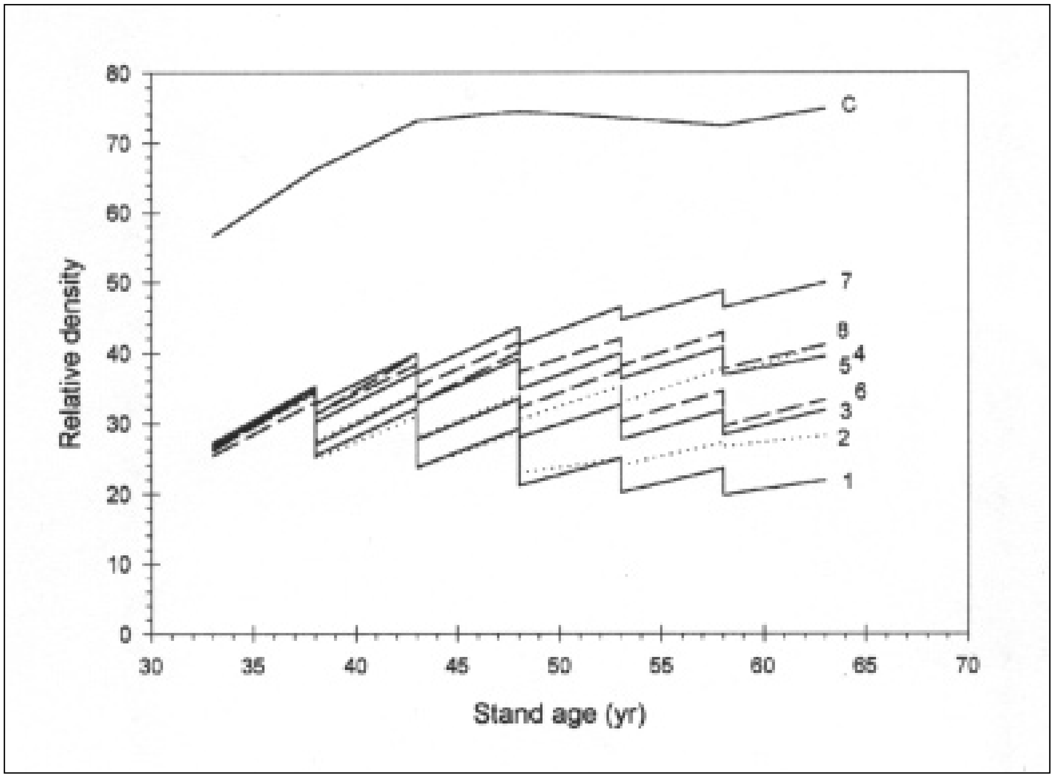

Figure 13—Trends of relative density (Curtis 1982) over time, by treatments.

Relative Density Measures

Relative density measures are useful in describing thinning regimes, as guides for density control, as values interpretable as measures of competition, and as predictors of growth. Here, treatments are compared by using two common relative density measures that are nearly equivalent, except for scale factors.These are Curtis' (1982) relative density (RD) and Reineke's (1933) stand density index (SDI).

Relative density—Relative density (RD) is defined by the equation,

$$RD = \text{basal area} \;/\; \sqrt{QMD} \,,$$

and is merely a rearrangement of Reineke's equation (with a slight difference in exponent) into a form that some find easier to use.

Figure 13 displays trends of RD over time for the various thinning regimes. The corresponding trends for the control are useful as reference points for thinning regimes (that is, their relation to "maximum"), and the asymptote represents an estimate of the maximum attainable density in an unthinned stand at this location.

Because the stand is nearly pure Douglas-fir and lacks the understory of tolerant species found at some other LOGS sites, RD values are unaffected by the biases introduced when such an understory is present, as at the Iron Creek LOGS installation (Curtis and Clendenen 1994).

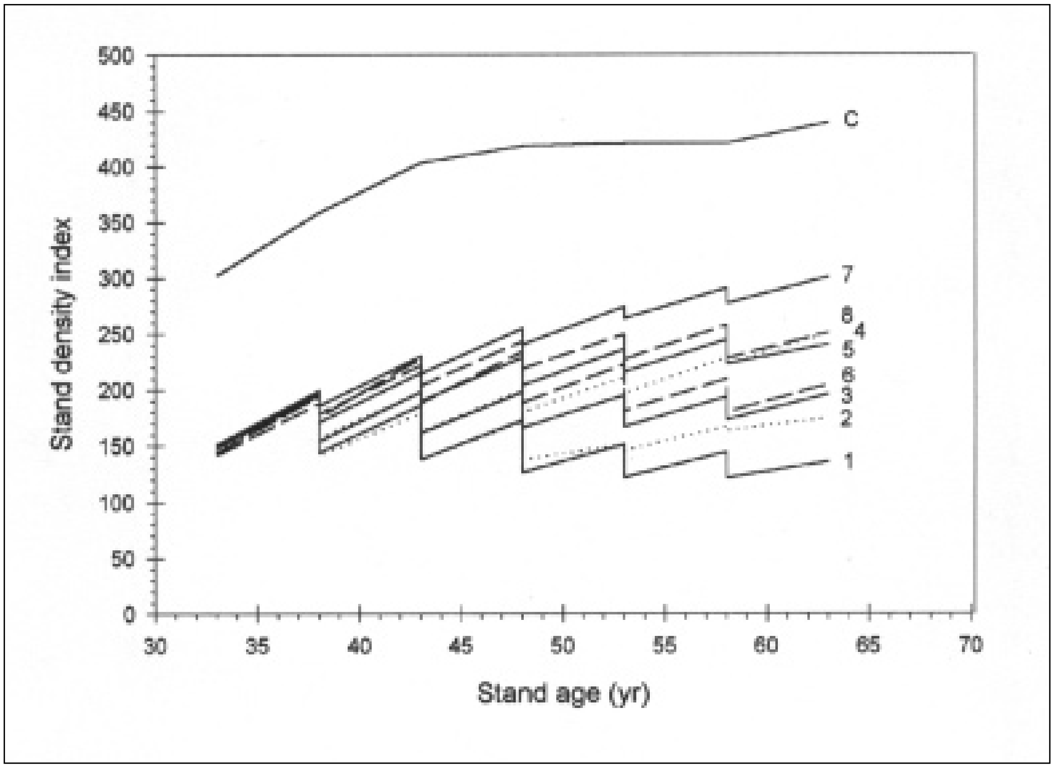

Figure 14—Trends of stand density index (Reineke 1933) over time, by treatments.

Stand density index—Figure 14 shows trends of SDI over time for the various thinning treatments. The control plots appear to be approaching a maximum in the vicinity of SDI 500.

Crown Development

From regressions of live crown ratio on d.b.h. fit separately for each treatment and measurement date, live crown ratios were estimated corresponding to (1) D40, mean diameter of the largest 40 trees per acre; and (2) QMD, the quadratic mean diameter of all trees. From these values and corresponding estimated heights, values also were calculated for live crown length and height to live crown. The resulting values for the most recent measurement, 1998, are shown in figures 15, 16, and 17.

Estimates of crown ratio and crown length are inherently imprecise, primarily because of the difficulty in defining base of live crown in a way that gives consistent successive measurements. Despite considerable resulting variation, the general trends shown are clear. Within each treatment category (fixed, increasing, decreasing) crown ratios and live crown lengths decline and heights to live crown increase as stocking level increases with lighter thinning. Crown ratios and crown lengths are consistently greater for the largest 40 trees per acre than for all trees, but the corresponding differences in heights to live crown are slight.

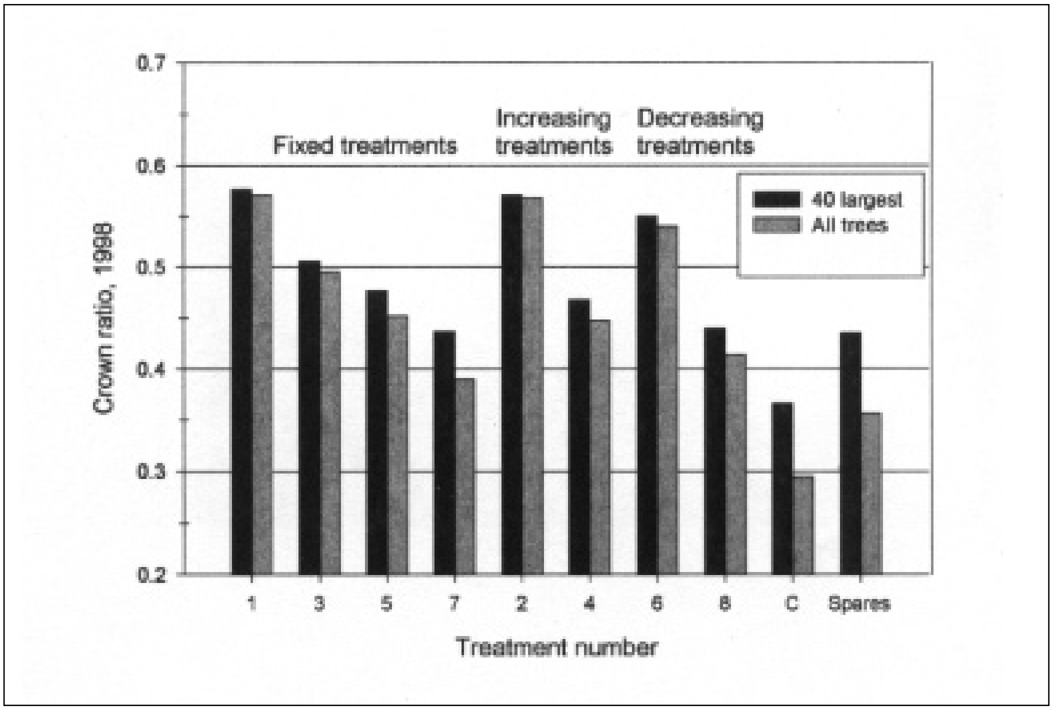

Figure 15—Live crown ratios, 1998, by treatments; means of 40 largest trees per acre and of all trees.

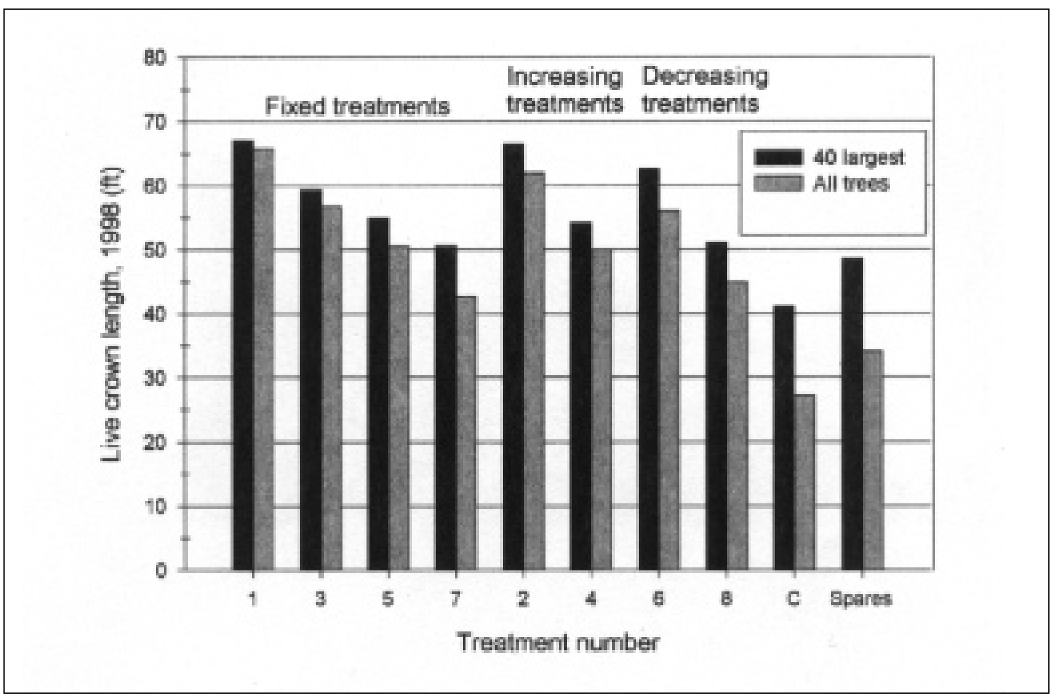

Figure 16—Live crown lengths, 1998, by treatments; means of 40 largest trees per acre and of all trees.

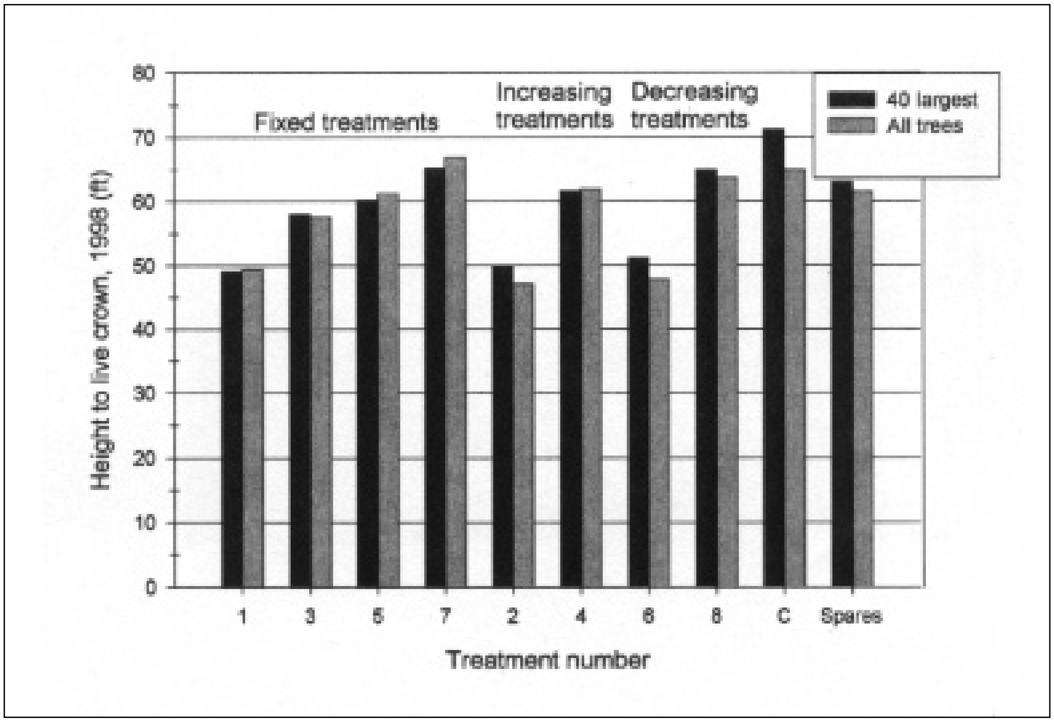

Figure 17—Heights to live crown, 1998, by treatments; means of 40 largest trees per acre and of all trees.

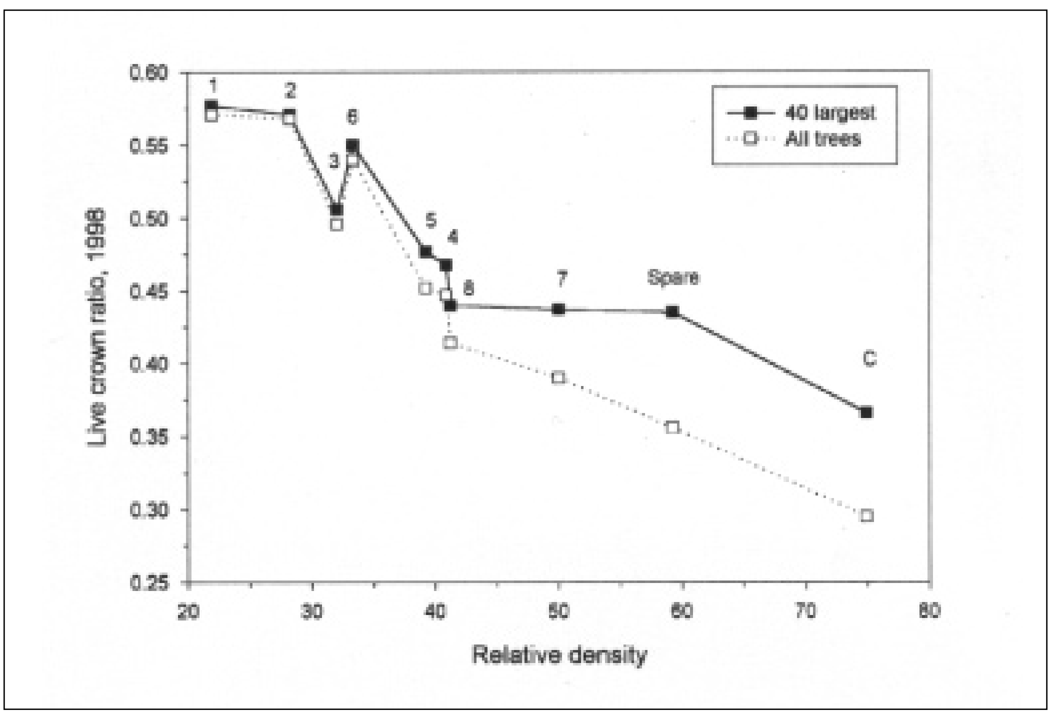

Figure 18—Live crown ratios in relation to relative density, 1998, by treatments, for 40 largest trees per acre and for all trees.

Crown ratios are likewise strongly related to relative density (fig. 18), with values for the 40 largest trees per acre and for all trees diverging sharply as stand density increases. There are similar relations (not shown) with basal area. Elevations of these curves differ at successive measurements. Thus, neither relative density nor basal area, considered alone, is an adequate predictor of crown ratio across measurement dates.

Mortality

The stand was initially of rather low density, and although the control is now well within the zone of competition-related mortality (figs. 14 and 15), relative density still is not extremely high. Although the control has had appreciable mortality in number of stems and basal area (table 12) and in volume (table 13), most of this has been fairly uniform over time and confined mainly to the smallest trees, whose loss has not had a major effect on volume and volume increment statistics.

All thinning treatments are well below densities at which competition-related mortality would be expected. There has been fairly severe episodic mortality in plots 91 and 113 in treatment 2 in 1983-88 and 1993-98, and in plot 114 in treatment 5 in 1993-98. This was due mostly to root rot and root rot-related windthrow, which removed a few large trees. On these small plots, loss of even a single large tree introduces large fluctuations in estimates of net periodic annual increment in basal area and in volume. This is a major contributor to the somewhat erratic variations in trends in graphs to be presented.

Cut

Statistics for cut trees, by treatment, period, and unit of measure, are given in tables 14 and 15. The mean of d/D (ratio of diameter of cut trees to diameter of all trees before cutting), over all thinning treatments and periods, was 0.81, with no clear trends over time or treatment. This value is considerably less than in other LOGS installations; reasons for this difference are unclear. It may be related to the fact that the initial stand was relatively open, of natural origin, and considerably taller than other LOGS installations and therefore might have had a wider initial range of diameters.

Cumulative Volume Production

Net total cubic volume—Trends of cumulative net total cubic volume (CVTS) are shown in figure 19. This is the sum of 1998 CVTS + CVTS removed in thinnings and does not include mortality (which was small except on treatment 2 and in the control).

The values shown do not include the volume removed in the calibration cut, which—estimated as the difference between mean of controls and mean postcalibration value of thinned plots—was 954 cubic feet per acre. *If this is included, there is little difference in cumulative CVTS production between treatments 7, 8, and the control.*

The apparent greater production of treatment 1 compared to treatment 2 is the reverse of the relation observed in other LOGS installations, where treatment 2 consistently has given somewhat higher production than treatment 1. The anomalous position of treatment 2 in this and other graphs apparently was caused by mortality, principally root disease and root disease-related windfall.

