INFLUENCE OF THINNING STYLE ON STAND STRUCTURE AND GROWTH IN UPLAND OAKS: A 58-YEAR CASE STUDY

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ABSTRACT.—In 1937, a study comparing low and high thinning (partial crop tree release) was established in northwestern Connecticut. Oaks accounted for 65 percent of the crop trees that were partially released at stand ages 17, 26, and 42 years. Sawtimber trees had greater diameters, higher volumes, and higher tree grades on thinned than unmanaged plots. The higher oak density on the unmanaged plot was concentrated in poletimber trees (5 to 10 inches dbh). Tree sapling and shrub densities were higher on the low thinning plots. Density of a shade tolerant midstory dominated by red maple (*Acer rubrum* L.) poles was increased by high thinning, but reduced by low thinning. The minimal gain in tree grade on thinned plots indicates that the high cost of thinning/cleaning in sapling stands, as implemented in this study, is unlikely to be recovered in future harvests of mature sawtimber.

Current management practices have long-term consequences on future forest resources. Uneven-aged management and extended periods of partial cuttings are being prescribed for increasing portions of the forest, and have been advocated as the preferred management option on some national forests (Guldin 1996). The long-term effects of partial cutting have been interpolated from short-term and stand reconstruction studies, because of the paucity of long-term studies. These studies suggest partial cutting accelerates the shift in dominance from midtolerant to tolerant species and may eventually decrease stand growth rates (Lamson and Smith 1991). Thus, changes in current management practices will affect the quality and variety of future forest resources.

Short-term impacts (< 10 years) of partial cutting are well documented. Partial cutting increases growth of residual trees (Hilt 1979, Sonderman 1984, Stringer and others 1988). Medium-term studies (10 to 40 years) suggest the initial gains in volume growth following partial cutting are not lost over time (Ward 1991). Thirty-two years after a single thinning, black and scarlet oak volumes were higher on thinned than control plots (Dwyer and Lowell 1988). Partial cuttings at 5-year intervals over a 20-year period increased black and northern red oak diameter growth (Rudolph and Lemmien 1976). Stand volume growth was higher on partially cut than control plots in West Virginia (Smith and Miller 1987).

Studies in unmanaged forests and research on partial cutting have reported the same pattern of increasing dominance by tolerant species (Rudolph and Lemmien 1976, Christensen 1977, Parker and others 1985, Ward 1992). While partial cutting has been reported to increase oak regeneration density (Kittredge and Ashton 1990), non-oak species often dominate regeneration after partial cutting in upland oak forests (Smith 1979, Hill and Dickman 1988, Heiligmann and others 1985). Stand reconstruction studies suggest partial cutting has accelerated succession towards dominance by more tolerant species (Jokela and Sawtelle 1985, Abrams and Scott 1989). However, heavy partial cutting (> 50 percent canopy removal) may allow northern red oak to achieve eventual canopy dominance (Lorimer 1983).

One method of partial cutting, crop tree management, has been demonstrated to enhance

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Citation for proceedings: Van Sambeek, J.W.; Dawson, J.O.; Ponder, F., Jr.; Loewenstein, E.F.; Fralish, J.S., eds. 2003. Proceedings, 13th Central Hardwood Forest conference; 2002 April 1-3; Urbana, IL. Gen. Tech. Rep. NC-234. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 565 p. [Peer-reviewed paper from oral presentation].

growth of selected crop trees and has been advocated as an alternative to traditional area-wide thinning (Perkey and others 1994). Therefore, it is prudent from both economic and ecological perspectives to document the long-term impact of this method of partial cutting on forest structure and composition.

The objective of my research was to examine the influence of two distinct methods of thinning (high and low) on short-term changes in crop tree growth response and long-term changes in stand structure and volume. This research illustrates the consequences of different methods of thinning on long-term changes in species composition and diameter distribution. These results can be used by forest managers to determine whether long-term changes initiated by thinning in young stands are appropriate for their management goals.

