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80 Years of Thinning Research on Northern Hardwoods in the Bartlett Experimental Forest, New Hampshire

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Abstract

Commercial and noncommercial thinning studies in northern hardwoods on the Bartlett Experimental Forest, New Hampshire, began in 1932. One of the studies, still maintained today, consisted of several precommercial treatments at age 25 (1959) and a commercial treatment in 2003. Although economic returns from precommercial work appear somewhat marginal and require additional research, commercial thinning in northern hardwoods is clearly advisable—almost necessary because evenaged northern hardwoods offer a unique thinning opportunity: a component of shade-intolerant aspen and paper birch maturing in 50 to 70 years coupled with a component of long-lived species that will mature at age 100 to 120 years.

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INTRODUCTION

Thinning is an intermediate partial cutting in an evenaged stand, beyond the sapling stage, designed to increase diameter growth, quality and health, and stand-level production without excessive opening of the canopy (Nyland 2002). The overall objective in northern hardwood stands is to produce quality saw logs in the shortest possible time. Regeneration is not an objective of thinning, although an understory often develops following a thinning operation.

Thinning research in northern hardwoods on the Bartlett Experimental Forest began in 1932, and one of the well-designed thinning studies, initiated in 1959 (Marquis 1969), still is maintained today. Results from these studies covered a range of topics: stand and tree growth responses, species and quality changes, economic returns, effects on rotation age, and damage from wind and harvesting. These topics are organized in this paper into two main sections: (1) the early studies, and (2) the 1959 study, separated into the early results, the followup, and the commercial harvest phase.

THE EARLY STUDIES

In 1932, the first Bartlett thinning study was initiated consisting of a thinned plot and an unthinned plot in a 60-year-old northern hardwood stand (Jensen 1940). Plot size was unrecorded, probably 1 acre. The purpose was to study the responses of yellow and paper birch (See Appendix Table 1 for common/scientific names) to the environmental changes caused by thinning; these two species often exhibit symptoms of decline following harvesting. The thinning was heavy, removing nearly half the volume; this would reduce the basal area per acre from an estimated 120 square feet/acre down to perhaps 60 square feet. The better stems of the two birches were left in the residual stand. The thinning resulted in higher maximum air and soil temperatures, slightly lower minimum temperatures, lower relative humidity, 50 percent greater wind movement, and more than 60 percent greater evaporation rates. These effects declined rapidly in the years following the thinning. During the second growing season after thinning, yellow birch showed signs of stress: epicormic branching on nearly half the trees and dieback of twigs and branches coupled with some evidence of shoestring fungus (*Armillaria mellea*). Other species appeared healthy. However, by 1937, 5 years after thinning, the yellow birch apparently had recovered from the thinning impacts, and the mixed-species understory was vigorous. The growth results from this study were expressed as basal area growth percent, which is difficult to evaluate. However, annual growth in volume was somewhat greater in the thinned plot (about 1 cord) as compared to the unthinned (about ½ cord), and the species/quality was much better. But the thinning apparently increased susceptibility to wind damage: the 1938 hurricane destroyed 15 percent of the volume on the thinned plot as compared to 1 percent on the unthinned.

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A second, more ambitious, thinning study began in 1936 (Wilson 1953), consisting of 40 contiguous ¼-acre thinned plots plus four controls (Compartment 16). However, six plots were heavily damaged by the 1938 hurricane and eliminated from the study. The stand was a 60-year-old northern hardwood stand on an excellent site: 20 percent of the basal area was in white ash. Percentages of basal area for the other species were red maple (32), paper birch (13), aspen (12), sugar maple (9), yellow birch (9), beech (3), and other species (2). The thinning (a commercial one), coupled with light hurricane damage, left a residual basal area of 80 square feet basal area per acre in 1941 out of an original stocking of 122 square feet. In the 10-year period from 1941 to 1951, the thinned plots produced an annual average of 2.6 square feet of basal area per acre while the unthinned plots averaged 0.7 square feet.