Table 12–Number, diameter, and basal area of trees recorded as dead at end of each period, by treatment, measurement date, and age (in parentheses)

Treatment	End of period: 1973 (38)	1978 (43)	1983 (48)	1988 (53)	1993 (58)	1998 (63)	Total
				Trees per acre			
Fixed:							
1	2	2	0	0	0	2	6
3	2	0	2	0	0	0	4
5	2	0	0	0	2	5	9
7	2	8	2	0	5	8	25
Increasing:							
2	3	5	0	5	2	5	20
4	5	3	2	0	0	0	10
Decreasing:							
6	3	3	0	2	2	2	12
8	0	2	0	3	0	3	8
Unthinned:							
C	65	118	205	170	105	43	706
				Quadratic mean diameter *Inches*			
Fixed:							
1	5.74	2.65	0.00	0.00	0.00	15.61	9.72
3	5.74	0.00	3.13	0.00	0.00	0.00	4.62
5	3.36	0.00	0.00	0.00	6.21	12.90	10.18
7	2.82	4.48	4.39	0.00	10.93	6.87	6.90
Increasing:							
2	6.76	7.51	0.00	15.66	7.31	14.84	11.94
4	4.69	7.54	9.40	0.00	0.00	0.00	6.76
Decreasing:							
6	3.78	3.75	0.00	8.03	11.23	6.75	6.82
8	0.00	6.21	0.00	5.97	0.00	10.05	7.80
Unthinned:							
C	2.36	2.63	2.89	3.33	5.01	5.25	3.49
				Basal area *Square feet per acre*			
Fixed:							
1	0.36	0.08	0.00	0.00	0.00	2.66	3.09
3	0.36	0.00	0.11	0.00	0.00	0.00	0.47
5	0.12	0.00	0.00	0.00	0.42	4.54	5.08
7	0.09	0.88	0.21	0.00	3.26	2.06	6.49
Increasing:							
2	0.75	1.54	0.00	6.69	0.58	6.01	15.56
4	0.60	0.93	0.96	0.00	0.00	0.00	2.49
Decreasing:							
6	0.23	0.23	0.00	0.70	1.38	0.50	3.04
8	0.00	0.42	0.00	0.58	0.00	1.65	2.66
Unthinned:							
C	1.97	4.45	9.35	10.27	14.36	6.47	46.86

Table 13–Volume of trees recorded as dead at end of each period, by treatment, measurement date, and age (in parentheses)

Treatment	End of period: 1973 (38)	1978 (43)	1983 (48)	1988 (53)	1993 (58)	1998 (63)	Total
			Volume *Cubic feet per acre*				
Fixed:							
1	8.1	0.7	0.0	0.0	0.0	113.2	122.0
3	7.6	0.0	1.5	0.0	0.0	0.0	9.1
5	1.7	0.0	0.0	0.0	12.1	185.0	198.8
7	1.3	17.3	4.6	0.0	132.8	64.5	220.5
Increasing:							
2	18.0	35.5	0.0	260.1	16.6	257.5	587.7
4	11.0	24.8	30.25	0.0	0.0	0.0	66.0
Decreasing:							
6	3.4	3.5	0.0	21.9	50.9	13.8	93.5
8	0.0	10.0	0.0	13.3	0.0	65.8	89.0
Unthinned:							
C	22.4	63.4	149.5	192.4	386.4	186.2	1,000.4
			Volume to a 6-inch top *Cubic feet per acre*				
Fixed:							
1	0.8	0.0	0.0	0.0	0.0	107.7	108.5
3	0.8	0.0	0.0	0.0	0.0	0.0	0.8
5	0.0	0.0	0.0	0.0	3.0	166.3	169.3
7	0.0	0.0	0.0	0.0	116.4	30.6	147.1
Increasing:							
2	11.2	15.8	0.0	243.6	8.8	239.3	518.7
4	0.8	17.7	24.3	0.0	0.0	0.0	42.7
Decreasing:							
6	0.0	0.0	0.0	14.4	45.7	5.6	65.6
8	0.0	2.5	0.0	0.3	0.0	58.8	61.6
Unthinned:							
C	0.0	10.6	6.4	13.7	100.2	58.9	189.8
			Volume *Scribner board feet per acre*				
Fixed:							
1	0.0	0.0	0.0	0.0	0.0	453.5	453.5
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	714.6	714.6
7	0.0	0.0	0.0	0.0	537.9	144.1	682.0
Increasing:							
2	50.0	35.4	0.0	1,029.4	45.8	1,059.1	2,219.7
4	0.0	83.7	96.0	0.0	0.0	0.0	179.7
Decreasing:							
6	0.0	0.0	0.0	83.7	210.9	0.0	294.6
8	0.0	0.0	0.0	0.0	0.0	250.7	250.7
Unthinned:							
C	0.0	52.0	0.0	43.7	463.5	265.6	824.9

Table 14–Number, diameter, and basal area of trees cut, by treatment, period, measurement date, and age (in parentheses)

Treatment	1973 (38)	1978 (43)	1983 (48)	1988 (53)	1993 (58)	Total
	End of period:					
			Trees per acre			
Fixed:						
1	100	60	50	20	12	242
3	90	47	28	27	13	205
5	47	32	30	27	27	163
7	18	20	18	13	13	82
Increasing:						
2	93	62	42	3	2	202
4	83	47	22	15	5	172
Decreasing:						
6	38	57	55	52	22	224
8	20	25	27	25	32	129
Unthinned:						
C	0	0	0	0	0	0
			Quadratic mean diameter *Inches*			
Fixed:						
1	6.8	8.6	9.4	12.5	14.9	8.9
3	6.4	8.5	10.7	10.1	13.1	8.6
5	6.6	8.6	8.9	8.1	8.0	7.9
7	6.8	8.5	8.5	8.5	10.1	8.4
Increasing:						
2	6.9	7.6	8.2	14.2	13.8	7.6
4	6.5	8.4	9.2	9.4	11.5	7.9
Decreasing:						
6	6.4	7.9	8.8	8.3	12.0	8.5
8	5.9	8.1	9.3	9.0	9.1	8.5
Unthinned:						
C	0.0	0.0	0.0	0.0	0.0	0.0
			Basal area *Square feet per acre*			
Fixed:						
1	25.2	24.4	23.9	17.0	14.6	105.0
3	20.1	18.5	17.6	15.0	12.2	83.4
5	11.1	12.9	12.9	9.5	9.5	56.0
7	4.6	7.9	7.1	5.1	7.2	31.9
Increasing:						
2	24.1	19.3	15.4	3.3	2.1	64.2
4	19.3	18.0	10.2	7.2	3.6	58.3
Decreasing:						
6	8.6	19.4	23.3	19.6	17.2	88.1
8	3.8	9.0	12.7	11.1	14.5	51.0
Unthinned:						
C	0.0	0.0	0.0	0.0	0.0	0.0

Table 15–Volume of trees cut, by treatment, period, measurement date, and age (in parentheses)

Treatment	End of period: 1973 (38)	1978 (43)	1983 (48)	1988 (53)	1993 (58)	Total
			Volume *Cubic feet per acre*			
Fixed:						
1	606	694	741	605	574	3,220
3	445	512	570	512	466	2,506
5	258	371	408	298	320	1,655
7	113	229	225	176	281	1,025
Increasing:						
2	566	502	424	125	89	1,706
4	434	492	319	234	132	1,612
Decreasing:						
6	189	517	693	607	649	2,656
8	84	253	410	371	532	1,649
Unthinned:						
C	0	0	0	0	0	0
			Volume to a 6-inch top *Cubic feet per acre*			
Fixed:						
1	280	468	553	538	538	2,377
3	165	336	474	403	418	1,796
5	95	242	289	185	219	1,030
7	50	148	147	117	227	689
Increasing:						
2	283	280	270	115	84	1,032
4	164	320	233	180	115	1,012
Decreasing:						
6	67	298	487	395	568	1,816
8	27	162	319	263	416	1,186
Unthinned:						
C	0	0	0	0	0	0
			Volume *Scribner board feet per acre*			
Fixed:						
1	1,033	1,839	2,312	2,248	2,095	9,527
3	508	1,330	1,777	1,677	1,752	7,043
5	296	931	1,199	839	964	4,230
7	214	596	599	526	1,000	2,936
Increasing:						
2	922	1,047	948	498	357	3,772
4	485	1,206	938	783	443	3,855
Decreasing:						
6	148	1,033	1,889	1,642	2,505	7,217
8	92	647	1,314	1,122	1,836	5,012
Unthinned:						
C	0	0	0	0	0	0

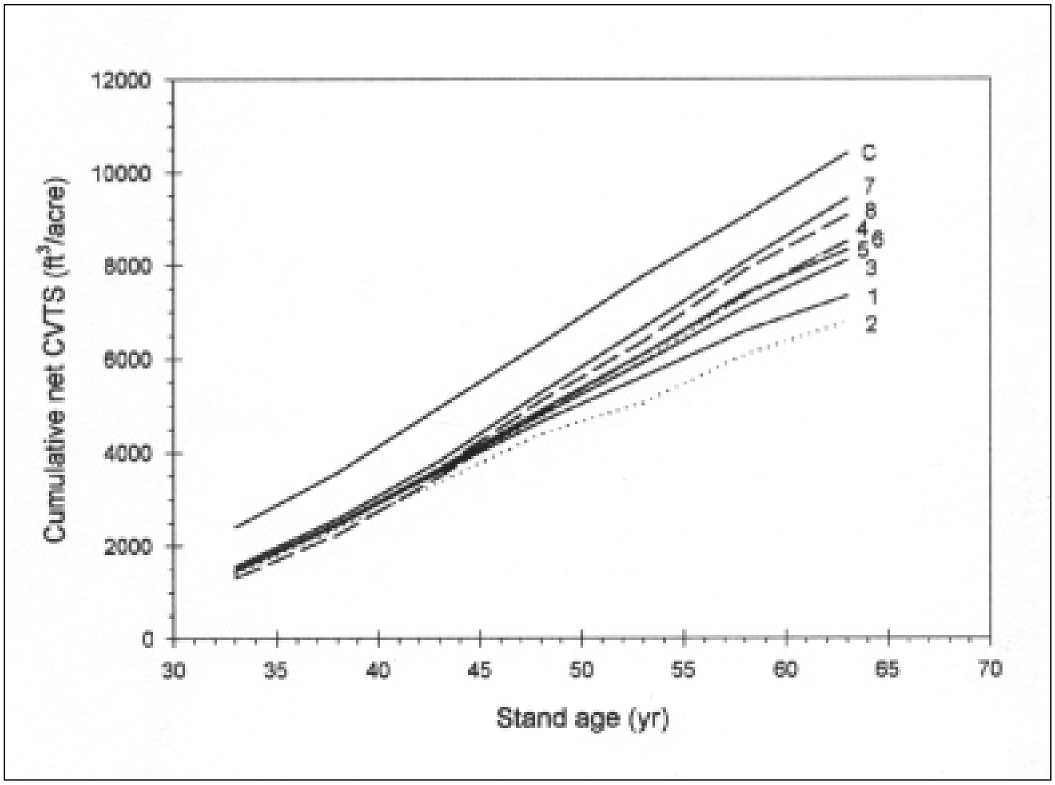

Figure 19—Trends of cumulative net total cubic volume (CVTS) production (standing volume + past thinnings) over time, by treatments.

Net merchantable cubic volume—Trends of cumulative net merchantable cubic volume (CV6) are shown in figure 20. Values are the sum of 1998 CV6 + CV6 removed in thinnings and do not include mortality (which was substantial in treatment 2). Average CV6 removed in the calibration cut was small (151 cubic feet per acre) and is not included. The general pattern of relations among treatments is similar to that for CVTS.

Ratios of thinning volumes to cumulative net production—Cumulative volumes cut in thinnings (excluding calibration), expressed as ratios to cumulative net yield as of 1998, are shown for CVTS and CV6 in the following tabulation:

Treatment	CVTS	CV6
Fixed:		
1	0.44	0.38
3	0.31	0.25
5	0.20	0.14
7	0.11	0.08
Increasing:		
2	0.25	0.18
4	0.19	0.13
Decreasing:		
6	0.31	0.25
8	0.18	0.14

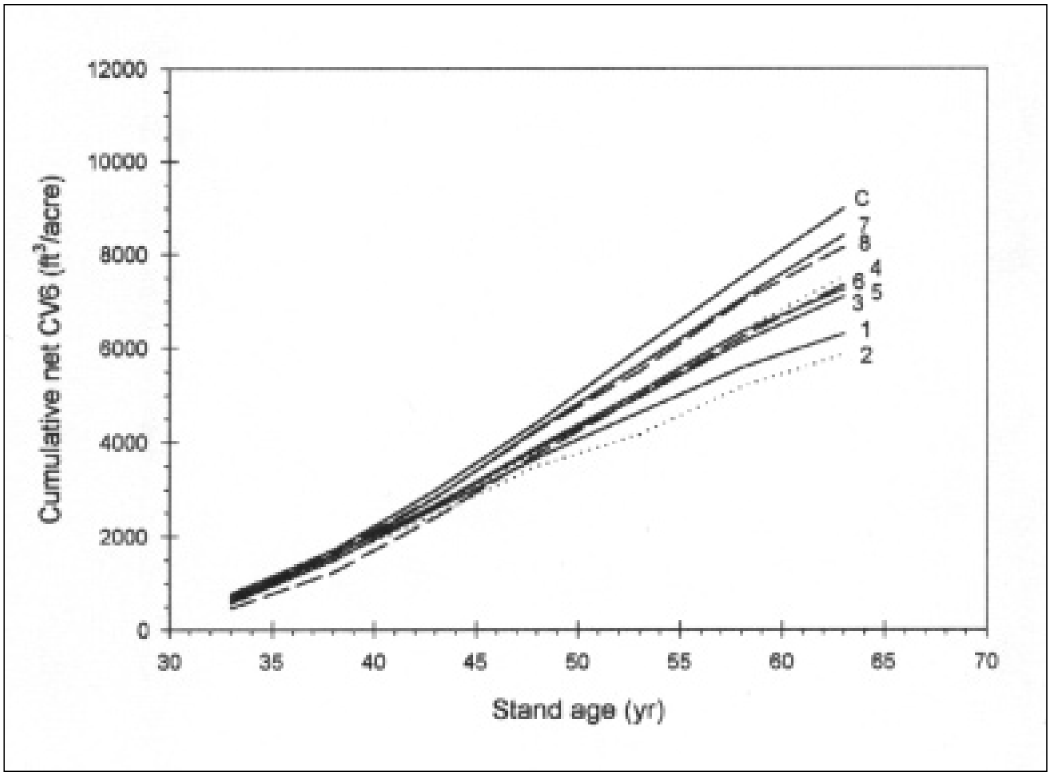

Figure 20—Trends of cumulative net merchantable cubic volume (CV6) production (standing volume + past thinnings) over time, by treatments.

Volume Distribution by Log Size Classes

Distributions of CV6 by log size classes are shown in figure 21 and table 16 as percentages of standing volume in live trees by 2-inch log diameter classes as of the end of the fifth treatment period (1998). Table 17 shows percentages of cumulative thinning volumes by 2-inch log diameter classes. Tables 18 and 19 give corresponding values for board-foot volumes (SV6).

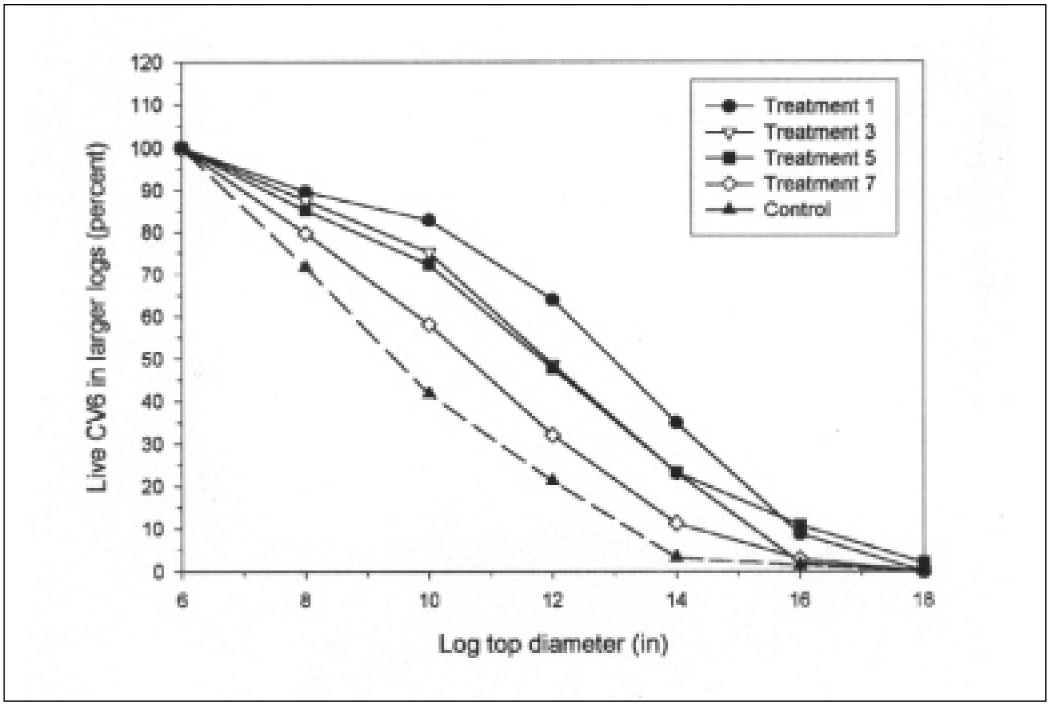

Figure 21—Percentage distribution of live merchantable cubic volume (CV6) in 1998, by log diameter classes for fixed treatments and control.