STUDY AREA

In 1937, the Connecticut State Forestry Department established a thinning (partial crop tree release) study in the Housatonic State Forest in northwestern Connecticut. Soils are well-drained Charlton-Hollis fine sandy loams (Typic Dystrochrepts) with 0-20 percent slopes derived from schist and granite glacial till (Hill and others 1980). Mean site index (black oak) is 68 feet. The area is in the northern temperate climate zone with 45 inches of annual precipitation evenly distributed over the year. The study plot was repeatedly cut over for charcoal production between 1840-1920, and numerous charcoal mounds are still evident.

Five species groups were found on the plots: Upland oaks—*Quercus alba* L., *Q. coccinea* Muenchh., *Q. prinus* L., *Q. rubra* L., and *Q. velutina* Lam.; Maple—*Acer rubrum* L. and *A. saccharum* Marsh.; Aspen—*Populus grandidentata* Michx.; Other—*Betula lenta* L., *B. papyrifera* Marsh., *Carya glabra* (Mill.) Sweet, *Fagus grandifolia* Ehrh., *Fraxinus americana* L., *Liriodendron tulipifera* L., *Pinus strobus* L., *Sassafras albidum* (Nutt.) Ness, and *Tilia americana* L.; and Shrubs—*Acer pensylvanicum* L., *Amelanchier arborea* (Michx.) Fern., *Carpinus caroliniana* Walt., *Castanea dentata* (Marsh.) Borkh., *Cornus florida* L., *Corylus cornuta* Marsh., *Hamamelis virginiana* L., *Kalmia latifolia* L., and *Ostrya virginiana* (Mill.) K Koch.

Increment cores of three trees/plot at 1 foot aboveground in 1962 determined the stand was established around 1920, i.e., the study was established in a 17-year-old stand. Aspen was the most numerous species in the 1- to 4-inch diameter class at stand age 17 (table 1), accounting for 52 percent of all stems. Upland oak predominated in the ≥ 5 inch diameter class (71 percent of stems). Average density before cutting was 2,360 stems/acre (dbh ≥ 1 inch). Initial basal area was slightly higher on the thinned plots, 43 ft^2/acre, than on the unmanaged plot, 36 ft^2/acre.

METHODS

Selection criteria for crop trees were not stringent, “the best trees, which promised to make the final crop.” (Hawes 1955). Crop tree density ranged from 135 stems/acre on low thinning plots to 147 stems/acre on control plots. Oaks accounted for 65 percent of crop trees, hickory 15 percent, maple 10 percent, and other species 10 percent. Slightly more than half of crop trees were in the intermediate crown class prior to the initial thinning. At the beginning of this study, mean diameter of oak crop trees was 3.5 inches and mean height was 32 feet.

Two plots were thinned from below (1.5 acres total), two plots were thinned from above (1.6 acres total), and one plot was left unmanaged to serve as a control (0.9 acres). In the low thinning plots, trees in the intermediate and suppressed crown classes that were competing

Table 1.—*Initial (precut) distribution of stems (n/ac) among diameter classes by species groups at stand age 17 in the Housatonic Blue Ribbon plots, Connecticut*

	Diameter class (inches)					
Species group[1]	1	2	3	4	> 5	Total
Upland oaks	169	187	100	42	12	510
Aspen	352	485	317	67	4	1225
Maple	357	104	11	0	0	472
Other	99	49	4	0	1	153
Total	977	825	432	109	17	2360

[1]Species are listed in Methods.

with crop trees were removed. Shrub species were not cut. In the high thinning plots, trees in the dominant and codominant crown classes that were competing with crop trees were removed. The one remaining tally sheet of stems cut at stand ages 17 indicates that 59 percent of cut stems were < 3 inches dbh and 76 percent of these were either aspen or maple. This roughly corresponds with the composition prior to the initial thinning.

Crop trees were released in 1937, 1946, and 1962 at stand ages 17, 26, and 42, respectively (fig. 1). In addition to the thinnings, several oaks with diameters greater than 10 inches were girdled in 1937 to eliminate potential wolf trees. Thinning reduced basal area by 28, 22, and 13 percent on high thinning plots at stand ages 17, 26, and 42 years. For the same periods, basal area was lowered by 45, 19, and 5 percent on low thinning plots.

Aspen and oak accounted for nearly 95 percent of basal area cut at stand age 42 on high thinning plots (table 2). Maple accounted for over 60 percent of trees cut on low thinning plots. Several pole-sized oaks in front of a deer stand were the only trees cut since 1962.