Average annual diameter growth in the thinned plots averaged 0.13 inches/year; sugar maple and beech grew a little faster: 0.15 and 0.16 inches, respectively (Table 1). D.b.h growth of the unthinned stand averaged between 0.05 and 0.10 inches annually depending upon tree diameter.

One of the more significant contributions from this thinning study was that it showed how evenaged stands develop a reverse J-shaped distribution (no. trees over d.b.h) due to the layering of short-lived shade-intolerant species over longer lived species that are intermediate or shade tolerant (Fig. 1). The less tolerant species present a somewhat normal distribution, but the tolerant species (beech, sugar maple, and hemlock) provide an understory that forms the reverse J-shape. The implication was that such stands can readily be handled by unevenaged methods, provided that the understory exhibits an acceptable species composition, but this is often not the case in northern hardwood stands.

Another message was that thinning maintains an increasing mean annual basal area (and cubic- volume) growth rate, thus extending the rotation age as compared to an unthinned stand where mean annual growth begins to decline at age 50 to 60. This theme was reevaluated some years later showing that thinning could extend the rotation age (based on mean annual cubic-foot increment) to 85 to 120 years (Leak 1999). Side benefits include larger, more valuable products, as well as lower regeneration acreages/costs/impacts. It is a common belief that thinning shortens the rotation; however, this would only be true for a rotation based on growing a certain-size tree—a so-called technical rotation.

Table 1.—Average diameters in 1941 (trees 4.6 inches plus) and average annual diameter growth of the thinned stand, 1941-51 (Wilson 1953)

Species	Average d.b.h.	Average d.b.h. growth
	(in.)	
Red maple	7.8	0.13
White ash	9.4	0.12
Paper birch	10.9	0.10
Yellow birch	7.2	0.11
Beech	6.1	0.16
Sugar maple	6.9	0.15
All	8.1	0.13

THE 1959 STUDY: EARLY RESULTS

In 1933-35, a 22-acre tract (Compartment 22) was completely clearcut, essentially a whole-tree harvest because about 60 cords of split fuelwood were removed per acre. At age 25, the stand was the site of a designed thinning (release) study. As described by Marquis (1969), twenty ¼-acre plots were established with 1-chain isolation strips between. Up to 100 crop trees were selected per plot. About half were paper birch and the rest were other species. Before thinning, the entire stand had more than 4,000 stems (0.5 inches and over) per acre, a basal area of 99 square feet, and an average diameter of 1.8 inches. The crop trees numbered 385 per acre with 33 square feet and an average diameter of 3.7 inches (Table 2). It is noteworthy that clearcutting on a fairly good northern hardwood site produces a significant proportion of long-lived, valuable species (sugar maple, yellow birch, and some white ash) in addition to paper birch and aspen.

To implement the thinning treatments, five blocks of four plots each were established based on plot characteristics of species composition and basal area per acre. Then four treatments were assigned at random within each block:

1. Heavy crop-tree: All trees that competed directly with each crop tree were removed, leaving a

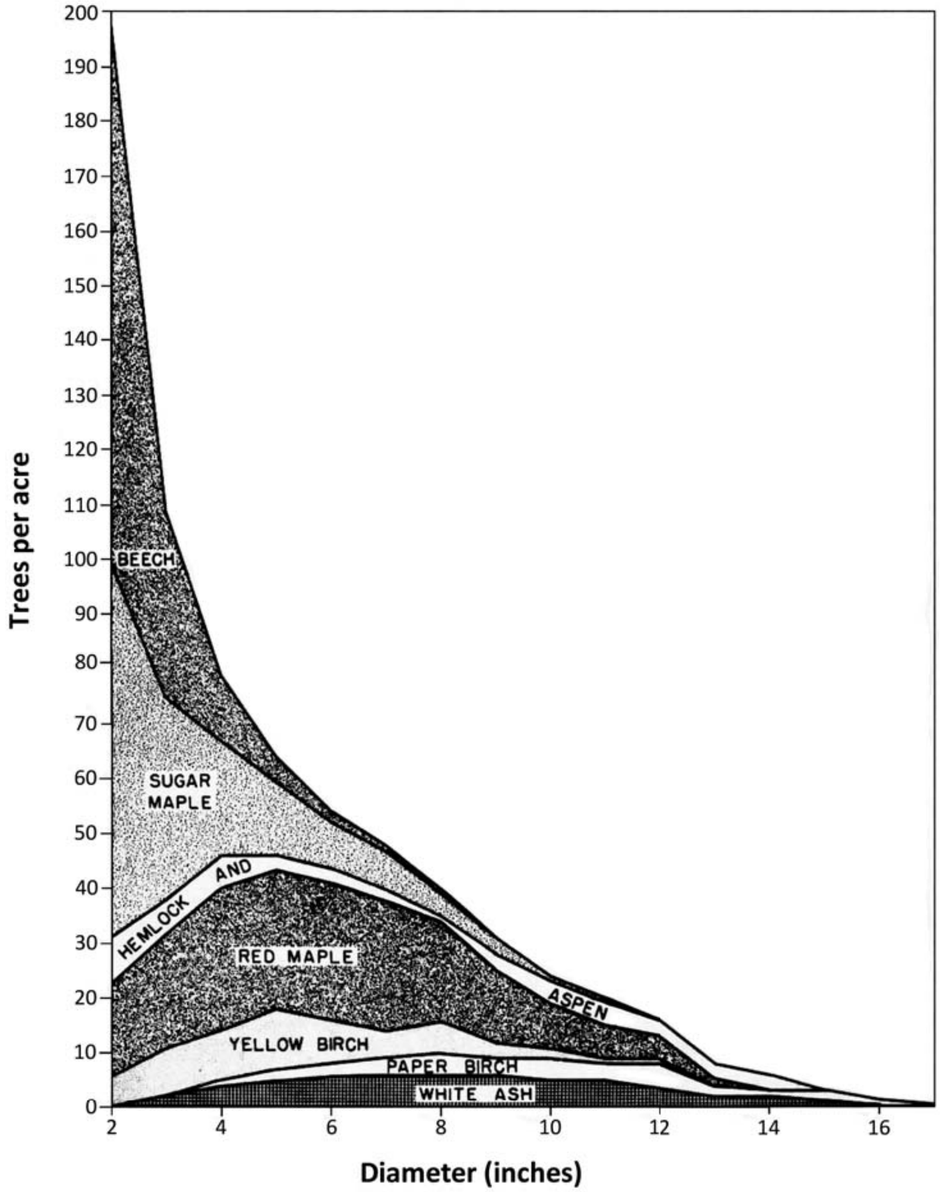

Figure 1.—Diameter distribution of the 60-year-old stand in 1936 (Wilson 1953).

residual basal area (0.5 inches d.b.h and larger) of 56 square feet per acre.

2. Light crop-tree: A maximum of one competing tree was removed around each crop tree; there were a few cases (crop trees that were strong dominants or when there was one competing tree between two crop trees) where less than one competitor was removed. Residual basal area was 72 square feet.
3. Species removal: All aspen, pin cherry, and striped maple were removed as well as red maple sprouts not selected as crop trees. Residual basal area was 66 square feet.
4. Control: Residual basal area was 100 square feet.

Thinning was done in late August 1959 with sodium arsenite in frills; red maple sprout clumps with a retained crop tree were thinned by hand.

At the outset of the study, crown class (including crown vigor) and bole condition were recorded for the crop trees. The bole conditions were:

1. Good: No live (including epicormic) branches in the first 17 feet. Only slight lean, crook, sweep, or wounds.
2. Medium: Up to one live branch and 5 epicormics in the first 17 feet. Slight to moderate lean, crook, or sweep. Slight wounds.