Table 16–Percentage of merchantable cubic volume (CV6) of live trees, 1998, in logs with scaling diameters larger than indicated value

Treatment	Scaling diameter (inches): 6	8	10	12	14	16	18	Total live CV6
	Percent							*Ft³/acre*
Fixed:								
1	100	89.8	82.9	64.1	35.0	8.8	0	3,935
3	100	87.6	75.2	48.7	23.3	2.1	0	5,317
5	100	85.3	72.3	47.8	23.3	10.8	2.1	6,239
7	100	79.8	58.1	32.1	11.4	3.0	0	7,737
Increasing:								
2	100	88.7	79.1	61.1	36.9	12.2	5.5	4,836
4	100	83.7	73.5	45.7	25.1	1.6	0	6,528
Decreasing:								
6	100	87.5	74.1	52.0	23.8	6.8	2.5	5,550
8	100	85.3	71.2	47.9	22.1	5.4	1.9	6,974
Unthinned:								
C	100	71.7	41.7	21.2	3.2	1.4	0	9,003

Table 17–Percentage of merchantable cubic volume (CV6) of trees removed in thinnings, in logs with scaling diameters larger than indicated value

	Scaling diameter (inches):							
Treatment	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**Total cut CV6**
	Percent							*Ft* ^{3}*/acre*
Fixed:								
1	100	54.5	33.2	15.6	6.1	0	0	2,377
3	100	53.2	25.5	10.0	2.3	0	0	1,796
5	100	53.7	22.5	13.2	3.0	1.6	0	1,030
7	100	41.7	22.8	10.6	2.5	0	0	689
Increasing:								
2	100	67.2	50.3	28.4	21.3	3.9	2.8	1,032
4	100	54.8	38.3	19.3	8.2	0	0	1,012
Decreasing:								
6	100	50.5	30.9	20.3	8.1	5.3	0	1,816
8	100	57.2	26.1	9.5	3.3	1.8	0	1,186
Unthinned:								
C	100	0	0	0	0	0	0	0

Table 18–Percentage of merchantable board-foot volume (SV6) of live trees, 1998, in logs with scaling diameters larger than indicated value

	Scaling diameter (inches):							Total live
Treatments	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**SV6**
	Percent							*Bd. ft./acre*
Fixed:								
1	100	92.4	85.8	64.9	36.0	9.6	0	17,934
3	100	89.7	77.6	49.0	24.2	2.2	0	23,768
5	100	87.8	75.5	49.7	25.2	11.8	2.3	28,434
7	100	81.4	60.4	33.6	12.4	4.0	0	35,899
Increasing:								
2	100	91.5	82.6	63.0	40.0	13.5	6.2	21,870
4	100	86.3	76.4	47.3	27.1	1.8	0	29,141
Decreasing:								
6	100	89.7	76.7	53.0	25.9	7.5	2.9	24,812
8	100	87.5	73.7	49.1	24.2	6.7	2.1	32,433
Unthinned:								
C	100	73.5	45.0	23.67	4.1	2.1	0	40,620

Table 19–Percentage of merchantable board-foot volume (SV6) of trees removed in thinnings, in logs with scaling diameters larger than indicated value

Treatment	Scaling diameter (inches) 6	8	10	12	14	16	18	Total cut SV6
	Percent							*Bd. ft./acre*
Fixed:								
1	100	61.5	44.3	27.6	14.4	0	0	9,527
3	100	60.8	38.4	17.7	5.4	0	0	7,043
5	100	65.3	38.6	23.1	6.6	3.9	0	4,230
7	100	51.8	35.6	22.3	5.5	0	0	2,936
Increasing:								
2	100	79.9	68.3	49.6	41.0	8.9	6.5	3,772
4	100	68.0	55.5	34.8	16.4	0	0	3,855
Decreasing:								
6	100	61.8	44.3	32.0	18.7	13.3	0	7,217
8	100	63.8	39.6	17.3	7.4	4.3	0	5,012
Unthinned:								
C	100	0	0	0	0	0	0	0

Periodic Annual Increment

Periodic annual increment (PAI) values presented are net unless otherwise specified and calculated as the difference between values at start of the period (after thinning) and those at end of the period (before thinning), divided by years in the period. Gross PAI values (which include mortality) also are presented for comparative purposes.

PAI in basal area—Time trends of net and gross periodic annual increment in basal area are shown in figure 22, by treatments. Initially the control is much above the others, but net PAI decreases rapidly because of the combination of reduced growth due to competition and increasing suppression-related mortality. Trends of gross PAI (fig. 23) are considerably more regular than those of net PAI, because of the effects of mortality. Although the control has low net PAI due to mortality, gross PAI of the control is generally higher than in any of the other treatments. This is consistent with the idea that gross growth of the control represents the productive capacity of the site. The thinning treatments with lowest stocking (treatments 1 and 2) are well below the others.

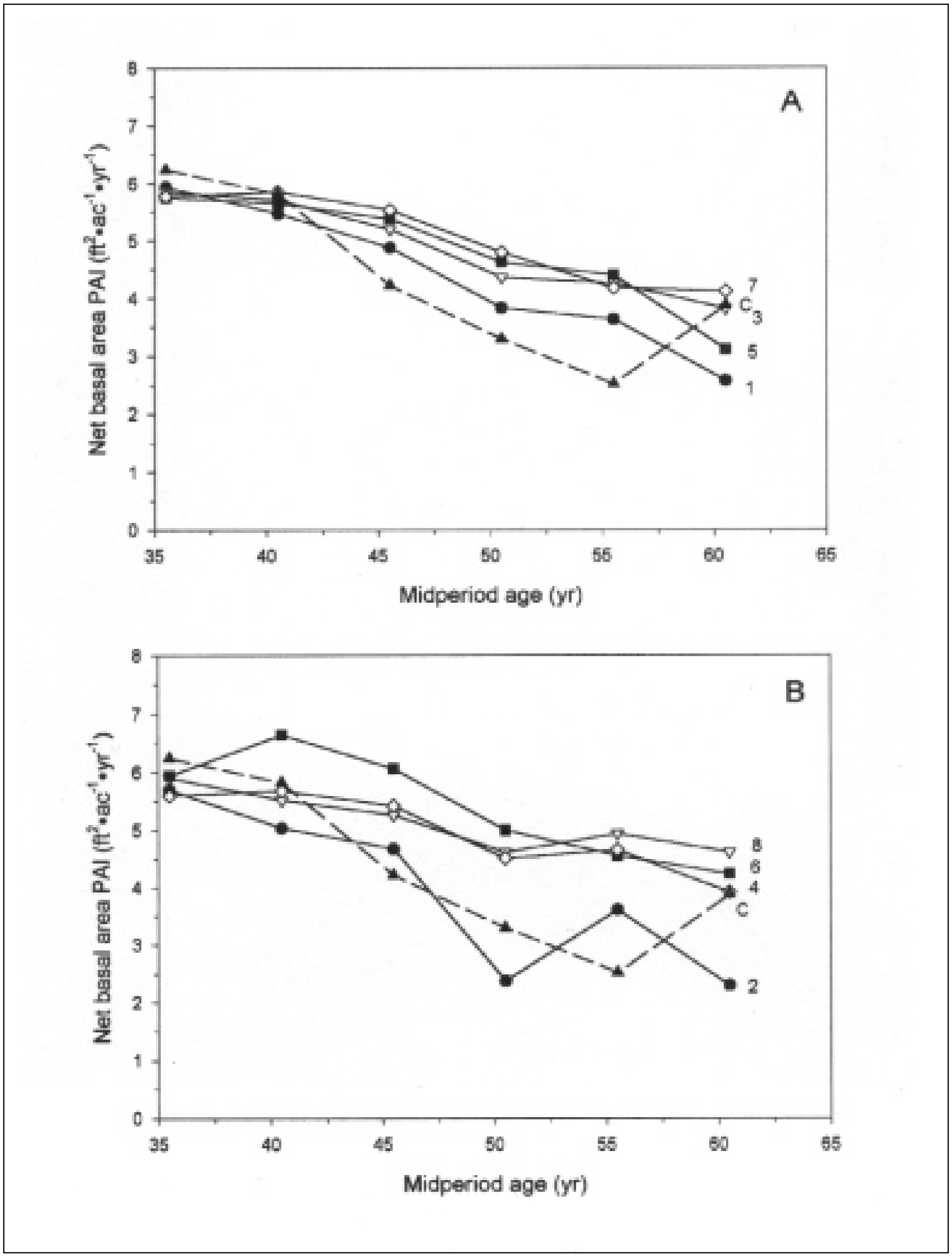

Figure 22—Net basal area periodic annual increment in relation to age, by treatments: **(A)** fixed treatments and control, and **(B)** variable treatments and control.

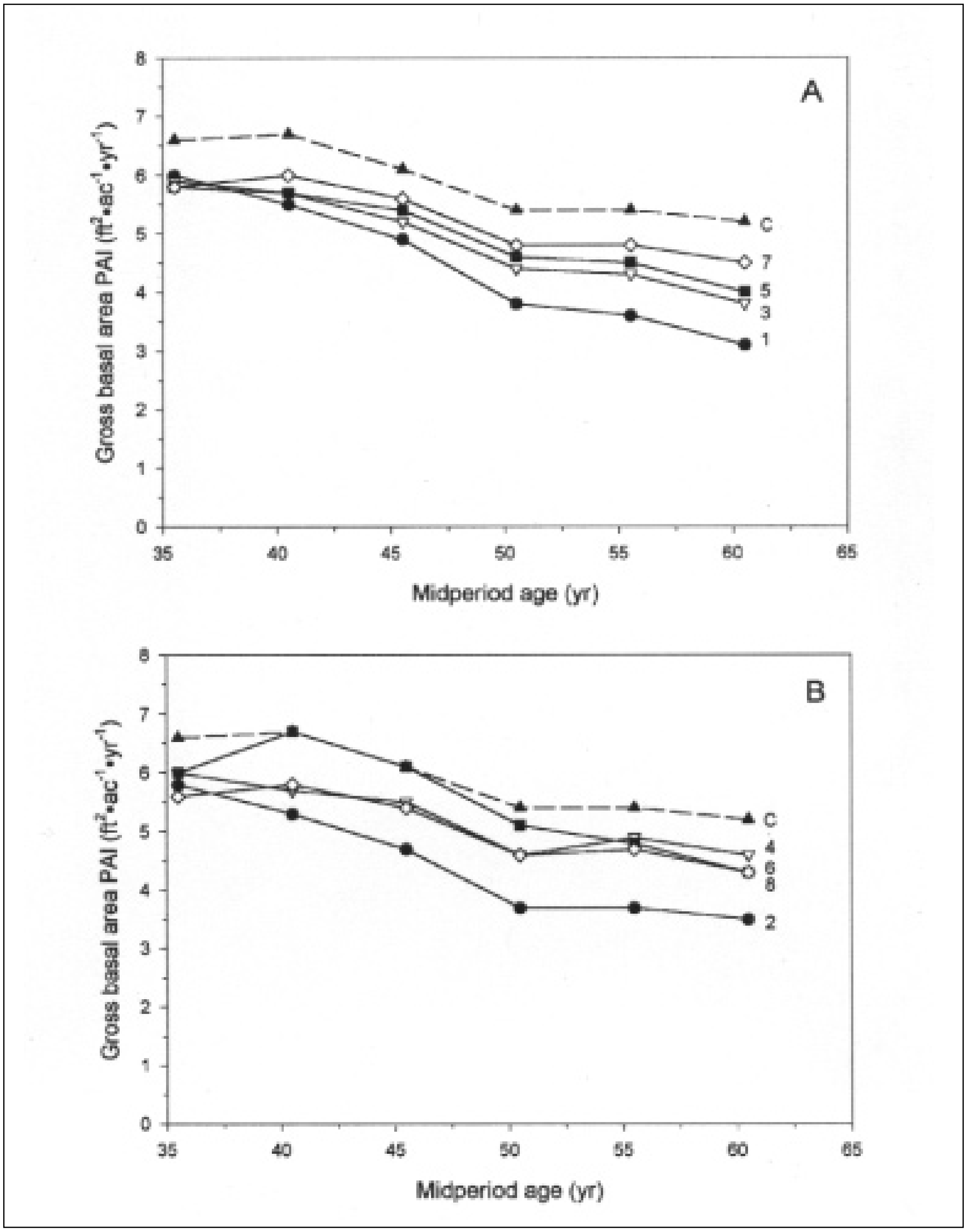

Figure 23—Gross basal area periodic annual increment in relation to age, by treatments: **(A)** fixed treatments and control, and **(B)** variable treatments and control.

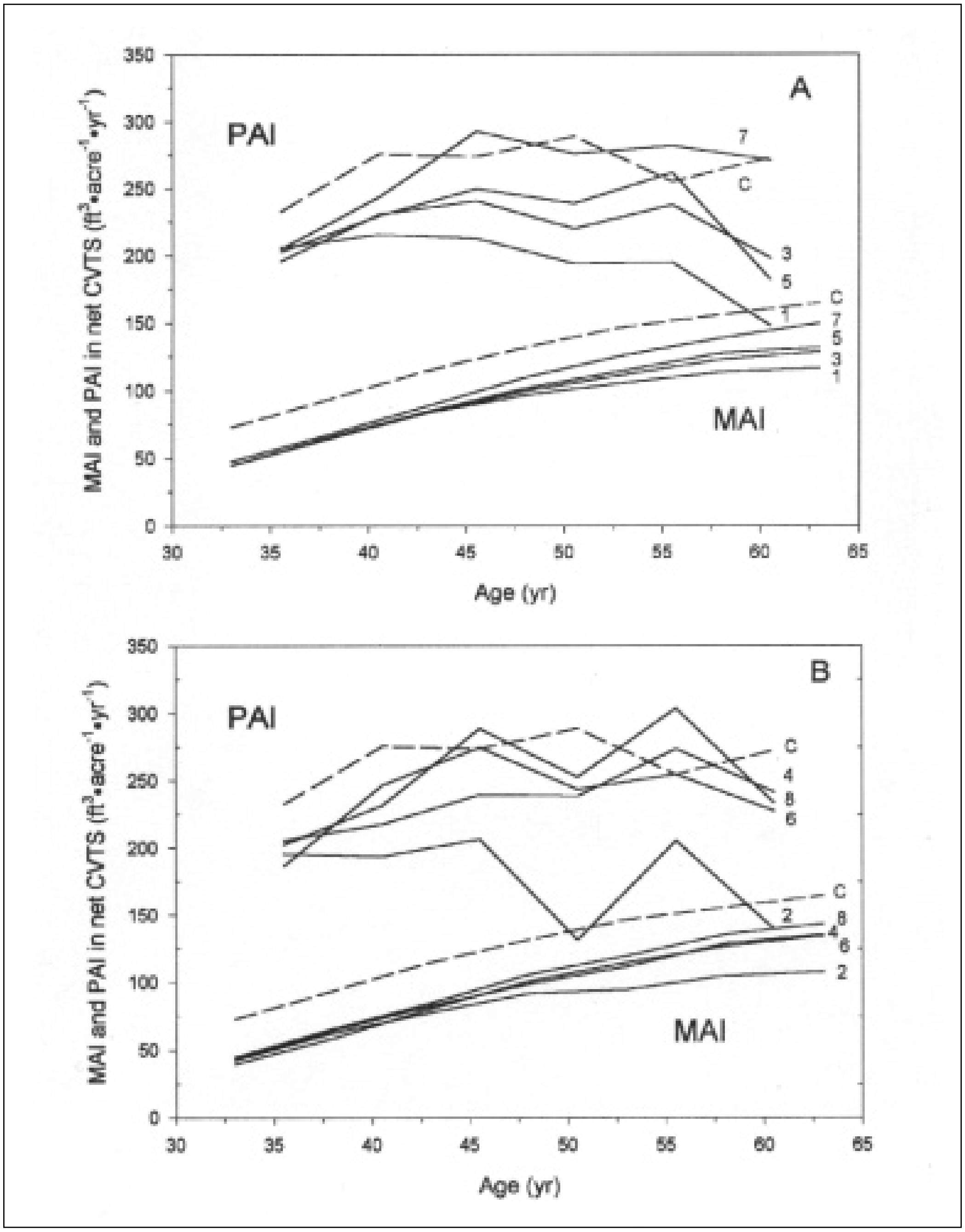

Figure 24—Mean annual increment and periodic annual increment in net total volume (CVTS) in relation to age and treatment: **(A)** fixed treatments and control, and **(B)** variable treatments and control.

PAI in volume—Time trends of net PAI in CVTS, CV6, and SV6 (Scribner) are shown in figures 24, 25, and 26.

Unlike basal area, where there was little difference in PAI among treatments other than the two lowest stockings (1 and 2), there are marked differences in volume PAI. The treatments that retain higher stocking levels have consistently greater volume PAIs.

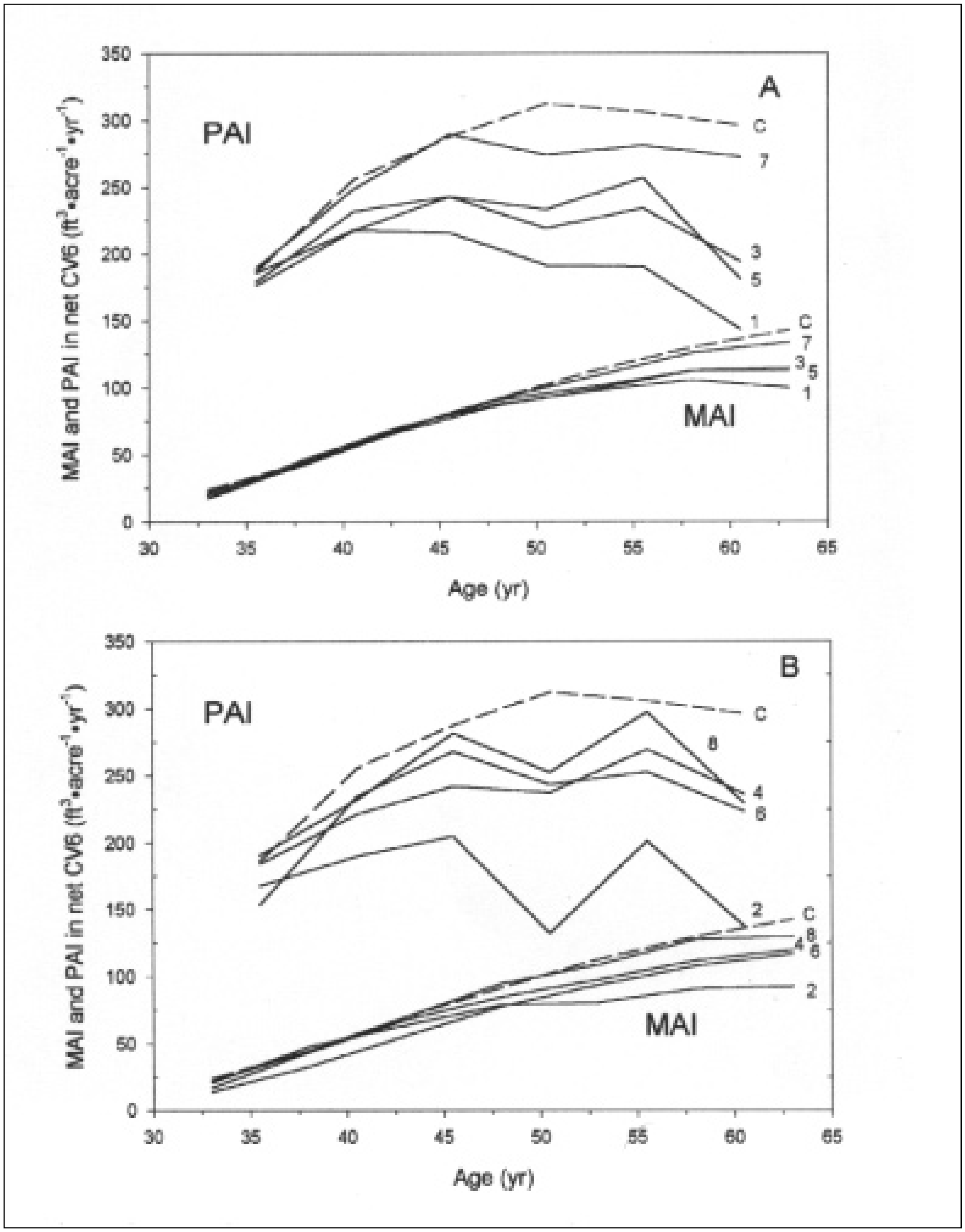

Figure 25—Mean annual increment and periodic annual increment in net merchantable cubic volume (CV6) in relation to age and treatment: **(A)** fixed treatments and control, and **(B)** variable treatments and control.