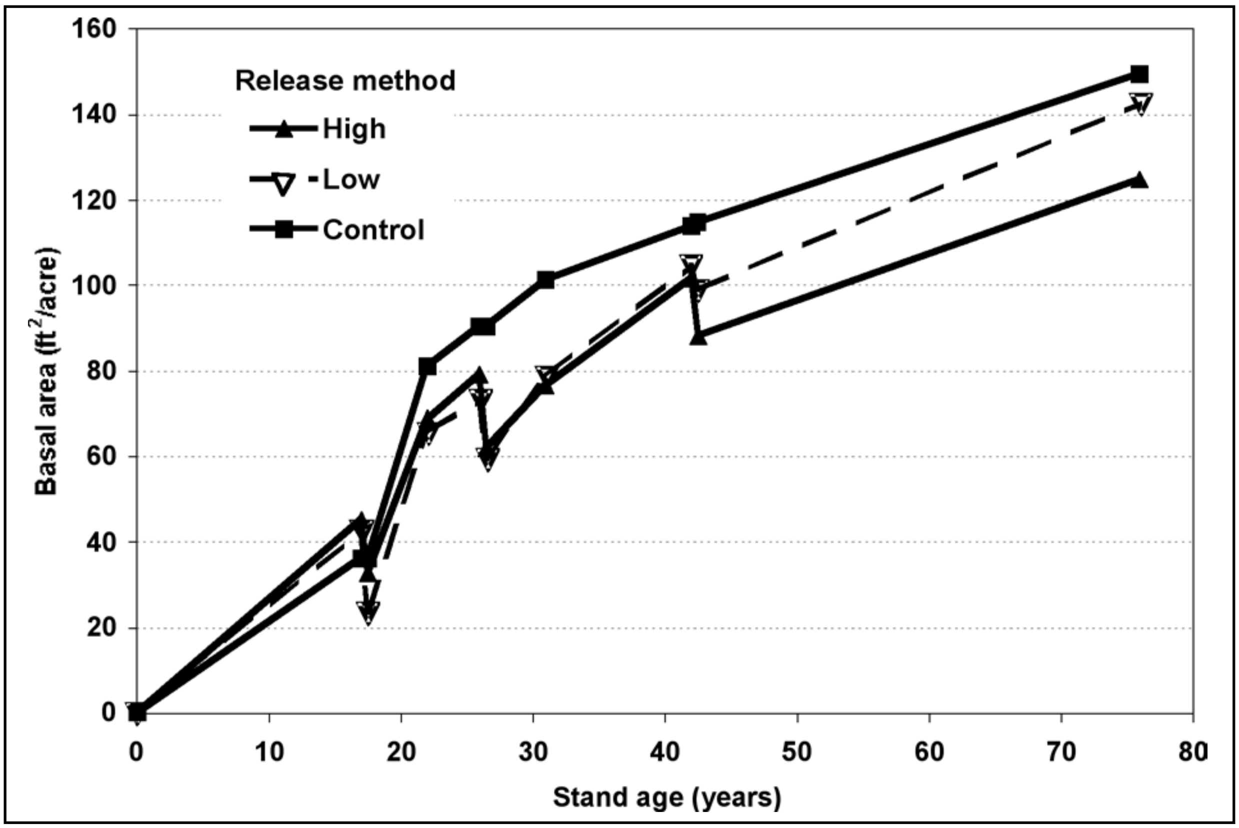

Figure 1.—*Basal area growth (ft²/ac) by release method in Housatonic Blue Ribbon plots, Connecticut. Treatments: High thinning (partial crop tree release from above), Low thinning (partial crop tree release from below), Control (no thinning).*

Table 2.—*Density (n/acre) and basal area (ft²/ac) removed by thinning method (high/low) at stand age 42 in the Housatonic Blue Ribbon plots, Connecticut*

Species group[1]	Density (n/ac) High	Density (n/ac) Low	Basal area (ft^2/ac) High	Basal area (ft^2/ac) Low
Upland oaks	11	12	3.6	1.4
Aspen	28	5	9.7	1.3
Maple	4	94	0.5	3.4
Other	2	36	0.3	1.0
Total	45	147	14.1	7.0

[1]Species are listed in Methods.