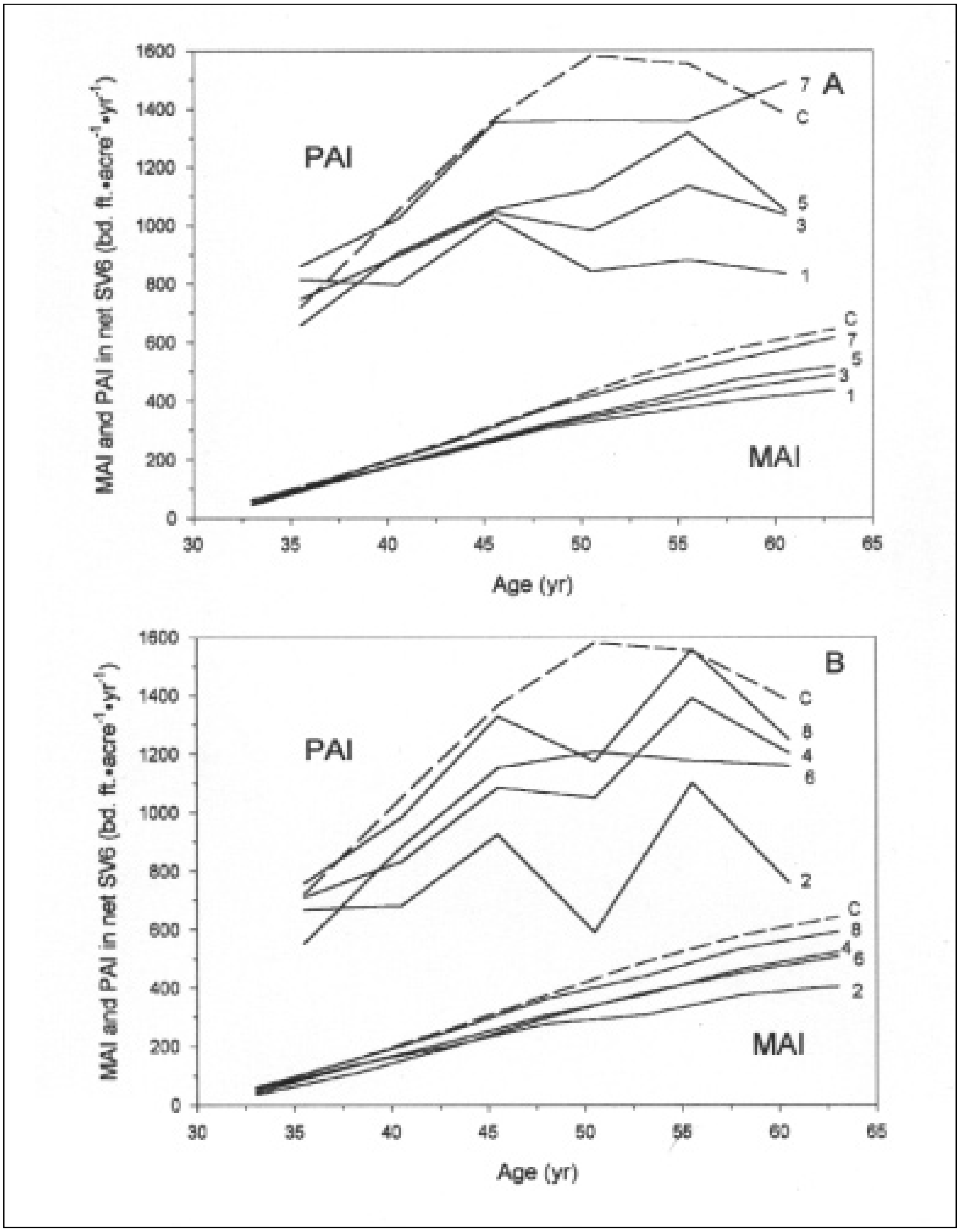

Figure 26—Mean annual increment and periodic annual increment in Scribner board feet (SV6) in relation to age and treatment: **(A)** fixed treatments and control, and **(B)** variable treatments and control.

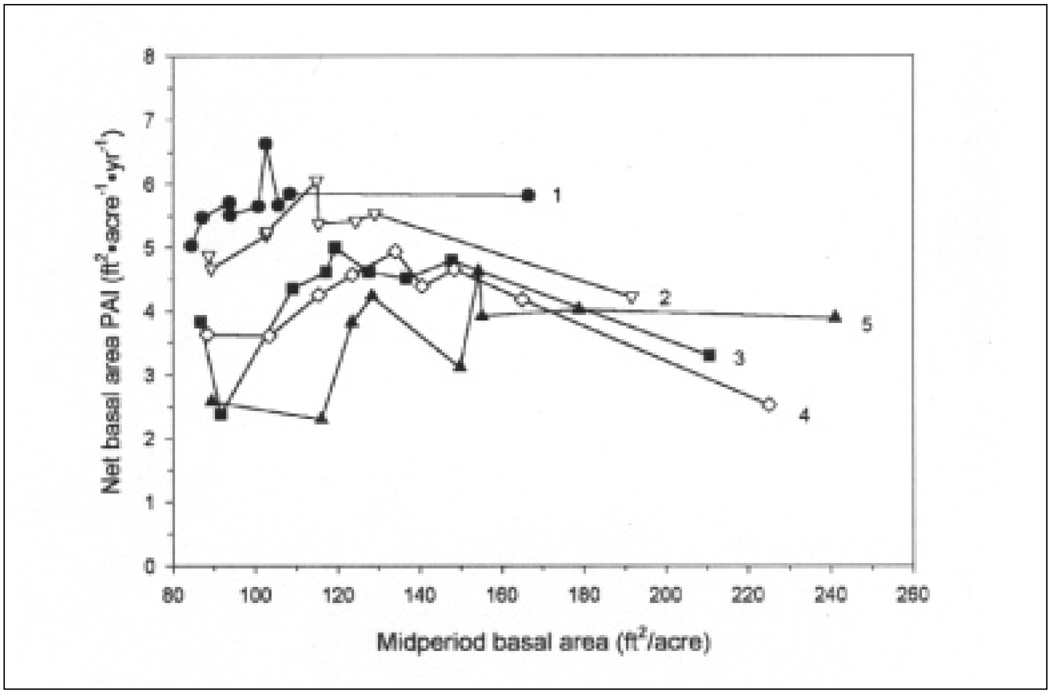

Figure 27—Net basal area periodic annual increment in relation to midperiod basal area, by periods.

There also are differences in trends for the different volume measures. SV6 shows a lesser decrease with increasing age; this is expected, because board-foot to cubic-foot ratios increase with increasing tree size.

Mean Annual Increment

Mean annual increment (MAI) is the quotient of cumulative net production up to a given age divided by that age; that is, the mean production rate over the period from age zero to the given age.

Mean annual increments in net CVTS, net CV6, and net SV6 are shown superimposed on the corresponding PAI curves in figures 25, 26, and 27.

Again, there are evident differences in curve shape with different measures of volume. The curves become more nearly linear as one progresses from CVTS to CV6 to SV6.

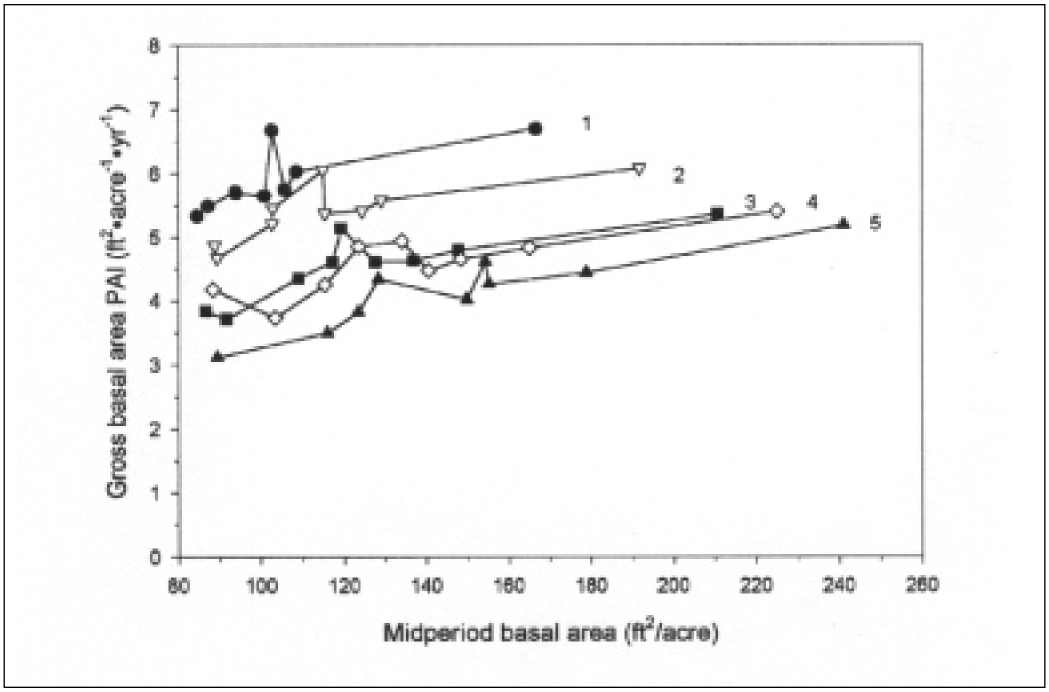

Figure 28—Gross basal area periodic annual increment in relation to midperiod basal area, by periods.

Growth-Growing Stock Relations

Figures 27 and 28 show observed trends of net and gross PAI in basal area in relation to midperiod basal area, by growth periods. Figures 29 and 30 make a similar comparison for CVTS.

Compared to net increment, the fluctuations arising from mortality on these small plots are markedly reduced when gross increment is used. In general, gross increment increases with basal area stocking and declines over successive growth periods. The relative rate of increase is greater, and the decline over successive periods less, for cubic volume than for basal area.

Similar differences appear for net increment, although they are somewhat obscured by mortality-related variation. Net basal area increment is nearly independent of stocking except at the lowest stocking levels, whereas gross basal area increment increases with stocking up to the maximum in the data. Net volume increment shows a maximum in the vicinity of the most heavily stocked thinning treatments, namely treatments 7 and 8; whereas gross increment continues to increase with stocking. Greater gross growth on the control is offset by increased mortality.

Relations of net volume increment to relative density and SDI, which are not shown, are similar to those shown for the relation to basal area, although the difference in scales produces a lateral shift in the positions of the curves for successive periods.

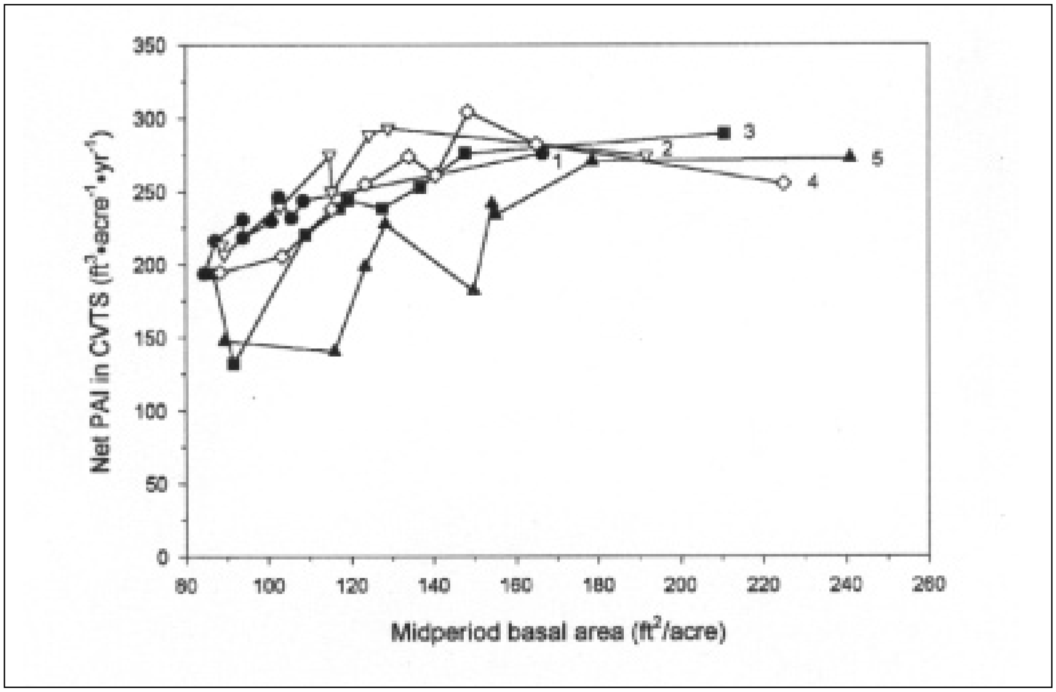

Figure 29—Net total cubic volume periodic annual increment in relation to midperiod basal area, by periods.

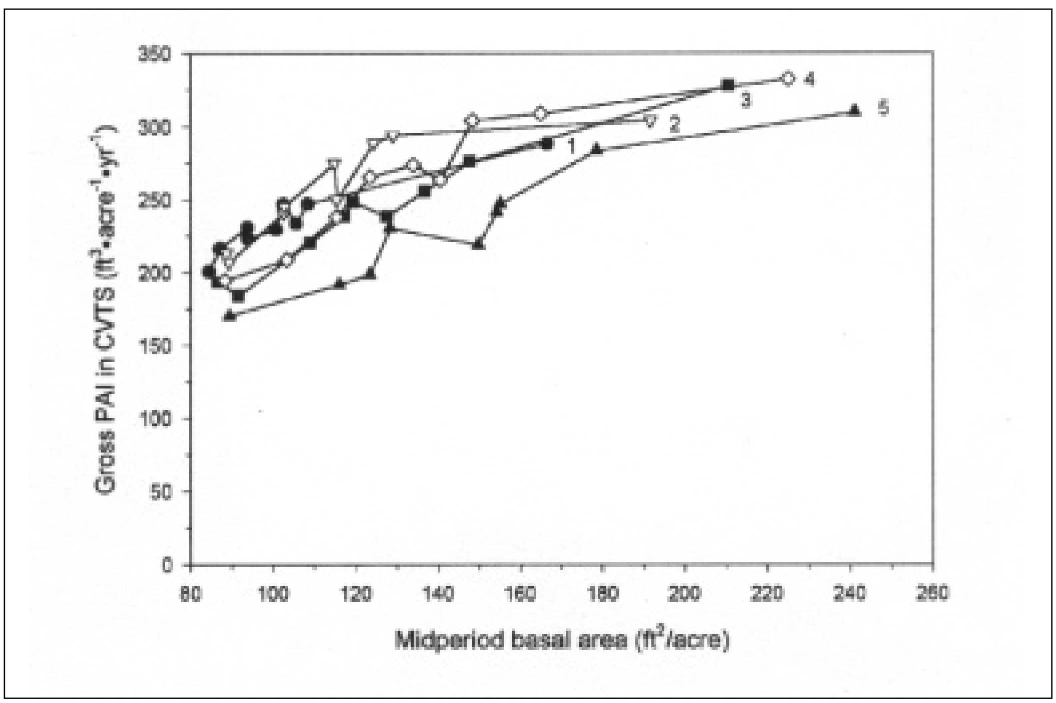

Figure 30—Gross total cubic volume periodic annual increment in relation to midperiod basal area, by periods.

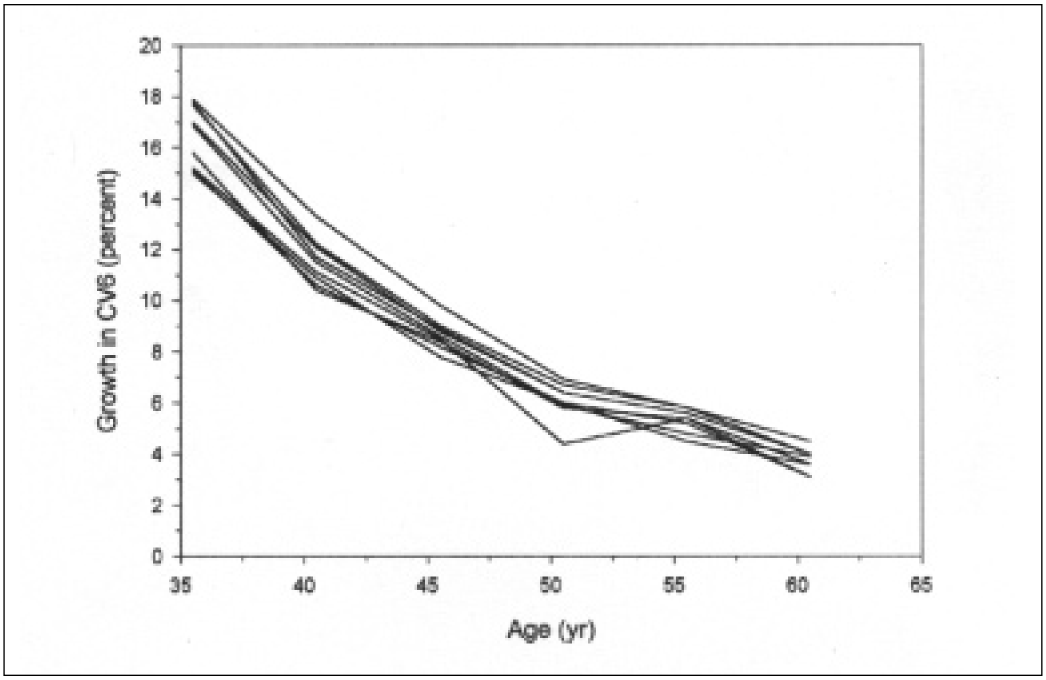

Figure 31—Trends of net merchantable volume growth percentage over time, all treatments.

Growth Percentage

Growth percentage is one method of expressing growth rates. The argument that one should seek maximum return on growing stock, one expression of which is growth percentage, had an important place in the thinking that led to the LOGS study. Growth percentages used here are calculated as,

$$\text{growth percent} = 100 \{PAI / [(X1 + X2) / 2]\} ,$$

where X1 and X2 are growing stock at the beginning and end of the growth period.

CV6 growth percentage—Trends over time of growth percentage in CV6 are shown in figure 31. Initial growth percentages are very high because of the small values of CV6 in the divisor. Ratios of merchantable volume to total volume increase faster on the lower stocked plots because of the larger trees; this tends to offset the relative increase in growth percentage expected from lower total volume of growing stock. The net effect is to reduce the differences in growth percentage among treatments.

Ratios of merchantable to total cubic volume change with increase in diameter, and this has a considerable effect on the trends. Compared to CV6, the trend for CVTS starts at a lower value and declines less rapidly; that for SV6 starts at a higher value and declines more steeply in the early years. Otherwise the general trends and comparative positions of the treatments are similar.

Comparisons for most recent period—Growth percentages in basal area, CVTS, CV6, and SV6 in relation to midperiod basal area stocking are compared in figure 32 for the most recent growth period. Figure 33 similarly compares growth percentages by units of measure and treatments (for fixed treatments and control for 1993-98 only).

Volume growth percentage is higher than basal area growth percentage, a difference representing the effect of continuing height growth. Growth percentages in CV6 are somewhat higher than in CVTS and, at this stage in stand development, do not differ much among treatments. In turn, growth percentages in SV6 are higher than those in CV6. Because value per unit of volume generally increases with tree size, presumably value growth percentages are higher than shown and might have somewhat different relations to level of growing stock and age.

Discussion

The numerous statistics discussed above are consolidated in tables 20-29 in the appendix, as means of values for the three plots in each treatment and measurement date, in both English and metric units. We anticipate that these detailed data will form the basis for additional comparisons and analyses in the future.

Relation to Results from Other LOGS Installations

Results from the Stampede Creek LOGS installation in general are qualitatively similar to those from other LOGS installations as of completion of the planned 60 feet of height growth, as reported in Curtis and Marshall (1986) and various subsequent individual installation reports. Although there are some quantitative differences related to site and stand peculiarities, results generally are consistent with and reinforce conclusions drawn previously from the other installations.

Stampede Creek was somewhat older and taller at establishment than other installations in the LOGS series and is on a poorer site than most installations. Therefore, although it is one of the oldest in terms of stand age, it is not now as far along in development as the higher site installations. As of 1998 it had just completed the planned 60 feet of height growth after calibration. In contrast, several of the higher site installations have had an additional 20 or 30 feet of height growth and a corresponding buildup in stocking subsequent to the final thinning; in some instances (Hoskins, Iron Creek), this is reflected in markedly increased mortality on the control and an increase in the ratio of production on the various thinning treatments to that of controls.

Two basic ideas played a major role in conception and design of the LOGS study. The first of these was a concept sometimes termed the “Langsaeter hypothesis” (Langsaeter 1941, as quoted by Braathe 1957; Staebler 1960), widely believed to have been demonstrated by European experience (Mar:Moller 1954) and stated in standard silviculture textbooks (for example, Smith 1962: 43). According to this hypothesis, the main effect of thinning, over a wide range of stand densities, is to redistribute a near-constant gross increment across various numbers of trees. If true, this would greatly simplify construction of yield tables and prediction of thinning effects. This hypothesis had never been tested for young Douglas-fir and was somewhat controversial in Europe in the late 1950s (Assman 1970, Holmsgaard 1958).

A second related idea (Staebler 1959) was that, for financial efficiency, one should retain the minimum amount of growing stock feasible without major loss in growth. If the Langsaeter hypothesis is assumed to hold, then growth percentage should be in direct inverse relation to growing stock over a considerable range in growing stock.

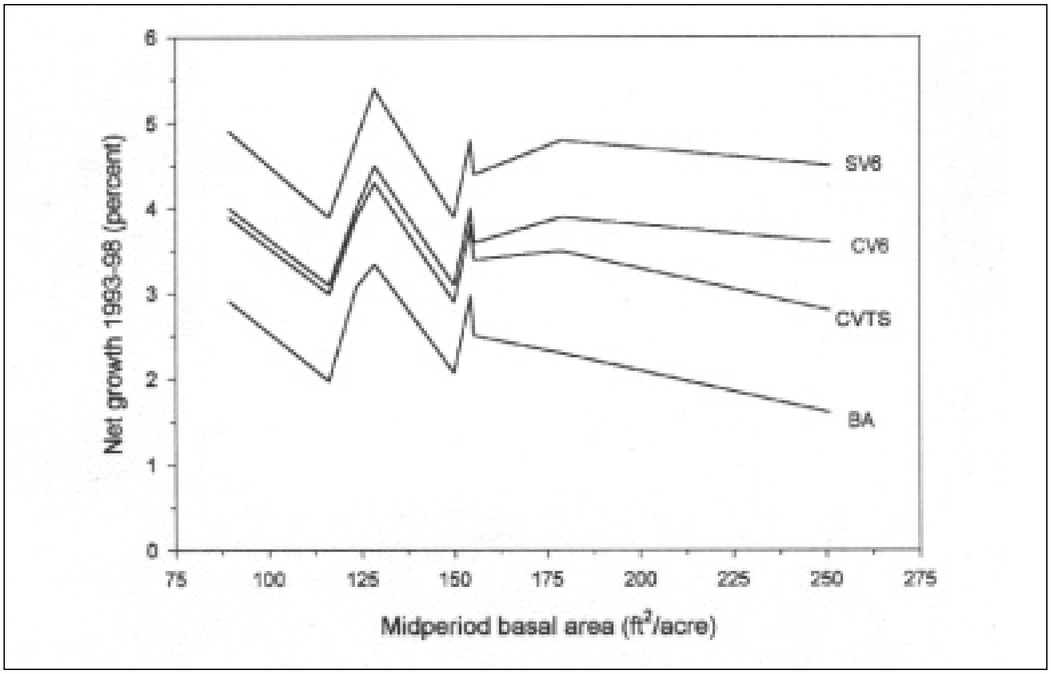

Figure 32—Net growth percentages in basal area, CVTS, CV6, and SV6 in the 1993-98 growth period, in relation to midperiod basal area.

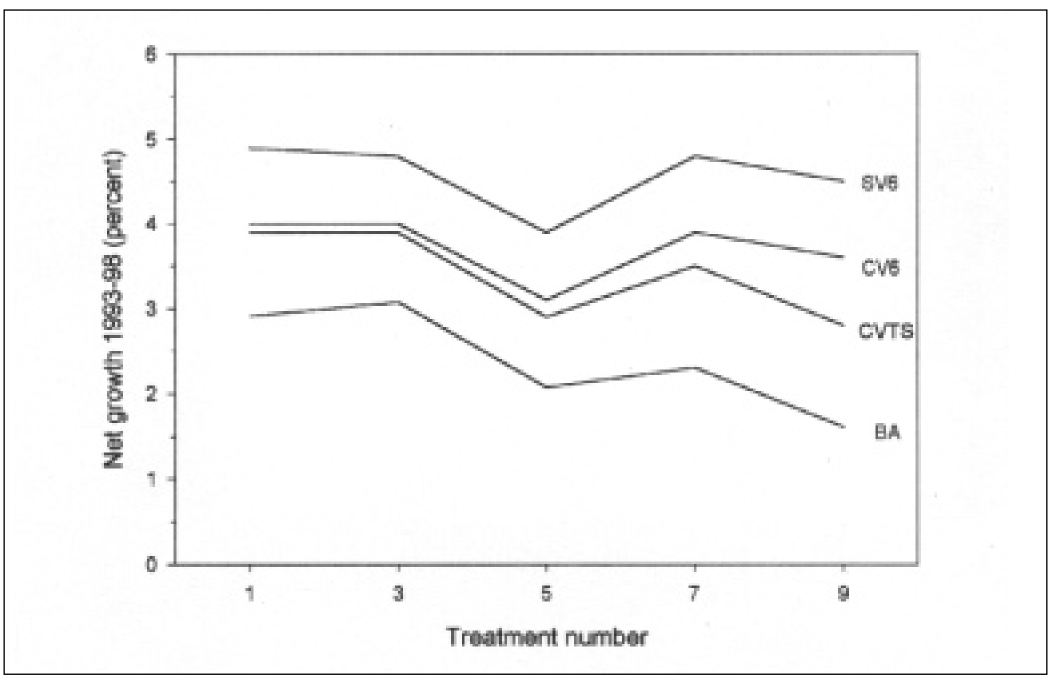

Figure 33—Net growth percentages in basal area, CVTS, CV6, and SV6 in the 1993-98 growth period, by treatments (fixed treatments and control only).

The LOGS study was designed to test these two concepts and to develop quantitative relations that could be used to design density control regimes. It also included specific additional comparisons between fixed, increasing, and decreasing trends in growing stock. And it was expected to provide much concomitant information.

Growth-Growing Stock Relations

Except where specifically indicated, the following discussion refers to net rather than to gross growth. (For thinned plots, gross and net growth are little different with the exception of treatment 2 and one plot in treatment 5; differences are somewhat greater for the control.)

The curves for net basal area PAI in relation to midperiod basal area (fig. 27) show an apparent maximum near the highest stocking in the thinned treatments. (This maximum is probably due to the effect of mortality on the control and would not appear were the control omitted.) Those for gross basal area growth (fig. 28) show PAI increasing with stocking, although the curves become flatter with advancing age. The curves form a consistent series, with elevation decreasing uniformly with advancing age.

Compared to the basal area increment trends, similar trends for gross and net CVTS increment (figs. 29 and 30) have considerably steeper slopes, still present in the most recent period. This reflects continuing height growth (Curtis and Marshall 1986: 80). No maximum is present for gross increment. For net increment, an apparent maximum occurs in the vicinity of the greatest basal area present on thinned plots and reflects mortality on the control.

These comparisons demonstrate that, in this comparatively young Douglas-fir stand, both net and gross volume increment are in fact strongly related to growing stock. This result is consistent with results from other LOGS installations (Curtis and Clendenen 1994, Curtis and Marshall 1986, Hoyer and others 1996, Marshall and others 1992). The relation is considerably weaker for basal area increment than for volume increment. We attribute the difference to the height growth component of volume increment. Like the other LOGS installations, Stampede Creek clearly demonstrates that the Langsaeter hypothesis does not hold for young Douglas-fir stands making rapid height growth. The increased individual tree sizes and values associated with lower growing stock levels are bought at the cost of decreased total cubic volume production.

Comparative Volume Production

Ranking by treatments—Figure 34 compares 1998 cumulative CV6 production by treatments and is expressed as percentages of CV6 production of the control. In general, production increases with stocking within each of the treatment groups (fixed, increasing, decreasing). The control currently exceeds all thinning treatments, although treatments 7 and 8 are very close. The rankings by CV6 are of course in inverse order to rankings by 1998 attained diameters.

The relatively low positions of treatments 2 and 5 relative to the general trends reflect in part the effect of mortality among large trees, primarily due to root disease and related windthrow.

Comparison of the relative density trends shown in figures 13 and 14 shows that treatments 1, 2, and 3 produce relative densities that are not only low but also declining over time. Given the demonstrated relation between volume production and stocking,

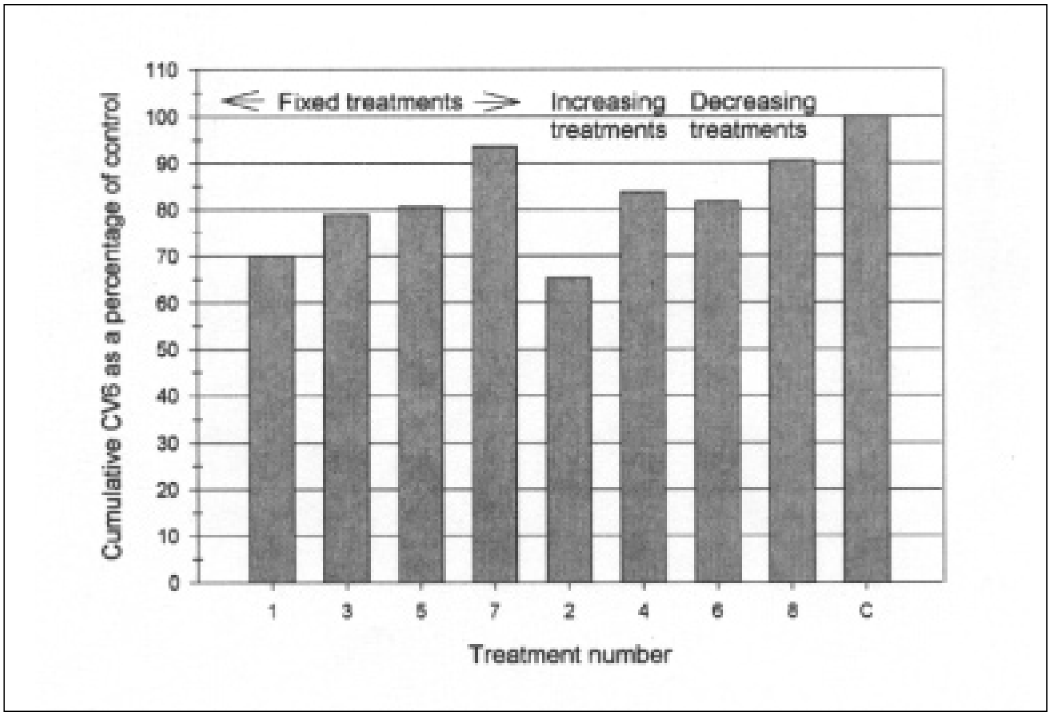

Figure 34—Cumulative net CV6 production by thinning treatment expressed as a percentage of net production on control.

the low production on these treatments is to be expected. Production comparisons (tables 17 to 25 and fig. 34) are consistent with the rule-of-thumb that commercial thinning regimes having timber production as their primary objective should generally aim to maintain relative densities in the range of RD35 to RD55 except in juvenile stands (QMD < ca. 6 inches), and somewhat higher as stands approach final harvest (Curtis and others 1981: 72). Aesthetic and wildlife enhancement objectives could of course modify this recommendation, as would premiums for rapid diameter growth.

Thinning removals—As would be expected, relative removals are much higher in the lower density treatments (tables 20 through 27), ranging from 44 percent of total net CVTS yield in treatment 1 to 12 percent in treatment 7 and 18 percent in treatment 8.

Increasing vs. decreasing treatments—The basal area trends projected in the original study plan (fig. 3) were expected to converge at the end of 60 feet of height growth at one point for treatments 2, 3, and 6 and at another and higher point for treatments 4, 5, and 8. In actuality, in the first group, basal areas for treatments 3 and 6 are nearly the same and that for 2 is considerably lower, probably reflecting mortality; and in the second group, basal areas for treatments 4 and 8 are almost identical and 5 is slightly lower, again probably reflecting mortality.

Among treatments 2, 3, and 6, treatment 6 (decreasing) has a slight advantage in CV6 production. Among treatments 4, 5, and 8, treatment 8 (decreasing) is superior, and the difference between 4 and 5 is small.

Spare plots—Three of the original spare plots were resurrected in 1983 and have been remeasured along with the others since then. It was thought that these would provide a measure of the development of a stand receiving an initial precommercial thinning and no subsequent treatment. The spare plots had somewhat lower H40 in 1998 than others (table 29), which suggests that there were reasons why these were not used and that they are somewhat lower sites. Hence, a direct comparison at the same ages is questionable. A comparison of trends in relation to attained H40, however, suggests that cubic volume production of the spares is in the general vicinity of that of treatments 7 and 8 at equivalent H40. Similarly, 1998 live crown ratio is similar to that of treatments 7 and 8 and substantially greater than for the control. Relative density in 1998 was 59 and live crown ratio (all trees) was about 0.36, indicating that the spares are at or somewhat beyond the stage where commercial thinning would be clearly appropriate and will soon enter the zone of suppression-related mortality.

MAI Trends and Age of Culmination

Mean annual increment (MAI) at any point in time is the quotient of cumulative net production divided by age; that is, average production rate achieved as of the specified age. Culmination age is the age when this attains a maximum, and this is also the age at which the PAI curve intersects the MAI curve.

Figures 24, 25, and 26 show observed trends of PAI and MAI for net volume in, respectively, CVTS, CV6, and SV6. Several points stand out:

1. The erratic PAI curve for treatment 2 and the decline in PAI of treatments 2 and 5 in the most recent growth period are partly the result of mortality and unrelated to stand density or thinning regime.

2. The decline in PAI in recent periods for treatments 1, 2, and 3 is associated with the very low and decreasing relative density in these treatments.

3. For most treatments, current PAI is still two to three times greater than MAI, indicating that the stands are not yet close to culmination.

4. Shape and relative position of the PAI and MAI curves are influenced by the unit of measure. PAI curves decline less sharply and MAI curves become more nearly linear as one goes from CVTS to CV6 to SV6. This is a consequence of the change in the ratio of merchantable to total volume that occurs as trees become larger.

Management Implications

LOGS was designed to determine relations among levels of growing stock, increment, and other stand attributes. The light and very frequent thinnings adopted to maintain close control of growing stock may not be operationally feasible or desirable in many situations. We believe, however, that much the same results could be achieved with considerably longer intervals between entries and correspondingly heavier removals. LOGS provides information useful in designing alternative regimes.

1. One pertinent result is that the Langsaeter hypothesis of equal production over a wide range of stand densities does not generally hold for young Douglas-fir. Volume production is in fact strongly related to growing stock and increases up to or through treatment 7, which was intended as the maximum level of growing stock thought consistent with avoidance of suppression mortality and maintenance of stand stability. In LOGS, through the planned 60 feet of height growth after initial thinning, thinned treatments have consistently produced less total volume than the control.

Current trends on several installations (Curtis and Clendenen 1994, Hoyer and others 1996, Marshall and Curtis 2002) strongly suggest that this will change in stands held for some time after the last planned thinning, as stands increase in density and as the controls are increasingly impacted by suppression-related mortality.

2. An associated result is that thinning does not automatically increase growth percentage in inverse relation to growing stock. Although heavy thinning does increase growth percentage, the anticipated increase is to a considerable extent offset by the decrease in growth associated with smaller growing stock. And, growth percentage for board feet is higher than for merchantable cubic volume, which in turn is higher than for total volume

3. LOGS installations were placed in areas carefully selected for full and uniform stocking. Thinned stand conditions after the calibration cut were little different from those existing on thousands of precommercially thinned acres. The unthinned controls, however, were and are denser and more uniform than many unthinned stands and relatively free from hardwoods. One might expect higher volume production from the controls in early life than from typical unthinned stands, and potential volume gains from operational thinning are probably underestimated by simple comparisons of LOGS thinned plots with LOGS control plots (Curtis and others 1997). There is also the possibility of a slight upward bias in growth estimates for the controls, because they are unbuffered plots surrounded by thinned plots of much lower density. Comparison of thinned vs. control in LOGS does not justify a generalization that volume production cannot be increased by thinning.

4. It is clear, however, from both LOGS and other existing long-term thinning studies, that the main benefits of thinning are not increased cubic volume production per se, but larger and more valuable trees, enhanced stand stability, the ability to provide timber and timber-related employment while maintaining forest cover for extended periods, and enhancement of visual and wildlife values.

5. A further result, largely unanticipated but which has become increasingly important, is the definition of the PAI and MAI curves and their implications for culmination age, growth and yield, and rotations. There are increasing pressures for forms of management that minimize the visual impacts of harvest operations and provide a range of stand ages with features favorable to wildlife. One option is the combination of extended rotations with repeated thinning.

   These results, together with other analyses of long-term studies (Curtis 1995) indicate that considerable extension of rotations combined with repeated thinning need not reduce and would probably increase long-term production, income, and employment. The associated higher growing stocks also would increase carbon sequestration (Haswell 2000). It is clear from figures 24, 25, and 26 and similar graphs from other LOGS studies that harvest on the very short rotations used by some owners ultimately must produce drastic reductions in production and employment; short-rotation harvest also creates large areas in early regeneration stages, the appearance of which generates much public opposition to forestry.

6. The LOGS data constitute a major portion of the database now available for simulation models. The original study plan (see footnote 1) stated the objective was "...to

determine how the amount of growing stock retained...affects cumulative wood production, tree size, and growth-growing stock ratios. The treatments are planned to cover a broad enough range in growing stock levels so that the findings will tell how to produce any combination of factors deemed optimum from a management standpoint."

The above was a very ambitious objective, and LOGS does not in itself provide such an answer. But, it has produced much information on trends in attainable diameter and volume growth under contrasting regimes and is still producing data that form a valuable part of the information needed. In 1962, modern simulation models were unknown to forestry, and the authors of the study plan could not have foreseen the developments in methodology that have occurred since then. LOGS represents probably the most extensive, most detailed, most tightly controlled, and highest quality thinning data set existing in the region. We anticipate continuing reliance on these data as an important component of future modeling efforts.

Future Value of the Study

Overall summaries of results for all the individual installations are now or soon will be available. The general similarity of results across installations has been pointed out (Curtis and Marshall 1986), but as yet there is no overall analysis of the combined data.

The most effective way to do this probably will be to use the LOGS data in combination with high-quality data from other sources as the basis for an overall growth model. This already has been done with the earlier LOGS data by Hann and others (1997), but the LOGS data available to them were incomplete, and considerable additional data from other sources are becoming available. This would necessarily be a major effort, beyond the scope and capabilities of the LOGS committee as presently constituted and possibly best handled through the Stand Management Cooperative.

There also are a number of subsidiary analyses that should be much more manageable and could produce reports in a fairly short time. These might include:

1. Combined data analyses of MAI and PAI trends. To date these have been discussed in connection with individual installations, but it may be possible to reduce these to a form representing the overall trends across installations, in a way that would provide a compact and readily interpretable presentation.

2. Examination of possible expression of crown length and crown ratio as functions of stand density and height. It is clear that fairly close relations exist within an individual installation. Can these be generalized across installations?

3. Evaluation of possible biases arising from the absence of buffers between plots. Although we believe such biases are minor, we cannot be certain in the absence of quantitative measures. Some LOGS installations have been stem-mapped, and a few installations have separate tree records for an interior 0.1-acre subplot. An evaluation would be useful both to enhance confidence in our results and to guide design of future experiments.

High-quality data from long-term permanent plot experiments such as LOGS provide an essential basis for development of growth and yield models and for predictions of the results of alternative management regimes. They also provide on-the-ground examples of the effect of management that can have important educational value. They have a credibility that no amount of short-term measurements and model assumptions can provide. And in the past, they often have produced results contradicting the accepted wisdom of the moment and have provided needed corrections.