High thinning at stand age 17 required 3.7 man-days/acre, low release required 8.0 man-days/acre. The thinnings at stand ages 17 and 26 removed a combined 410 ft^3/ac on these plots. Volume data for trees cut on low thinning plots has been lost. Harvests at stand age 42 removed 330 and 120 ft^3/ac on high and low thinning plots, respectively.

Field Measurements

Selected crop trees on all plots were banded at 4.5 feet and numbered with blue paint. Diameters were recorded to the nearest 0.1 inch. Heights were recorded to the nearest 1 foot for all crop trees. All other trees > 0.5 inches dbh were tallied by species and by 1-in. dbh classes (table 1). Trees that were cut to release crop trees were tallied by species and 1-in. dbh classes. Individual crop tree measurements (diameter, height, and crown class) for 1937, 1942, 1946, and 1951 exist for three of the plots. Individual tree data for the other two plots were lost.

Complete stand summaries by species and crown class were recorded following the 1937, 1942, 1946, and 1951 inventories. Crown class designation standards through the survey in 1962 were based on Hawley and Hawes (1925), which are nearly identical to those used in the 1995 survey (Smith 1962). For this paper, upper canopy is defined as trees in the dominant and codominant crown classes.

Plot corners were permanently marked with stone cairns and chestnut posts. All original plot corners were relocated in 1995 and the original chestnut posts were replaced with iron stakes. Species and dbh were recorded for all stems > 0.5 inches dbh. Diameters at stump height (dsh, 1 foot aboveground) were measured for all trees > 4 inches dbh. Total height, pulp height (to 4 inch tip), and saw log height (to 9 inch tip) were recorded to the nearest foot for all trees ≥ 10.6 inches dbh. Pulp height was recorded for trees with diameters between 4.6 and 10.5 inches. Tree grades were assigned using standards for the northeastern forest survey (Alerich 1996). Stump diameter and species were recorded for all snags and dead and down trees.

Data Analysis

Statistical analysis of stand level characteristics (basal area, board-foot and cubic volume) was not possible because there was no replication of the control plot. Therefore, this research was treated as a case study and data from the 2 high thinning plots were pooled as were those from the 2 low thinning plots. Pearson chi-square statistics were used to determine whether the distribution of stems among species groups were independent of thinning method (high/low/control). Because shrub species were not tallied until the survey in 1995, they were not included in the chi-square analysis. Pearson chi-square statistics were also used to determine whether the distribution of oak sawtimber stems among tree grades were independent of thinning method. Tukey's HSD test was used to test differences of quantitative tree data (dbh, saw log height, pulpwood height, volume) among treatments. Differences were judged significant at $p \leq 0.05$.

Board-foot (International 1/4-inch rule) volumes and cubic-foot volumes were calculated using equations developed by Scott (1979, 1981). Volumes cut in 1937 and 1946 were originally recorded in cords. These were converted to cubic feet using 60 cubic feet per cord (Wenger 1984, p. 277). Trees were categorized by diameter class: saplings (0.6 to 4.5 inches dbh), poles (4.6-10.5 inches dbh), and sawtimber (≥ 10.6 inches dbh).

RESULTS

Basal area steadily increased on all plots after thinning. At stand age 76, lower basal area was observed on high thinning (125 ft^2/ac) and low thinning (143 ft^2/ac) plots, than on the unmanaged plot (150 ft^2/ac). The basal area difference among thinning methods was not related to differential stand basal area growth rates (fig. 1). Basal area growth rates were similar among thinning methods for a given period. Basal area growth decreased with stand age from a high of 5.5 ft^2/ac/yr between stand ages 17 and 26, to 1.6 ft^2/ac/yr between stand ages 26 and 42, to 1.2 ft^2/ac/yr between stand ages 42 and 76.

Crown class transitions of crop trees were not significantly different among species or thinning methods. Therefore, species and thinning methods were pooled (table 3). Nearly all crop trees in the dominant crown class at stand age 17 remained in the upper canopy through stand age 31. In contrast, nearly half of crop trees in the intermediate crown class regressed into the suppressed crown class and fewer than 12 percent were in the upper canopy at stand age 31.