Stampede Creek has reached the end of the planned thinning sequence, and further thinning is not feasible because of the small plot sizes. Possible edge effects associated with the lack of buffers may become more important as trees become fewer and larger; however, conditions on either side of a thinned plot boundary are in most cases not drastically different, and it seems unlikely that edge effects have materially affected results thus far. We believe that continued maintenance and measurement are important. With the buildup of growing stock over time, trends may develop that are considerably different from those observed to date. This is already happening on some other installations, such as Iron Creek, Francis, and Hoskins, where some thinned-plot production-curves are crossing those of the controls, and where competition-related mortality on the controls is increasing rapidly and appears likely to produce earlier culmination in the control than in the thinned stands.

Stampede Creek is unique among the LOGS installations in its location and site characteristics. We therefore believe it is important that the installation be maintained and measured periodically over at least the next decade, and preferably longer.

Metric Equivalents

1 inch	= 2.54 centimeters
1 foot	= 0.3048 meter
1 square foot	= 0.09290 square meter
1 cubic foot	= 0.028 cubic meter
1 acre	= 0.4047 hectare
1 square foot per acre	= 0.2296 square meter per hectare
1 cubic foot per acre	= 0.06997 cubic meter per hectare
ºF	= 1.8 × ºC + 32

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Table 20a–Stand development table for treatment 1 (plots 41, 72, and 126), by year, per acre basis

		After thinning							Removed in thinning								Mortality				
		40 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Feet*	*Inches*	*No.*	*Inches*	*Ft²*	- -*Cubic feet* - -		*No.*	*Inches*	*Ft²*	- - - - - - - - - -*Cubic feet* - - - - - - - - -					*No.*	*Inches*	*Ft²*	- - *Ft³* - -	
1968	33	58	9.2	295	6.5	68.9	1,480	586	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0
1973	38	69	10.9	193	8.4	73.4	1,905	1,236	100	6.8	25.2	606	280	6.1	5.3	0.87	2	6.3	0.4	8	1
1978	43	80	12.7	132	10.4	76.5	2,293	1,856	60	8.6	24.4	694	468	11.6	9.4	0.88	2	2.9	0.1	1	0
1983	48	89	14.6	82	13.3	77.0	2,619	2,382	50	9.4	23.9	741	553	14.8	12.3	0.79	0	0.0	0.0	0	0
1988	53	99	16.4	62	15.4	79.2	2,983	2,802	20	12.5	17.0	605	538	30.3	26.9	0.85	0	0.0	0.0	0	0
1993	58	109	18.1	50	17.5	82.9	3,382	3,217	12	15.1	14.6	574	538	47.8	44.8	0.89	0	0.0	0.0	0	0
1998	63	116	19.6	48	19.1	95.8	4,120	3,935	0	0.0	0.0	0	0	0.0	0.0	0.00	2	17.1	2.7	113	108

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - *Cubic feet* - - - - - - - - -				- - -*Inches*- - -		*Square feet*		- - - - - - - - - - - - - - - - *Cubic feet* - - - - - - - - - - - - - - - - - -							
1968	33	1,480	1,480	586	586	0.00	0.00	0.0	0.0	0	45	0	18	0	45	0	18
1973	38	2,511	2,520	1,515	1,516	0.26	0.26	5.9	6.0	206	66	186	40	208	66	186	40
1978	43	3,593	3,602	2,604	2,605	0.30	0.29	5.5	5.5	216	84	218	61	217	84	218	61
1983	48	4,660	4,669	3,683	3,684	0.31	0.31	4.9	4.9	213	97	216	77	213	97	216	77
1988	53	5,628	5,637	4,641	4,642	0.31	0.31	3.8	3.8	194	106	192	88	194	106	192	88
1993	58	6,602	6,611	5,594	5,595	0.34	0.34	3.6	3.6	195	114	191	96	195	114	191	96
1998	63	7,340	7,462	6,313	6,421	0.33	0.33	2.6	3.1	148	117	144	100	170	118	165	102

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h. and larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 3,220 cubic feet (49 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 122 cubic feet (2 percent of the total gross yield).

Table 20b––Stand development table for treatment 1 (plots 41, 72, and 126), by year, per hectare basis

		After thinning							Removed in thinning								Mortality				
		100 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Meters*	*cm*	*No.*	*cm*	*m²*	*Cubic meters*		*No.*	*cm*	*m²*	- - - - - - - - *Cubic meters* - - - - - - - -					*No.*	*cm*	*m²*	- - *m³* - -	
1968	33	18.1	23.3	729	16.6	15.8	104.1	41.5	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	21.6	27.8	478	21.3	16.9	133.9	87.0	247	17.3	5.8	42.9	20.1	0.2	0.2	0.87	4	16.0	0.1	1.1	0.6
1978	43	24.8	32.3	325	26.3	17.6	161.0	130.4	148	21.9	5.6	49.1	33.3	0.3	0.3	0.88	4	7.4	0.0	0.6	0.5
1983	48	27.7	37.2	202	33.7	17.7	183.9	167.3	124	23.8	5.5	52.3	39.2	0.4	0.4	0.79	0	0.0	0.0	0.0	0.0
1988	53	30.7	41.5	152	39.2	18.2	209.3	196.7	49	31.7	3.9	42.8	38.2	0.9	0.8	0.85	0	0.0	0.0	0.0	0.0
1993	58	33.8	46.0	124	44.4	19.1	237.2	225.7	29	38.5	3.4	40.7	38.2	1.4	1.3	0.89	0	0.0	0.0	0.0	0.0
1998	63	36.0	49.9	119	48.7	22.0	288.9	276.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	4	43.5	0.6	8.4	8.0

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
Year	Stand age	Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - *Cubic meters* - - - - -				*Centimeters*		- - - *m²* - - -		- - - - - - - - - - - - - - - *Cubic meters* - - - - - - - - - - - - - - -							
1968	33	104.1	104.1	41.5	41.5	0.00	0.00	0.0	0.0	0.0	3.6	0.0	1.7	0.0	3.6	0.0	1.7
1973	38	176.3	176.9	106.6	106.6	0.67	0.66	1.4	1.4	14.9	5.1	13.5	3.3	15.1	5.1	13.5	3.3
1978	43	252.0	252.7	182.8	182.8	0.75	0.74	1.3	1.3	15.6	6.3	15.7	4.7	15.7	6.4	15.7	4.7
1983	48	326.7	327.3	258.3	258.4	0.79	0.79	1.1	1.1	15.4	7.3	15.6	5.9	15.4	7.3	15.6	5.9
1988	53	394.5	395.1	325.4	325.5	0.79	0.79	0.9	0.9	14.1	7.9	13.9	6.6	14.1	7.9	13.9	6.6
1993	58	462.6	463.2	392.1	392.2	0.85	0.85	0.8	0.8	14.1	8.5	13.8	7.3	14.1	8.5	13.8	7.3
1998	63	514.3	522.8	442.4	450.0	0.85	0.83	0.6	0.7	10.8	8.7	10.6	7.5	12.4	8.8	12.1	7.6

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. and larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 225.4 cubic meters (49 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 8.5 cubic meters (2 percent of the total gross yield).

Table 21a––Stand development table for treatment 2 (plots 91, 112, and 113), by year, per acre basis

		After thinning							Removed in thinning								Mortality				
		40 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Feet*	*Inches*	*No.*	*Inches*	*Ft ²*	- -*Cubic feet* - -		*No.*	*Inches*	*Ft ²*	- - - - - - - - - -*Cubic feet* - - - - - - - - -					*No.*	*Inches*	*Ft²*	- - *Ft³* - -	
1968	33	59	10.4	287	6.6	67.5	1,413	686	0	0.0	0.0	0	0	0	0.0	0.00	0	0.0	0.0	0	0
1973	38	71	12.3	190	8.4	71.8	1,829	1,243	93	6.9	24.1	566	283	6.1	5.9	0.87	3	6.4	0.7	18	11
1978	43	81	14.1	123	10.8	77.6	2,296	1,914	62	7.6	19.3	502	280	8.1	6.2	0.77	5	7.5	1.5	36	16
1983	48	91	15.8	82	14.0	85.6	2,916	2,670	42	8.2	15.4	424	270	10.1	8.2	0.67	0	0.0	0.0	0	0
1988	53	98	17.2	73	15.5	94.2	3,442	3,219	3	13.4	3.3	125	115	41.7	38.3	0.88	5	15.7	6.7	260	244
1993	58	108	18.9	70	17.1	110.2	4,381	4,145	2	15.1	2.1	89	84	44.5	42.0	0.89	2	8.0	0.6	17	9
1998	63	116	20.4	65	18.6	121.7	5,082	4,836	0	0.0	0.0	0	0	0.0	0.0	0.00	5	14.8	6.0	258	239

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - *Cubic feet* - - - - - - - - -				- - -*Inches* - - -		*Square feet*		- - - - - - - - - - - - - - - - *Cubic feet* - - - - - - - - - - - - - - - - - -							
1968	33	1,413	1,413	686	686	0.00	0.00	0.0	0.0	0	43	0	21	0	43	0	21
1973	38	2,395	2,413	1,526	1,537	0.26	0.26	5.7	5.8	196	63	168	40	200	64	170	40
1978	43	3,364	3,418	2,478	2,505	0.30	0.29	5.0	5.3	194	78	190	58	201	79	194	58
1983	48	4,398	4,452	3,504	3,531	0.30	0.30	4.7	4.7	207	92	205	73	207	93	205	74
1988	53	5,059	5,373	4,168	4,439	0.28	0.31	2.4	3.7	132	95	133	79	184	101	182	84
1993	58	6,087	6,417	5,178	5,457	0.31	0.30	3.6	3.7	206	105	202	89	209	111	204	94
1998	63	6,788	7,376	5,869	6,388	0.30	0.28	2.3	3.5	140	108	138	93	192	117	186	101

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h. and larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 1,706 cubic feet (27 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 588 cubic feet (8 percent of the total gross yield).

Table 21b––Stand development table for treatment 2 (plots 91, 112, and 113), by year, per hectare basis

		After thinning							Removed in thinning								Mortality				
		100 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Meters*	*cm*	*No.*	*cm*	*m²*	*Cubic meters*		*No.*	*cm*	*m²*	- - - - - - - *Cubic meters*- - - - - - - - -					*No.*	*cm*	*m²*	- - *m³* - -	
1968	33	18.6	26.4	708	16.7	15.5	99.4	48.5	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	22.2	31.3	469	21.3	16.5	128.6	87.5	231	17.5	5.6	40.1	20.3	0.2	0.2	0.87	8	16.3	0.2	1.8	1.3
1978	43	25.2	35.7	305	27.5	17.9	161.3	134.5	152	19.3	4.4	35.6	20.1	0.2	0.2	0.77	12	19.1	0.4	3.0	1.6
1983	48	28.3	40.2	202	35.6	19.7	203.9	187.4	103	20.9	3.5	30.2	19.4	0.3	0.2	0.67	0	0.0	0.0	0.0	0.0
1988	53	30.5	43.7	181	39.4	21.7	241.4	225.9	8	34.2	0.8	9.2	8.5	1.1	1.0	0.88	12	39.8	1.5	18.7	17.6
1993	58	33.5	47.9	173	43.6	25.3	307.2	290.7	4	38.4	0.5	6.7	6.4	1.5	1.5	0.89	4	20.4	0.1	1.7	1.1
1998	63	35.8	51.7	161	47.4	28.0	356.2	339.1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	12	37.7	1.4	18.5	17.3

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - *Cubic meters* - - - - - -				- - - *cm* - - -		*Square meters*		- - - - - - - - - - - - - - - *Cubic meters* - - - - - - - - - - - - - - -							
1968	33	99.4	99.4	48.5	48.5	0.00	0.00	0.0	0.0	0.0	3.5	0.0	2.0	0.0	3.5	0.0	2.0
1973	38	168.2	169.4	107.3	108.1	0.67	0.66	1.3	1.3	14.2	4.9	12.3	3.3	14.5	4.9	12.4	3.3
1978	43	236.0	239.8	173.9	175.8	0.76	0.75	1.2	1.2	14.1	6.0	13.8	4.5	14.6	6.1	14.1	4.6
1983	48	308.4	312.1	245.8	247.7	0.77	0.77	1.1	1.1	15.0	6.9	14.9	5.6	15.0	7.0	14.9	5.6
1988	53	354.6	376.6	292.3	311.2	0.70	0.79	0.5	0.9	9.7	7.2	9.8	6.0	13.4	7.6	13.2	6.4
1993	58	426.6	449.7	362.9	382.5	0.80	0.75	0.8	0.9	14.9	7.8	14.6	6.7	15.1	8.2	14.8	7.1
1998	63	475.7	516.8	411.3	447.6	0.76	0.71	0.5	0.8	10.3	8.0	10.2	7.0	13.9	8.7	13.5	7.6

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. and larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 119.4 cubic meters (27 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 41.1 cubic meters (8 percent of the total gross yield).

Table 22a––Stand development table for treatment 3 (plots 51, 103, and 121), by year, per acre basis

Year	Stand age	After thinning: 40 largest trees[a] HT	D.b.h.	Trees	QMD[b]	Basal area	Volume[c] CVTS	CV6[d]	Removed in thinning: Trees	QMD	Basal area	Volume CVTS	CV6[d]	Volume/tree CVTS	CV6[d]	d/D[e]	Mortality: Trees	QMD	Basal area	Volume CVTS	CV6[d]
	Years	*Feet*	*Inches*	*No.*	*Inches*	*Ft²*	*- -Cubic feet - -*		*No.*	*Inches*	*Ft²*	*- - - - - - - - - -Cubic feet - - - - - - - - -*					*No.*	*Inches*	*Ft²*	*- - Ft³ - -*	
1968	33	59	9.4	290	6.7	70.2	1,481	604	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0
1973	38	69	11.2	198	8.6	79.4	2,015	1,336	90	6.4	20.1	445	165	4.9	3.7	0.80	2	6.3	0.4	8	1
1978	43	80	12.9	152	10.4	89.6	2,658	2,160	47	8.5	18.5	512	336	10.9	8.0	0.85	0	0.0	0.0	0	0
1983	48	90	14.6	122	12.2	98.0	3,291	2,900	28	10.7	17.6	570	474	20.4	17.6	0.90	2	3.4	0.1	2	0
1988	53	99	16.2	95	14.3	104.7	3,881	3,593	27	10.2	15.0	512	403	19.0	14.9	0.76	0	0.0	0.0	0	0
1993	58	109	17.6	82	16.0	113.8	4,605	4,346	13	12.9	12.2	466	418	35.8	32.2	0.83	0	0.0	0.0	0	0
1998	63	114	19.0	82	17.3	132.9	5,598	5,317	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0

Year	Stand age	Cumulative yield[f] Net CVTS	Gross CVTS	Net CV6	Gross CV6	QMD growth Net PAI	Surv. PAI	BA growth Net PAI	Gross PAI	Net volume growth CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	Gross volume growth CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - Cubic feet - - - - - - - - -				*- - - Inches - - -*		*Square feet*		*- - - - - - - - - - - - - - - - Cubic feet - - - - - - - - - - - - - - - - - -*							
1968	33	1,481	1,481	604	604	0.00	0.00	0.0	0.0	0	45	0	18	0	45	0	18
1973	38	2,460	2,467	1,501	1,502	0.26	0.26	5.9	5.9	196	65	179	40	197	65	180	40
1978	43	3,616	3,623	2,661	2,662	0.28	0.28	5.7	5.7	231	84	232	62	231	84	232	62
1983	48	4,818	4,827	3,875	3,876	0.30	0.29	5.2	5.2	241	100	243	81	241	101	243	81
1988	53	5,920	5,929	4,971	4,972	0.26	0.26	4.4	4.4	220	112	219	94	220	112	219	94
1993	58	7,112	7,121	6,142	6,143	0.28	0.28	4.2	4.2	238	123	234	106	238	123	234	106
1998	63	8,104	8,113	7,112	7,113	0.26	0.26	3.8	3.8	198	129	194	113	198	129	194	113

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h. and larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 2,506 cubic feet (35 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 9 cubic feet (0.1 percent of the total gross yield).

Table 22b––Stand development table for treatment 3 (plots 51, 103, and 121), by year, per hectare basis

		After thinning							Removed in thinning								Mortality				
		100 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	Meters	cm	No.	cm	m^2	Cubic meters		No.	cm	m^2	Cubic meters					No.	cm	m^2	m^3	
1968	33	18.4	23.9	716	16.9	16.2	104.2	42.8	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	21.4	28.3	490	21.8	18.3	141.5	94.0	222	16.3	4.6	31.6	12.1	0.1	0.1	0.80	4	16.0	0.1	1.0	0.6
1978	43	24.9	32.8	375	26.5	20.6	186.6	151.7	115	21.7	4.2	36.4	24.0	0.3	0.2	0.85	0	0.0	0.0	0.0	0.0
1983	48	28.1	37.2	301	30.9	22.5	230.9	203.5	70	27.2	4.1	40.4	33.6	0.6	0.5	0.90	4	8.7	0.0	0.6	0.5
1988	53	30.7	41.1	235	36.3	24.1	272.1	252.0	66	25.9	3.5	36.4	28.7	0.5	0.4	0.76	0	0.0	0.0	0.0	0.0
1993	58	33.6	44.8	202	40.7	26.2	322.9	304.8	33	32.9	2.8	33.2	29.7	1.0	0.9	0.83	0	0.0	0.0	0.0	0.0
1998	63	35.3	48.2	202	44.0	30.6	392.4	372.7	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		Cubic meters				cm		Square meters		Cubic meters							
1968	33	104.2	104.2	42.8	42.8	0.00	0.00	0.0	0.0	0.0	3.6	0.0	1.8	0.0	3.6	0.0	1.8
1973	38	172.7	173.2	105.6	105.6	0.66	0.66	1.3	1.4	14.2	5.0	13.1	3.3	14.3	5.0	13.1	3.3
1978	43	253.6	254.1	186.8	186.8	0.72	0.72	1.3	1.3	16.7	6.4	16.7	4.8	16.7	6.4	16.7	4.8
1983	48	337.8	338.4	271.8	271.8	0.75	0.73	1.2	1.2	17.3	7.5	17.5	6.2	17.4	7.5	17.5	6.2
1988	53	414.9	415.5	348.5	348.5	0.65	0.65	1.0	1.0	15.9	8.3	15.8	7.1	15.9	8.3	15.8	7.1
1993	58	498.3	498.9	430.4	430.5	0.70	0.70	1.0	1.0	17.2	9.1	16.9	7.9	17.2	9.1	16.9	7.9
1998	63	567.8	568.4	498.4	498.4	0.66	0.66	0.9	0.9	14.4	9.5	14.1	8.4	14.4	9.5	14.1	8.4

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. and larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 175.4 cubic meters (35 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 0.6 cubic meters (0.1 percent of the total gross yield).