On all plots, there were an average of 16 snags/acre and 39 dead and down trees/acre at stand age 76. The dbh of dead and down trees was predicted using stump diameter (dsh):

Oak: dbh = 0.98 + 0.72*dsh, n=329, r^2=0.95, and Other: dbh = -0.31 + 0.89*dsh, n=584, r^2=0.97. Both absolute and relative oak mortality (snags and dead/down at stand age 76) were higher on control than thinned plots. Oak accounted for 69 percent of the 20 ft^2/ac mortality on the unmanaged plots compared with 45 percent of the 13 ft^2/ac on the high thinning plots. In contrast, aspen accounted for the largest proportion of mortality on the high (46 percent) and low (48 percent) thinning plots.

The distinct thinning methods resulted in distinct diameter distributions by stand age 76 for several species groups (fig. 2). Both high and low thinning reduced the number of smaller oaks, but did not increase the density of larger, more valuable trees. In contrast, both thinning methods increased the number of larger diameter aspen compared with the unmanaged plot. There were less than three aspen stems per acre larger than 13 inches dbh on the unmanaged plot, compared with 20 and 32 per acre on high and low thinning plots, respectively. Relative to the unmanaged plot, high thinning decreased the number of red maple saplings and increased the number of red maple pole trees. The lowest number of red maple saplings was found on the low thinning plots. Shrub density was highest on low thinning and lowest on high thinning plots.

Table 3.—*Crown class transitions between stand ages 17 and 31 of crop tree on the Housatonic Blue Ribbon plots, Connecticut. Only three plots included because of missing data*

Crown class at stand age 17	N[1]	Crown class at stand age 31(percent) Upper canopy	Intermediate	Suppressed	Mortality
Dominant	29	96.6	3.5	0.0	0.0
Codominant	101	76.2	18.8	5.0	0.0
Intermediate	183	11.5	39.3	44.3	4.9

[1]Sample size

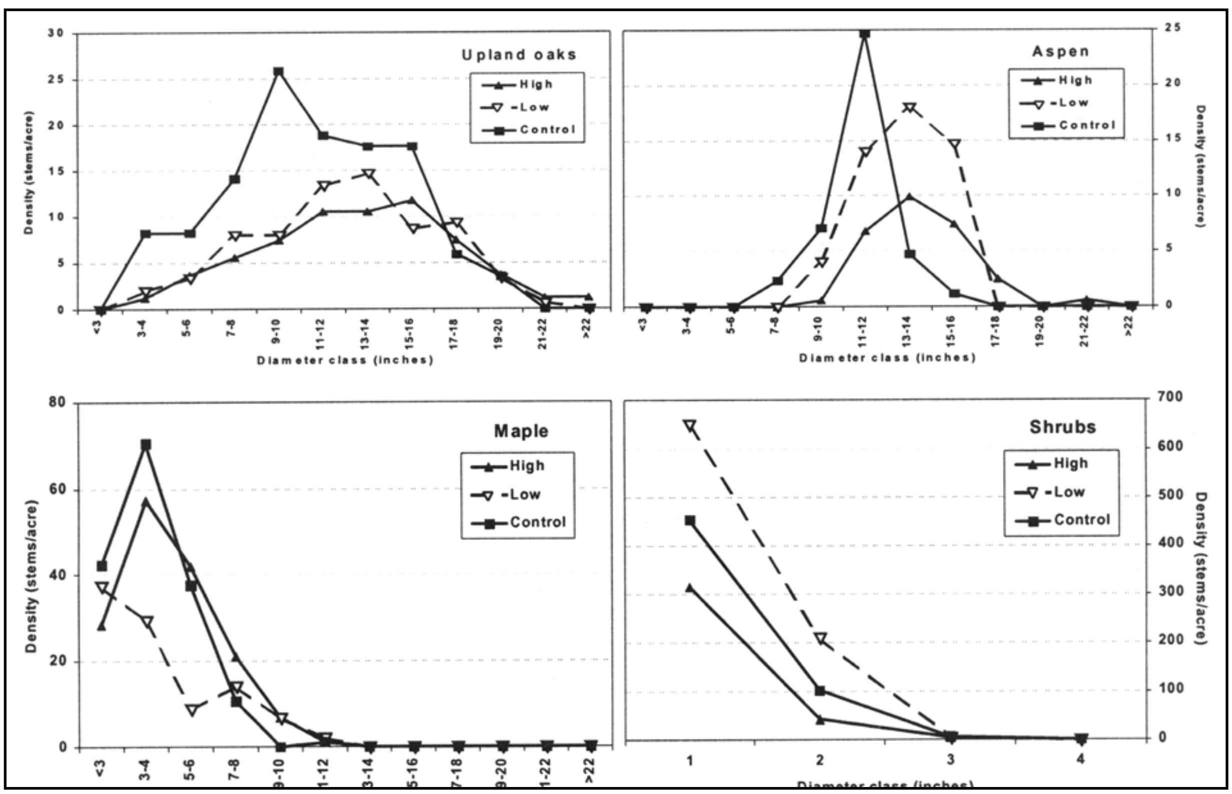

Figure 2.—*Distribution of stems by diameter class and species groups at stand age 76 in Housatonic Blue Ribbon plots, Connecticut. Treatments: High thinning (partial crop tree release from above), Low thinning (partial crop tree release from below), Control (no thinning). Diameter classes for upland oaks and aspen are identical to those for maple.*

Significant differences (χ^2 = 121.5, d.f. = 6, p ≤ 0.001) in species composition among treatments had developed by stand age 31 (table 4) and remained through stand age 76 (χ^2 = 129.8, d.f. = 6, p ≤ 0.001). Absolute and relative oak densities were higher on unmanaged than thinned plots. The differences in oak density among the thinning methods increased with stand age. By stand age 76, oak density on the high thinning plots (65 stems/ac) was less than half that on the unmanaged plot (131 stems/acre). However, most of the increased oak density was in the smaller diameter classes (fig. 2).

Maple density on low thinning plots was 42 percent lower than on the unmanaged plot and 69 percent lower than on high thinning plots at stand age 31 (table 5). Relative maple densities increased more on high thinning and control plots than on low thinning plots. Both relative and absolute aspen densities have fallen through stand age 76 on thinned plots (71 to 88 percent). Relative aspen density decreased from over 30 percent at stand age 31 to less than 10 percent at stand age 76. Aspen densities were lower on thinned plots than the unmanaged plot.

Cubic-foot and board-foot volumes were higher on low thinning plots than either the high thinning or unmanaged plots at stand age 76 (table 5). However, stand volumes of the more valuable oak species differed little among thinning methods.

Table 4.—*Density (n/acre) of stems (> 1.5 inches dbh) by species group and stand age for each thinning method on the Housatonic Blue Ribbon plots, Connecticut*

Period	Species group[1]	Thinning method High	Low	None
Stand age 31	Upland oak	272	148	452
	Aspen	254	197	316
	Maple	227	70	121
	Other	91	51	89
	Total	844	466	979
Stand age 42	Upland oak	187	140	301
	Aspen	133	138	139
	Maple	302	133	209
	Other	147	121	105
	Total	769	532	754
Stand age 76	Upland oak	65	79	131
	Aspen	31	56	46
	Maple	165	101	171
	Other	98	247	171
	Total	359	483	519

[1]Species are listed in Methods.

Table 5.—*Stand volumes at stand age 76 by thinning method and species group on the Housatonic Blue Ribbon plots, Connecticut*

Species group[1]	Thinning method High	Low	None
	Board-foot volume (International ¼/ acre)		
Upland oak	5772	5687	6061
Non-oak species	3163	5241	1484
Total	8934	10929	7545
	Cubic-foot volume (ft^3/acre)		
Upland oak sawtimber	1564	1627	1806
Non-oak sawtimber	956	1534	728
Poles	560	604	1093
Total	3080	3765	3626

[1]Species are listed in Methods.

Aspen accounted for most of the "Other" sawtimber volume. Cubic-foot volume of pole trees was much higher on the unmanaged than thinned plots.