Table 23a––Stand development table for treatment 4 (plots 71, 82, and 115), by year, per acre basis

		After thinning							Removed in thinning								Mortality				
		40 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	Feet	Inches	No.	Inches	Ft^2	- -Cubic feet - -		No.	Inches	Ft^2	- - - - - - - - - -Cubic feet - - - - - - - - -					No.	Inches	Ft^2	- - Ft^3 - -	
1968	33	58	9.1	297	6.6	69.7	1,446	577	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0
1973	38	69	10.9	208	8.4	80.0	2,043	1,336	83	6.5	19.3	434	164	5.2	3.4	0.82	5	4.7	0.6	11	1
1978	43	79	12.8	158	10.2	89.5	2,643	2,125	47	8.4	18.0	492	320	10.5	8.4	0.86	3	7.2	0.9	25	18
1983	48	90	14.6	135	12.0	105.6	3,522	3,104	22	9.3	10.2	319	233	14.5	12.9	0.80	2	10.3	1.0	30	24
1988	53	101	16.1	120	13.7	121.6	4,482	4,113	15	9.4	7.2	234	180	15.6	15.0	0.71	0	0.0	0.0	0	0
1993	58	112	17.9	115	15.2	142.7	5,719	5,345	5	11.5	3.6	132	115	26.4	23.0	0.77	0	0.0	0.0	0	0
1998	63	118	19.4	115	16.4	165.8	6,927	6,528	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
Year	Stand age	Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - Cubic feet - - - - - - - - -				- - - -Inches- - -		Square feet		- - - - - - - - - - - - - - - - Cubic feet - - - - - - - - - - - - - - - - - -							
1968	33	1,446	1,446	577	577	0.00	0.00	0.0	0.0	0	44	0	17	0	44	0	17
1973	38	2,477	2,488	1,500	1501	0.27	0.26	5.9	6.0	206	65	184	39	208	65	185	39
1978	43	3,570	3,606	2,609	2,627	0.28	0.28	5.5	5.7	218	83	222	61	223	84	225	61
1983	48	4,768	4,834	3,821	3,863	0.30	0.29	5.3	5.5	240	99	242	80	246	101	247	80
1988	53	5,961	6,027	5,010	5,053	0.25	0.25	4.6	4.6	239	112	238	95	239	114	238	95
1993	58	7,331	7,397	6,357	6,400	0.27	0.27	5.0	5.0	274	126	269	110	274	128	269	110
1998	63	8,539	8,605	7,539	7,582	0.24	0.24	4.6	4.6	242	136	236	120	242	137	236	120

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h. and larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 1,612 cubic feet (22 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 66 cubic feet (1 percent of the total gross yield).

Table 23b––Stand development table for treatment 4 (plots 71, 82, and 115), by year, per hectare basis

		After thinning							Removed in thinning								Mortality				
		100 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Meters*	*cm*	*No.*	*cm*	*m^2*	*Cubic meters*		*No.*	*cm*	*m^2*	- - - - - - - - *Cubic meters*- - - - - - - - -					*No.*	*cm*	*m^2*	- - *m^3* - -	
1968	33	18.0	23.2	733	16.7	16.0	101.7	40.9	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	21.6	27.8	515	21.5	18.4	143.5	94.0	206	16.6	4.4	30.9	12.0	0.1	0.1	0.82	12	11.9	0.1	1.3	0.6
1978	43	24.7	32.4	391	26.0	20.6	185.5	149.3	115	21.4	4.1	35.0	22.9	0.3	0.2	0.86	8	18.2	0.2	2.2	1.7
1983	48	28.0	37.2	333	30.6	24.3	247.1	217.8	54	23.7	2.4	22.8	16.8	0.4	0.4	0.80	4	26.2	0.2	2.6	2.2
1988	53	31.3	41.0	296	34.9	28.0	314.2	288.4	37	23.8	1.6	16.9	13.1	0.4	0.4	0.71	0	0.0	0.0	0.0	0.0
1993	58	34.6	45.4	284	38.7	32.8	400.8	374.7	12	29.3	0.8	9.8	8.6	0.8	0.7	0.77	0	0.0	0.0	0.0	0.0
1998	63	36.4	49.3	284	41.7	38.1	485.4	457.4	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - *Cubic meters* - - - - -				- - - *cm* - - -		*Square meters*		- - - - - - - - - - - - - - - *Cubic meters* - - - - - - - - - - - - - - -							
1968	33	101.7	101.7	40.9	40.9	0.00	0.00	0.0	0.0	0.0	3.6	0.0	1.7	0.0	3.6	0.0	1.7
1973	38	173.9	174.7	105.5	105.5	0.68	0.66	1.4	1.4	14.9	5.1	13.4	3.3	15.1	5.1	13.4	3.3
1978	43	250.4	252.9	183.1	184.4	0.72	0.72	1.3	1.3	15.8	6.3	16.0	4.7	16.1	6.4	16.3	4.8
1983	48	334.3	338.9	267.9	270.9	0.75	0.75	1.2	1.3	17.3	7.5	17.5	6.1	17.7	7.5	17.8	6.1
1988	53	417.8	422.4	351.2	354.2	0.64	0.64	1.1	1.1	17.2	8.4	17.1	7.1	17.2	8.5	17.1	7.2
1993	58	513.7	518.3	445.5	448.5	0.68	0.68	1.1	1.1	19.7	9.3	19.4	8.2	19.7	9.4	19.4	8.2
1998	63	598.2	602.8	528.3	531.3	0.60	0.60	1.1	1.1	17.4	10.0	17.1	8.9	17.4	10.1	17.1	8.9

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. and larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 112.8 cubic meters (22 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 4.6 cubic meters (1 percent of the total gross yield).

Table 24a––Stand development table for treatment 5 (plots 92, 114, and 125), by year, per acre basis

		After thinning							Removed in thinning								Mortality				
		40 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Feet*	*Inches*	*No.*	*Inches*	*Ft²*	*- -Cubic feet*	*- -*	*No.*	*Inches*	*Ft²*	*- - - - - - - - - -Cubic feet*				*- - - - - - - - -*	*No.*	*Inches*	*Ft²*	*- - Ft³*	*- -*
1968	33	62	10.4	285	6.7	68.9	1,498	726	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0
1973	38	74	12.3	237	8.2	86.5	2,254	1,513	47	6.6	11.1	258	95	5.5	3.2	0.83	2	3.7	0.1	2	0
1978	43	84	14.1	205	9.6	101.9	3,032	2,357	32	8.6	12.9	371	242	11.6	8.6	0.92	0	0.0	0.0	0	0
1983	48	94	15.8	175	11.1	115.9	3,874	3,284	30	8.9	12.9	408	289	13.6	10.7	0.83	0	0.0	0.0	0	0
1988	53	102	17.2	148	13.0	129.5	4,770	4,265	27	8.1	9.5	298	185	11.0	10.3	0.67	0	0.0	0.0	0	0
1993	58	112	18.6	120	15.1	142.0	5,758	5,332	27	8.1	9.5	320	219	11.9	12.9	0.59	2	6.8	0.4	12	3
1998	63	118	19.9	115	16.2	157.6	6,667	6,239	0	0.0	0.0	0	0	0.0	0.0	0.00	5	12.9	4.5	185	166

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - Cubic feet			*- - - - - - - - -*	*- - -Inches*	*- - -*	*Square feet*		*- - - - - - - - - - - - - - - Cubic feet*							*- - - - - - - - - - - - - - - - -*
1968	33	1,498	1,498	726	726	0.00	0.00	0.0	0.0	0	45	0	22	0	45	0	22
1973	38	2,512	2,514	1,608	1,608	0.26	0.26	5.8	5.8	203	66	176	42	203	66	176	42
1978	43	3,661	3,663	2,695	2,695	0.25	0.25	5.7	5.7	230	85	217	63	230	85	217	63
1983	48	4,911	4,913	3,910	3,910	0.24	0.24	5.4	5.4	250	102	243	81	250	102	243	81
1988	53	6,105	6,107	5,077	5,077	0.22	0.22	4.6	4.6	239	115	233	96	239	115	233	96
1993	58	7,412	7,426	6,362	6,365	0.23	0.22	4.4	4.5	262	128	257	110	264	128	258	110
1998	63	8,322	8,521	7,269	7,439	0.22	0.22	3.1	4.0	182	132	181	115	219	135	215	118

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 1,655 cubic feet (22 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 199 cubic feet (2 percent of the total gross yield).

Table 24b––Stand development table for treatment 5 (plots 92, 114, and 125), by year, per hectare basis

		After thinning							Removed in thinning								Mortality				
		100 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Meters*	*cm*	*No.*	*cm*	*m^2*	*Cubic meters*		*No.*	*cm*	*m^2*	*- - - - - - - - Cubic meters- - - - - - - - -*					*No.*	*cm*	*m^2*	*- - m^3 - -*	
1968	33	19.5	26.5	704	16.9	15.9	105.4	51.3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	23.1	31.3	585	20.9	19.9	158.3	106.4	115	16.8	2.6	18.5	7.2	0.2	0.1	0.83	4	9.4	0.0	0.6	0.5
1978	43	26.1	35.8	506	24.4	23.4	212.8	165.5	78	22.0	3.0	26.5	17.5	0.3	0.2	0.92	0	0.0	0.0	0.0	0.0
1983	48	29.0	40.1	432	28.4	26.6	271.7	230.3	74	22.6	3.0	29.1	20.7	0.4	0.3	0.83	0	0.0	0.0	0.0	0.0
1988	53	31.7	43.8	366	33.1	29.8	334.4	299.0	66	20.6	2.2	21.4	13.4	0.3	0.3	0.67	0	0.0	0.0	0.0	0.0
1993	58	34.8	47.4	296	38.4	32.7	403.5	373.7	66	20.5	2.2	22.9	15.8	0.3	0.4	0.59	4	17.3	0.1	1.3	0.7
1998	63	36.6	50.5	284	41.2	36.2	467.2	437.2	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	12	32.8	1.0	13.5	12.1

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - Cubic meters - - - - - -				*- - - cm - - -*		*Square meters*		*- - - - - - - - - - - - - - - Cubic meters - - - - - - - - - - - - - - -*							
1968	33	105.4	105.4	51.3	51.3	0.00	0.00	0.0	0.0	0.0	3.7	0.0	2.0	0.0	3.7	0.0	2.0
1973	38	176.4	176.5	113.1	113.1	0.66	0.65	1.3	1.3	14.7	5.1	12.8	3.5	14.7	5.1	12.8	3.5
1978	43	256.8	256.9	189.1	189.1	0.64	0.64	1.3	1.3	16.6	6.5	15.7	4.9	16.6	6.5	15.7	4.9
1983	48	344.3	344.4	274.2	274.2	0.61	0.61	1.2	1.2	18.0	7.7	17.5	6.2	18.0	7.7	17.5	6.2
1988	53	427.8	428.0	355.9	355.9	0.55	0.55	1.1	1.1	17.2	8.6	16.8	7.2	17.2	8.6	16.8	7.2
1993	58	519.4	520.3	445.8	446.0	0.58	0.56	1.0	1.0	18.8	9.4	18.5	8.2	19.0	9.5	18.5	8.2
1998	63	583.0	597.0	509.3	521.2	0.56	0.55	0.7	0.9	13.2	9.7	13.2	8.6	15.8	10.0	15.5	8.8

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. and larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 115.8 cubic meters (22 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 13.9 cubic meters (2 percent of the total gross yield).

Table 25a––Stand development table for treatment 6 (plots 32, 101, and 102), by year, per acre basis

		After thinning							Removed in thinning								Mortality				
		40 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Feet*	*Inches*	*No.*	*Inches*	*Ft²*	- - *Cubic feet* - -		*No.*	*Inches*	*Ft²*	- - - - - - - - - - *Cubic feet* - - - - - - - - -					*No.*	*Inches*	*Ft²*	- - *Ft³* - -	
1968	33	58	9.1	320	6.1	64.7	1,327	474	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0
1973	38	68	10.9	278	7.6	85.8	2,071	1,176	38	6.4	8.6	189	67	5.0	3.3	0.87	3	3.6	0.2	3	0
1978	43	79	12.8	218	9.2	99.6	2,787	2,054	57	7.9	19.4	517	298	9.1	6.2	0.89	3	3.6	0.2	3	0
1983	48	90	14.6	163	11.0	1,06.7	3,470	2,908	55	8.8	23.3	693	487	12.6	11.3	0.84	0	0.0	0.0	0	0
1988	53	99	16.3	110	13.8	1,12.0	4,084	3,732	52	8.3	19.6	607	395	11.7	10.7	0.68	2	8.8	0.7	22	14
1993	58	109	17.9	87	15.9	1,17.7	4,712	4,429	22	12.1	17.2	649	568	29.5	25.8	0.80	2	12.3	1.4	51	46
1998	63	116	19.4	85	17.4	1,38.9	5,850	5,550	0	0.0	0.0	0	0	0.0	0.0	0.00	2	7.4	0.5	14	6

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - *Cubic feet* - - - - - - - - -				- - -*Inches*- - - -		*Square feet*		- - - - - - - - - - - - - - - - *Cubic feet* - - - - - - - - - - - - - - - - - -							
1968	33	1,327	1,327	474	474	0.00	0.00	0.0	0.0	0	40	0	14	0	40	0	14
1973	38	2,261	2,264	1,243	1,243	0.26	0.26	6.0	6.0	187	59	154	33	187	60	154	33
1978	43	3,494	3,501	2,419	2,419	0.28	0.27	6.6	6.7	247	81	235	56	247	81	235	56
1983	48	4,869	4,876	3,760	3,760	0.26	0.26	6.1	6.1	275	101	268	78	275	102	268	78
1988	53	6,090	6,119	4,980	4,994	0.26	0.25	5.0	5.1	244	115	244	94	249	115	247	94
1993	58	7,367	7,447	6,245	6,305	0.29	0.29	4.6	4.8	255	127	253	108	266	128	262	109
1998	63	8,506	8,599	7,366	7,431	0.30	0.28	4.3	4.4	228	135	224	117	230	136	225	118

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 2,656 cubic feet (36 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 93 cubic feet (1 percent of the total gross yield).

Table 25b––Stand development table for treatment 6 (plots 32, 101, and 102), by year, per hectare basis

		After thinning							Removed in thinning								Mortality				
		100 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Meters*	*cm*	*No.*	*cm*	*m^2*	*Cubic meters*		*No.*	*cm*	*m^2*	*Cubic meters*					*No.*	*cm*	*m^2*	*m^3*	
1968	33	18.2	23.1	790	15.5	14.9	93.4	33.7	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	21.1	27.8	687	19.2	19.7	145.5	82.8	95	16.3	2.0	13.8	5.2	0.1	0.1	0.87	8	9.1	0.1	0.7	0.5
1978	43	24.6	32.5	539	23.4	22.9	195.6	144.3	140	20.2	4.5	36.7	21.4	0.3	0.2	0.89	8	9.0	0.1	0.7	0.5
1983	48	27.8	37.1	403	28.1	24.5	243.4	204.0	136	22.4	5.3	49.0	34.6	0.4	0.3	0.84	0	0.0	0.0	0.0	0.0
1988	53	30.8	41.3	272	35.0	25.8	286.4	261.7	128	21.2	4.5	43.0	28.2	0.3	0.3	0.68	4	22.4	0.2	2.0	1.5
1993	58	33.8	45.5	214	40.3	27.1	330.3	310.5	54	30.7	4.0	46.0	40.3	0.8	0.7	0.80	4	31.3	0.3	4.1	3.7
1998	63	35.9	49.3	210	44.2	32.0	410.0	389.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	4	18.8	0.1	1.5	0.9

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		Cubic meters				*cm*		*Square meters*		*Cubic meters*							
1968	33	93.4	93.4	33.7	33.7	0.00	0.00	0.0	0.0	0.0	3.3	0.0	1.5	0.0	3.3	0.0	1.5
1973	38	158.7	159.0	87.5	87.5	0.67	0.66	1.4	1.4	13.6	4.7	11.3	2.8	13.6	4.7	11.3	2.8
1978	43	245.1	245.5	169.8	169.8	0.71	0.69	1.5	1.5	17.8	6.2	17.0	4.4	17.8	6.2	17.0	4.4
1983	48	341.3	341.8	263.7	263.7	0.67	0.67	1.4	1.4	19.8	7.6	19.3	6.0	19.8	7.6	19.3	6.0
1988	53	426.8	428.8	349.1	350.1	0.65	0.64	1.1	1.2	17.6	8.5	17.6	7.1	17.9	8.6	17.8	7.1
1993	58	516.2	521.8	437.6	441.8	0.73	0.73	1.0	1.1	18.4	9.4	18.2	8.0	19.1	9.5	18.8	8.1
1998	63	595.9	602.4	516.1	520.7	0.77	0.72	1.0	1.0	16.4	10.0	16.2	8.7	16.6	10.1	16.3	8.8

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 185.9 cubic meters (36 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 6.5 cubic meters (1 percent of the total gross yield).

Table 26a––Stand development table for treatment 7 (plots 62, 106, and 107), by year, per acre basis

		After thinning							Removed in thinning								Mortality				
		40 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Feet*	*Inches*	*No.*	*Inches*	*Ft²*	- -*Cubic feet* - -		*No.*	*Inches*	*Ft²*	- - - - - - - - - -*Cubic feet* - - - - - - - - -					*No.*	*Inches*	*Ft²*	- - *Ft³* - -	
1968	33	61	9.5	280	6.7	69.4	1,574	648	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0
1973	38	71	11.3	260	8.1	93.7	2,486	1,546	18	6.8	4.6	113	50	6.3	6.3	0.84	2	3.1	0.1	1	0
1978	43	82	13.0	232	9.6	115.1	3,477	2,639	20	8.5	7.9	229	148	11.4	8.7	0.90	8	4.4	0.9	17	0
1983	48	94	14.5	212	10.9	135.7	4,718	3,939	18	8.4	7.1	225	147	12.5	11.3	0.79	2	4.8	0.2	5	0
1988	53	104	15.8	198	12.0	154.6	5,923	5,194	13	8.4	5.1	176	117	13.5	9.8	0.71	0	0.0	0.0	0	0
1993	58	114	17.1	180	13.1	168.3	7,053	6,374	13	10.0	7.2	281	227	21.6	18.9	0.77	5	10.9	3.3	133	116
1998	63	122	18.3	172	14.3	188.9	8,406	7,737	0	0.0	0.0	0	0	0.0	0.0	0.00	8	6.7	2.1	65	31

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - *Cubic feet* - - - - - - - - -				- - - -*Inches*- - -		*Square feet*		- - - - - - - - - - - - - - - - *Cubic feet* - - - - - - - - - - - - - - - - - -							
1968	33	1,574	1,574	648	648	0.00	0.00	0.0	0.0	0	48	0	20	0	48	0	20
1973	38	2,600	2,601	1,596	1,596	0.26	0.26	5.8	5.8	205	68	190	42	206	68	190	42
1978	43	3,820	3,839	2,838	2,838	0.27	0.25	5.9	6.0	244	89	248	66	247	89	248	66
1983	48	5,286	5,309	4,285	4,285	0.23	0.22	5.5	5.6	293	110	289	89	294	111	289	89
1988	53	6,667	6,690	5,656	5,656	0.19	0.19	4.8	4.8	276	126	274	107	276	126	274	107
1993	58	8,079	8,235	7,062	7,179	0.19	0.19	4.2	4.8	282	139	281	122	309	142	305	124
1998	63	9,431	9,652	8,425	8,573	0.23	0.18	4.1	4.5	271	150	273	134	283	153	279	136

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 1,025 cubic feet (12 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 221 cubic feet (2 percent of the total gross yield).