There were marginal differences in the characteristics of saw log oak trees at stand age 76 (table 6). Trees on high thinning plots had slightly larger diameters and longer saw logs than trees on the unmanaged plot. These differences resulted in higher per tree volumes on high thinning plots compared with the unmanaged plot. Board-foot volumes were 26 percent higher, and cubic-foot volumes were 17 percent higher on high thinning than unmanaged plots. Significant differences ($\chi^2 = 13.5$, d.f. = 6, $p \leq 0.04$) in tree grade of oak sawtimber among treatments had developed by stand age 76. Both high and low thinning plots had more Grade 1 and 2 oak sawtimber than did the unmanaged plot. A higher proportion of potential Grade 1 oak sawtimber (≥ 16 inches dbh) were Grade 1 on the high and low thinning plots (75 and 69 percent) than on the unmanaged plot (50 percent).

Differences in saw log characteristics among thinning methods were more pronounced for the non-oak saw log trees (table 6). Mean diameter was significantly greater on both high and low thinning plots than on the unmanaged plot. Saw log and pulpwood heights were significantly higher on low thinning than unmanaged plots. Both board-foot and cubic-foot volumes were significantly higher on the thinned than unmanaged plots, 72 and 36 percent, respectively.

DISCUSSION

Thinning has long been recommended as a method of concentrating growth on residual trees. More recently, crop tree management has been advocated as an alternative to area-wide thinning (Perkey and others 1994). However, few studies have compared the long-term impact of various thinning methods on stand structure and growth. Sixty years after a cleaning reduced basal area by 61 percent in an 8-year-old stand in the southern Appalachians, basal area was 23 percent higher and volume 26 percent higher in the cleaned than uncleaned sections (Della-Bianca 1983).

Fifty-five years after an intense surface fire in central Connecticut killed 84 percent of stems and decreased basal area by 38 percent (analogous to a heavy low thinning), stand basal area and density were higher in burned than unburned

Table 6.—*Characteristics of saw log trees (> 10.5 inches dbh) by thinning method at stand age 76 on the Housatonic Blue Ribbon plots, Connecticut*

	Thinning method					
	High		Low		None	
Tree grade (stems/acre)						
Grade 1	7.4		6.0		3.5	
Grade 2	14.8		16.7		12.9	
Grade 3	19.1		22.0		28.2	
Ties, timbers, and culls	1.9		4.7		12.9	
Upland oaks[1]						
Diameter (inches)	14.3	a[2]	13.8	ab	13.4	b
Sawlog height (feet)	34	a	32	a	30	a
Pulpwood height (feet)	66	a	64	ab	63	b
Board-ft volume (Int. ¼)	132	a	115	ab	105	b
Cubic-foot volume	35	a	32	ab	30	b
Sample size	73		77		52	
Non-oak species						
Diameter (inches)	13.2	a	13.0	a	11.5	b
Sawlog height (feet)	34	ab	40	a	26	b
Pulpwood height (feet)	69	ab	73	a	68	b
Board-ft volume (Int. ¼)	109	a	116	a	66	b
Cubic-foot volume	30	a	30	a	22	b
Sample size	51		77		28	

[1]*Species are listed in Methods.*
[2]*Values within a row with the same letter were not significantly different at $p \leq 0.05$ (upper case), or $p \leq 0.10$ (lower case).*

sections (Ward and Stephens 1989). Both studies reported that the short-term (≤ 10 years) impact was to reduce stand basal area. Metzger and Schultz (1984) reported differences in understory composition had diminished 50 years after initial thinning method with different harvest methods (clearcutting, group selection, individual tree selection). Long-term research is essential because short and medium-term changes can be ephemeral or even deceptive.

This study found the long-term impact of both high and low thinning on residual stand basal area growth has been minimal (fig. 1). Basal area growth between stand ages 42 and 76 was slightly higher on low thinning plots. A 10-year study in 53-year-old Allegheny hardwood stands found that annual basal area growth was higher on low thinned than on high thinned and unthinned plots (Marquis and Ernst 1991). The long-term impact of thinning on stand volume of oak sawtimber was minor (table 5). There were fewer, but larger, sawtimber oaks on the thinned plots than on the unmanaged plots. In contrast, thinning, especially low thinning, increased the stand volume of non-oak sawtimber.

High and free thinning increase diameter growth rates (Sonderman 1984, Leak and Solomon 1997). Not surprisingly, this study also found that diameter, merchantable heights, and volumes were generally higher on both high and low thinning plots than on the unmanaged plot (table 6), significantly higher for oak sawtimber.