Table 26b––Stand development table for treatment 7 (plots 62, 106, and 107), by year, per hectare basis

		After thinning							Removed in thinning								Mortality				
		100 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Meters*	*cm*	*No.*	*cm*	*m²*	*Cubic meters*		*No.*	*cm*	*m²*	- - - - - - - - *Cubic meters* - - - - - - - -					*No.*	*cm*	*m²*	- - *m³* - -	
1968	33	19.2	24.2	692	17.1	16.0	110.6	45.9	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	22.3	28.8	642	20.7	21.6	174.6	108.7	45	17.2	1.0	8.4	4.0	0.2	0.2	0.84	4	7.9	0.0	0.6	0.5
1978	43	25.5	33.0	572	24.3	26.5	243.9	185.2	49	21.6	1.8	16.5	10.9	0.3	0.2	0.90	21	11.2	0.2	1.7	0.5
1983	48	29.1	36.9	523	27.6	31.2	330.7	276.3	45	21.4	1.6	16.3	10.8	0.4	0.3	0.79	4	12.2	0.0	0.8	0.5
1988	53	32.1	40.2	490	30.5	35.6	415.1	364.1	33	21.4	1.2	12.8	8.7	0.4	0.3	0.71	0	0.0	0.0	0.0	0.0
1993	58	35.3	43.3	445	33.4	38.7	494.2	446.7	33	25.3	1.7	20.2	16.4	0.6	0.6	0.77	12	27.8	0.7	9.8	8.7
1998	63	37.7	46.5	424	36.3	43.4	588.9	542.1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	21	17.1	0.5	5.0	2.6

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - *Cubic meters* - - - - - -				- - - *cm* - - -		*Square meters*		- - - - - - - - - - - - - - - *Cubic meters* - - - - - - - - - - - - - - -							
1968	33	110.6	110.6	45.9	45.9	0.00	0.00	0.0	0.0	0.0	3.8	0.0	1.9	0.0	3.8	0.0	1.9
1973	38	182.5	182.6	112.2	112.2	0.66	0.66	1.3	1.3	14.9	5.3	13.8	3.4	14.9	5.3	13.8	3.4
1978	43	267.9	269.2	199.1	199.1	0.68	0.63	1.3	1.4	17.6	6.7	17.9	5.1	17.8	6.7	17.9	5.1
1983	48	370.5	372.1	300.4	300.4	0.57	0.56	1.3	1.3	21.0	8.2	20.8	6.7	21.1	8.2	20.8	6.7
1988	53	467.2	468.8	396.4	396.4	0.47	0.47	1.1	1.1	19.8	9.3	19.7	8.0	19.8	9.3	19.7	8.0
1993	58	566.0	576.9	494.9	503.0	0.48	0.47	1.0	1.1	20.3	10.3	20.2	9.0	22.1	10.4	21.8	9.2
1998	63	660.7	676.1	590.3	600.6	0.58	0.45	0.9	1.0	19.4	11.0	19.6	9.9	20.3	11.2	20.0	10.0

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 71.8 cubic meters (12 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 15.4 cubic meters (2 percent of the total gross yield).

Table 27a––Stand development table for treatment 8 (plots 96, 111, and 116), by year, per acre basis

		After thinning							Removed in thinning								Mortality				
		40 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	Feet	Inches	No.	Inches	Ft^2	- -Cubic feet - -		No.	Inches	Ft^2	- - - - - - - - - -Cubic feet - - - - - - - - -					No.	Inches	Ft^2	- - Ft^3 - -	
1968	33	61	10.1	255	7.0	67.1	1,488	729	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0
1973	38	73	12.1	235	8.5	91.3	2,419	1,658	20	5.9	3.8	84	27	4.2	3.9	0.71	0	0.0	0.0	0	0
1978	43	83	13.8	208	9.9	110.8	3,326	2,658	25	8.1	9.0	253	162	10.1	8.1	0.83	2	6.8	0.4	10	3
1983	48	95	15.4	182	11.3	125.3	4,361	3,749	27	9.3	12.7	410	319	15.2	15.9	0.85	0	0.0	0.0	0	0
1988	53	106	16.8	153	12.8	136.7	5,256	4,750	25	9.0	11.1	371	263	14.8	12.0	0.73	3	5.7	0.6	13	0
1993	58	117	18.2	122	14.8	145.4	6,247	5,823	32	9.2	14.5	532	416	16.6	20.8	0.66	0	0.0	0.0	0	0
1998	63	124	19.5	118	16.0	165.0	7,417	6,974	0	0.0	0.0	0	0	0.0	0.0	0.00	3	9.5	1.7	66	59

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
Year	Stand age	Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - Cubic feet - - - - - - - - -				- - -Inches- - -		Square feet		- - - - - - - - - - - - - - - - Cubic feet - - - - - - - - - - - - - - - - - -							
1968	33	1,488	1,488	729	729	0.00	0.00	0.0	0.0	0	45	0	22	0	45	0	22
1973	38	2,502	2,502	1,685	1,685	0.27	0.27	5.6	5.6	203	66	191	44	203	66	191	44
1978	43	3,662	3,672	2,846	2,849	0.25	0.25	5.7	5.8	232	85	232	66	234	85	233	66
1983	48	5,107	5,117	4,256	4,258	0.23	0.23	5.4	5.4	289	106	282	89	289	107	282	89
1988	53	6,374	6,397	5,520	5,522	0.22	0.20	4.5	4.6	253	120	253	104	256	121	253	104
1993	58	7,896	7,919	7,009	7,011	0.21	0.21	4.6	4.6	304	136	298	121	304	137	298	121
1998	63	9,066	9,155	8,160	8,222	0.23	0.21	3.9	4.2	234	144	230	130	247	145	242	131

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 1,649 cubic feet (21 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 89 cubic feet (1 percent of the total gross yield).

Table 27b––Stand development table for treatment 8 (plots 96, 111, and 116), by year, per hectare basis

		After thinning							Removed in thinning								Mortality				
		100 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Meters*	*cm*	*No.*	*cm*	*m^2*	*Cubic meters*		*No.*	*cm*	*m^2*	*Cubic meters*					*No.*	*cm*	*m^2*	*m^3*	
1968	33	19.0	25.8	630	17.7	15.4	104.7	51.6	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	22.8	30.6	580	21.5	21.0	169.8	116.6	49	15.0	0.9	6.4	2.4	0.1	0.1	0.71	0	0.0	0.0	0.0	0.0
1978	43	25.8	34.9	515	25.3	25.5	233.3	186.6	62	20.6	2.1	18.2	11.8	0.3	0.2	0.84	4	17.3	0.1	1.2	0.7
1983	48	29.6	39.2	449	28.7	28.8	305.8	262.9	66	23.7	2.9	29.2	22.8	0.4	0.4	0.85	0	0.0	0.0	0.0	0.0
1988	53	32.7	42.7	379	32.6	31.5	368.4	333.0	62	23.0	2.6	26.5	18.9	0.4	0.3	0.73	8	14.4	0.1	1.4	0.5
1993	58	36.3	46.2	301	37.7	33.5	437.8	408.1	78	23.3	3.3	37.7	29.6	0.5	0.6	0.66	0	0.0	0.0	0.0	0.0
1998	63	38.4	49.6	292	40.7	37.9	519.7	488.7	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	8	24.2	0.4	5.1	4.6

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
Year	Stand age	Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		Cubic meters				*cm*		*Square meters*		*Cubic meters*							
1968	33	104.7	104.7	51.6	51.6	0.00	0.00	0.0	0.0	0.0	3.7	0.0	2.0	0.0	3.7	0.0	2.0
1973	38	175.7	175.7	118.4	118.4	0.67	0.67	1.3	1.3	14.7	5.1	13.9	3.6	14.7	5.1	13.9	3.6
1978	43	256.9	257.6	199.7	199.9	0.64	0.64	1.3	1.3	16.7	6.5	16.8	5.1	16.9	6.5	16.8	5.1
1983	48	358.0	358.7	298.4	298.6	0.59	0.59	1.3	1.3	20.7	7.9	20.2	6.7	20.7	8.0	20.2	6.7
1988	53	446.7	448.3	386.9	387.1	0.56	0.51	1.0	1.1	18.2	8.9	18.2	7.8	18.4	8.9	18.2	7.8
1993	58	553.2	554.9	491.1	491.3	0.53	0.53	1.1	1.1	21.8	10.0	21.3	9.0	21.8	10.1	21.3	9.0
1998	63	635.1	641.4	571.7	576.0	0.60	0.54	0.9	1.0	16.9	10.6	16.6	9.6	17.8	10.7	17.4	9.6

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Yield does not include any volume removed in the calibration cut. Volume (CVTS) removed in thinnings = 115.5 cubic meters (21 percent of the total gross yield at the last thinning). Volume (CVTS) in mortality = 6.2 cubic meters (1 percent of the total gross yield).

Table 28a––Stand development table for treatment 9, unthinned control (plots 61, 105, and 122), by year, per acre basis

		After thinning							Removed in thinning								Mortality				
		40 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	Feet	Inches	No.	Inches	Ft^2	- -Cubic feet - -		No.	Inches	Ft^2	- - - - - - - - - -Cubic feet - - - - - - - - -					No.	Inches	Ft^2	- - Ft^3 - -	
1968	33	59	9.7	1,075	4.6	120.8	2,417	780	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0
1973	38	70	11.2	1,010	5.3	152.0	3,581	1,713	0	0.0	0.0	0	0	0.0	0.0	0.00	65	2.4	2.0	22	0
1978	43	81	12.6	890	6.1	181.1	4,961	2,991	0	0.0	0.0	0	0	0.0	0.0	0.00	118	2.6	4.4	63	11
1983	48	89	14.0	685	7.4	202.2	6,333	4,430	0	0.0	0.0	0	0	0.0	0.0	0.00	205	2.9	9.3	149	6
1988	53	100	15.3	515	8.8	218.7	7,779	5,992	0	0.0	0.0	0	0	0.0	0.0	0.00	170	3.3	10.3	192	14
1993	58	109	16.4	410	10.2	231.3	9,055	7,522	0	0.0	0.0	0	0	0.0	0.0	0.00	105	5.0	14.4	386	100
1998	63	116	17.6	367	11.2	250.7	10,418	9,003	0	0.0	0.0	0	0	0.0	0.0	0.00	43	5.2	6.5	186	59

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - Cubic feet - - - - - - - - -				- - -Inches- - - -		Square feet		- - - - - - - - - - - - - - - - Cubic feet - - - - - - - - - - - - - - - - - -							
1968	33	2,417	2,417	780	780	0.00	0.00	0.0	0.0	0	73	0	24	0	73	0	24
1973	38	3,581	3,604	1,713	1,713	0.14	0.12	6.2	6.6	233	94	187	45	237	95	187	45
1978	43	4,961	5,047	2,991	3,002	0.17	0.12	5.8	6.7	276	115	256	70	289	117	258	70
1983	48	6,333	6,568	4,430	4,447	0.24	0.12	4.2	6.1	274	132	288	92	304	137	289	93
1988	53	7,779	8,207	5,992	6,022	0.29	0.11	3.3	5.4	289	147	312	113	328	155	315	114
1993	58	9,055	9,869	7,522	7,653	0.27	0.12	2.5	5.4	255	156	306	130	332	170	326	132
1998	63	10,418	11,418	9,003	9,192	0.20	0.12	3.9	5.2	273	165	296	143	310	181	308	146

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Volume (CVTS) in mortality = 1,000 cubic feet (9 percent of the total gross yield).

Table 28b––Stand development table for treatment 9, unthinned control (plots 61, 105, and 122), by year, per hectare basis

		After thinning							Removed in thinning								Mortality				
		100 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Meters*	*cm*	*No.*	*cm*	*m^2*	*Cubic meters*		*No.*	*cm*	*m^2*	*- - - - - - - Cubic meters- - - - - - - -*					*No.*	*cm*	*m^2*	*- - m^3 - -*	
1968	33	18.6	24.6	2,655	11.6	27.8	169.7	55.1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	21.9	28.4	2,495	13.4	35.0	251.2	120.4	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	161	6.0	0.5	2.1	0.5
1978	43	25.1	32.1	2,198	15.6	41.6	347.8	209.9	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	292	6.7	1.0	4.9	1.2
1983	48	27.7	35.7	1,692	18.7	46.5	443.8	310.6	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	506	7.4	2.1	11.0	0.9
1988	53	30.9	38.8	1,272	22.5	50.3	545.0	419.9	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	420	8.5	2.4	14.0	1.5
1993	58	33.8	41.8	1,013	25.9	53.2	634.3	527.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	259	12.7	3.3	27.5	7.5
1998	63	35.9	44.6	906	28.5	57.7	729.7	630.7	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	107	13.3	1.5	13.5	4.6

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - Cubic meters - - - - -				*- - - cm - - -*		*Square meters*		*- - - - - - - - - - - - - - - Cubic meters - - - - - - - - - - - - - - -*							
1968	33	169.7	169.7	55.1	55.1	0.00	0.00	0.0	0.0	0.0	5.6	0.0	2.2	0.0	5.6	0.0	2.2
1973	38	251.2	252.8	120.4	120.4	0.36	0.31	1.4	1.5	16.8	7.1	13.6	3.7	17.1	7.1	13.6	3.7
1978	43	347.8	353.8	209.9	210.6	0.43	0.31	1.3	1.5	19.8	8.6	18.4	5.4	20.7	8.7	18.5	5.4
1983	48	443.8	460.3	310.6	311.8	0.62	0.29	1.0	1.4	19.7	9.7	20.6	7.0	21.8	10.1	20.7	7.0
1988	53	545.0	575.0	419.9	422.1	0.75	0.28	0.8	1.2	20.8	10.8	22.4	8.4	23.4	11.3	22.6	8.5
1993	58	634.3	691.3	527.0	536.2	0.69	0.31	0.6	1.2	18.4	11.4	21.9	9.6	23.8	12.4	23.3	9.7
1998	63	729.7	799.8	630.7	644.0	0.52	0.30	0.9	1.2	19.6	12.1	21.2	10.5	22.2	13.2	22.1	10.7

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Volume (CVTS) in mortality = 70.0 cubic meters (9 percent of the total gross yield).

Table 29a––Stand development table for treatment 10, spares (plots 21, 81, and 123), by year, per acre basis

		After thinning							Removed in thinning								Mortality				
		40 largest trees[a]					Volume[c]					Volume		Volume/tree						Volume	
Year	Stand age	HT	D.b.h.	Trees	QMD[b]	Basal area	CVTS	CV6[d]	Trees	QMD	Basal area	CVTS	CV6[d]	CVTS	CV6[d]	d/D[e]	Trees	QMD	Basal area	CVTS	CV6[d]
	Years	*Feet*	*Inches*	*No.*	*Inches*	*Ft²*	- -*Cubic feet* - -		*No.*	*Inches*	*Ft²*	- - - - - - - - - -*Cubic feet* - - - - - - - - -					*No.*	*Inches*	*Ft²*	- - *Ft³* - -	
1968	33	50	8.5	330	5.8	60.7	1,131	341	0	0.0	0.0	0	0	0.0	0.0	0.00	0	0.0	0.0	0	0
1973	38	62	10.0	323	6.9	84.5	1,897	939	0	0.0	0.0	0	0	0.0	0.0	0.00	8	5.5	1.4	29	14
1988	53	93	14.5	302	10.0	162.4	5,413	4,344	0	0.0	0.0	0	0	0.0	0.0	0.00	23	5.0	3.1	70	7
1993	58	102	15.9	277	11.1	183.2	6,639	5,645	0	0.0	0.0	0	0	0.0	0.0	0.00	25	6.4	5.7	161	70
1998	63	110	17.2	263	12.0	205.0	7,959	7,001	0	0.0	0.0	0	0	0.0	0.0	0.00	13	6.6	3.2	93	43

		Cumulative yield[f]				QMD growth		BA growth		Net volume growth				Gross volume growth			
		Net CVTS	Gross CVTS	Net CV6	Gross CV6	Net PAI	Surv. PAI	Net PAI	Gross PAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI	CVTS PAI	CVTS MAI	CV6 PAI	CV6 MAI
		- - - - - - - *Cubic feet* - - - - - - - -				- - -*Inches*- - -		*Square feet*		- - - - - - - - - - - - - - - *Cubic feet* - - - - - - - - - - - - - - - - - -							
1968	33	1,131	1,131	341	341	0.00	0.00	0.0	0.0	0	34	0	10	0	34	0	10
1973	38	1,897	1,926	939	953	0.22	0.22	4.8	5.0	153	50	120	25	159	51	122	25
1988	53	5,413	5,512	4,344	4,365	0.20	0.20	5.2	5.4	234	102	227	82	239	104	227	82
1993	58	6,639	6,899	5,645	5,736	0.22	0.17	4.1	5.3	245	114	260	97	277	119	274	99
1998	63	7,959	8,311	7,001	7,135	0.19	0.15	4.4	5.0	264	126	271	111	283	132	280	113

[a] Average height and d.b.h. of the 40 largest trees per acre (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 6-inch top diameter (CV6), inside bark.
[d] Only trees 7.6 inches d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Volume (CVTS) in mortality = 352 cubic feet (4 percent of the total gross yield).

Table 29b––Stand development table for treatment 10, spares (plots 21, 81, and 123), by year, per hectare basis

Year	Stand age	After thinning: 100 largest trees[a] HT	After thinning: 100 largest trees[a] D.b.h.	After thinning: Trees	After thinning: QMD[b]	After thinning: Basal area	After thinning: Volume[c] CVTS	After thinning: Volume[c] CV6[d]	Removed in thinning: Trees	Removed in thinning: QMD	Removed in thinning: Basal area	Removed in thinning: Volume CVTS	Removed in thinning: Volume CV6[d]	Removed in thinning: Volume/tree CVTS	Removed in thinning: Volume/tree CV6[d]	Removed in thinning: d/D[e]	Mortality: Trees	Mortality: QMD	Mortality: Basal area	Mortality: Volume CVTS	Mortality: Volume CV6[d]
	Years	*Meters*	*cm*	*No.*	*cm*	*m²*	*Cubic meters*		*No.*	*cm*	*m²*	- - - - - - - - *Cubic meters* - - - - - - - -					*No.*	*cm*	*m²*	- - *m³* - -	
1968	33	15.8	21.6	815	14.8	14.0	79.7	24.3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0	0.0	0.0
1973	38	19.4	25.5	799	17.7	19.4	133.3	66.2	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	21	14.0	0.3	2.5	1.5
1988	53	28.9	36.9	745	25.5	37.4	379.4	304.6	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	58	12.6	0.7	5.4	1.0
1993	58	31.6	40.4	683	28.2	42.1	465.3	395.7	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	62	16.4	1.3	11.7	5.4
1998	63	34.1	43.7	650	30.6	47.1	557.6	490.6	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	33	16.8	0.7	7.0	3.5

Year	Stand age	Cumulative yield[f] Net CVTS	Cumulative yield[f] Gross CVTS	Cumulative yield[f] Net CV6	Cumulative yield[f] Gross CV6	QMD growth Net PAI	QMD growth Surv. PAI	BA growth Net PAI	BA growth Gross PAI	Net volume growth CVTS PAI	Net volume growth CVTS MAI	Net volume growth CV6 PAI	Net volume growth CV6 MAI	Gross volume growth CVTS PAI	Gross volume growth CVTS MAI	Gross volume growth CV6 PAI	Gross volume growth CV6 MAI
		- - - - - - *Cubic meters* - - - - - -				- - - *cm* - - -		*Square meters*		- - - - - - - - - - - - - - *Cubic meters* - - - - - - - - - - - - - -							
1968	33	79.7	79.7	24.3	24.3	0.00	0.00	0.0	0.0	0.0	2.9	0.0	1.2	0.0	2.9	0.0	1.2
1973	38	133.3	135.3	66.2	67.2	0.57	0.57	1.1	1.2	11.2	4.0	8.9	2.2	11.6	4.0	9.1	2.3
1988	53	379.4	386.3	304.6	306.0	0.52	0.50	1.2	1.2	16.9	7.6	16.4	6.2	17.2	7.8	16.4	6.3
1993	58	465.3	483.4	395.7	402.0	0.55	0.42	1.0	1.2	17.7	8.5	18.7	7.3	19.9	8.8	19.7	7.4
1998	63	557.6	582.3	490.6	500.0	0.48	0.38	1.0	1.2	19.0	9.3	19.5	8.3	20.3	9.7	20.1	8.4

[a] Average height and d.b.h. of the 100 largest trees per hectare (estimated from d.b.h. and HT-d.b.h. curves).
[b] Quadratic mean diameter at breast height.
[c] All volumes are total stem cubic (CVTS) or merchantable cubic to a 15.25-cm top diameter (CV6), inside bark.
[d] Only trees 19.3 cm d.b.h. or larger.
[e] QMD cut ÷ QMD before thinning.
[f] Net = standing + thinning; gross = standing + thinning + mortality. Volume (CVTS) in mortality = 24.7 cubic meters (4 percent of the total gross yield).

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