Low thinning is seldom prescribed in eastern hardwood forests. While low thinning had little or no effect on residual tree growth in Pennsylvania (Marquis and Ernst 1991) and Ohio (Dale 1975), a positive growth response has been reported on the western edge of the Central Hardwood Region (Dale 1975). Dale (1975) attributed the differential response to lower precipitation in Missouri and Iowa compared with the more eastern states.

The increased growth of non-oak trees, mostly aspen, to low thinning observed in this study (table 6) is probably not related to increased moisture availability. The increased growth is more likely attributable to the removal of midstory trees, such as red maple. The shading produced by midstory trees accelerates pruning of lower branches, especially in shade intolerant species. Low thinning removed midstory trees allowing residual trees to retain a longer live crown and grow larger boles.

Earlier studies have suggested that the economic benefit of increased diameter growth following release may be offset by reduced clear bole length (Lamson and Smith 1978, Sonderman 1984). In contrast, saw log and pulpwood heights on the Housatonic Blue Ribbon plots were not reduced by early thinning (table 6). Oak sawtimber tree grade was also higher on the thinned plots than the unmanaged plot). This contradiction may be a function of the shorter observation periods (< 10 years) of the aforementioned studies. Trimble (1973) reported that thinning retarded stem pruning of yellow-poplar for several years, but after 7 years thinning had no effect on the length of clear bole.

This study further reinforces the futility of releasing trees in lower canopy positions (Trimble 1974). Using the crown class transition in table 3, to obtain 100 upper canopy crop trees would require releasing 870 intermediate trees compared with only 104 dominant or 131 codominant trees. Crown class regression appears to be a common problem of both released and unmanaged stems for oaks (Lamson and Smith 1978) and other hardwoods (Smith 1979). It is not prudent to select intermediate trees for crop tree release or as the residual trees left after a thinning.

Previous research has suggested that thinning method affects stand composition. Thinning from below has favored an increase in midtolerant species (Graney 1988, Ward 1992) and shrubs (Kirkham and Carvell 1980), while thinning from above favors tolerant species (Sander 1979, Abrams and Scott 1989). Low thinning resembles natural thinning in the absence of disturbance—higher mortality in the smaller than larger size classes.

Thinning from below increased shrub density in this study (fig. 2). Thinning from below also reduced density of red maple in the large sapling and small pole-size classes. Not surprisingly, this study found that high thinning increased the number of pole and sawtimber sized red maples. Therefore, commercial thinning, which often resembles high thinning because of the necessity of recovering cost, encourages growth of low value species such as red maple and American beech.

SUMMARY

This study found that both high and low thinning concentrate growth on selected crop trees with an improvement in tree quality. However, there was no increased stand volume or value that could justify the high cost of thinning/cleaning in sapling stands. Therefore, the choice of thinning method should depend on desired intermediate product(s) and desired future stand composition. Changes in future stand composition induced by different thinning methods will not only affect the quality and variety of future forest products, but will also affect the quality and variety of recreational opportunities and wildlife habitats (Scanlon 1992, Annand and Thompson 1997). A small woodlot owner may prefer a low thinning prescription; cutting large saplings and poles for fuelwood on weekends. Financial considerations will limit many landowners and forest managers to wait until trees in the lower crown classes have grown large enough for a commercial pulpwood operation.

The general results of this research suggest that forest managers should consider the long-term effects of different intermediate cuttings on the composition of the sapling strata. Sapling composition at the time of stand regeneration can have a large influence on the composition of the future stand. Therefore, forest managers should remember that the choice of intermediate cutting prescription can have the long-term consequence of affecting the composition of the next forest.

ACKNOWLEDGMENTS

I thank H. McKusick for establishing these plots; J.P. Barsky for tree grading and assistance in the 1995 field survey; David Smith, Don Smith, and J. Pronovost for passing along the original data sheets; E. Zaglio and W. Kearns for relocating the plots; A. Aijala, B. Dickinson, G. Cromie, R. Kienholz, H. Mattern, Mitchell, M. Pochan, J. Olson, Reiske, and Wienzierl for earlier surveys; and the Division of Forestry, Connecticut Department of Environmental Protection for protecting the study area. This research was partly funded by McIntire-Stennis Project CONH-550.

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