Table 2.—The 25-year-old stand before thinning (Marquis 1969)

Species	Entire stand			Crop trees		
	Stems/acre	Basal area/acre	Mean d.b.h.	Stems/acre	Basal area/acre	Mean d.b.h.
	(no.)	(sq. ft.)	(in.)	(no.)	(sq. ft.)	(in.)
Beech	1,029	11	1.3	24	1	2.7
Sugar maple	1,041	11	1.3	73	3	2.8
Striped maple	126	2	1.4	--	--	--
Conifers	58	1	1.8	--	--	--
Yellow birch	474	10	1.7	67	4	3.2
White ash	93	3	2.3	31	3	3.9
Red maple	176	5	2.0	21	2	3.5
Paper birch	401	24	2.7	169	20	4.4
Aspen	54	9	5.1	--	--	--
Pin cherry	636	23	2.4	--	--	--
All	4,088	99	1.8	385	33	3.7

Table 3.—Five-year growth responses to thinning of the entire stand and of the crop trees only (Marquis 1969)

Treatment	Entire stand		Crop trees	
	5-year mortality	Annual basal area growth	Annual basal area growth	Annual diameter growth
	(no. stems/acre)	(sq. ft./acre)	(sq. ft./acre)	(in.)
Heavy	1,019	4.0	3.2	0.18
Light	1,129	3.3	2.7	0.15
Species	977	4.9	2.7	0.15
Control	1,502	2.2	2.1	0.11

3. Fair: Any number of live or epicormic branches in the first 17 feet. Slight to moderate lean, crook, sweep, or wounds.
4. Poor: Any number of defects.

Results of the thinnings over a 5-year period showed that annual basal area growth of the entire stand ranged from 2.2 square feet per acre in the control plots to 4.9 square feet for the species thinning (Table 3). Mortality in number of stems over the 5-year period ranged from about 1,000 stems in the thinned plots to about 1,500 stems in the controls. Annual basal area growth of the crop trees ranged from about 2.1 square feet in the control to 3.2 square feet following the heavy thinning; the comparable rates of diameter growth were 0.11 inches and 0.18 inches, respectively. In general, growth responses indicated that the thinnings were effective.

Responses in quality were less clear. Briefly, the thinnings resulted in much higher proportions of crop trees in dominant and strong codominant positions, as expected (Table 4). There was very little change in bole quality classes. However, a high proportion of crop trees (40 to 60 percent) showed increases in epicormic branching, mostly very small epicormics, following all thinning treatments. Sugar maple and yellow birch were the most prolific epicormic sprouters; however, at this stage, it is doubtful whether epicormic branching would result in long-term changes in quality.

Table 4.—Selected quality responses of the crop trees by treatment over the 5 years after the 1959 thinning (Marquis 1969)

Response	Heavy	Light	Species	Control
	Percent			
Percent dominants/strong codominants	49	40	40	27
Percent change in trees with bole class 1 and 2	+3	+4	+3	+1
Percent change in trees with no epicormics	-9	-27	-18	-9
Percent of trees with increased numbers of epicormics	41	59	49	57

THE 1959 STUDY: FOLLOWUP

The long-term effects of these early precommercial treatments were evaluated by a remeasurement in 1990, 31 years after the initial thinning (Leak and Solomon 1997).

Comparisons of crop-tree development showed that the response varied by species. White ash and yellow birch showed little long-term diameter response to the 1959 treatments; i.e., the thinned crop trees were about the same size as the unthinned. Paper birch, sugar maple, beech, and red maple showed increased crop-tree diameters of up to 2 inches larger than controls as a result of the early treatments. For paper birch, red maple, and beech (to a lesser extent) all of the thinning treatments produced about the same response. For sugar maple, the light and species-removal treatments produced about a 1-inch gain; the heavy treatment, about a 2-inch gain.

A broader analysis of the 1990 remeasurement (Leak and Smith 1996) showed that the 1959 treatments had only minimal effects by age 56 on stems numbers, stand structure, and species mix except for a moderate proportion (about 10 percent) of aspen in the control and light crop-tree treatments. Pin cherry and striped maple were absent and minimal, respectively, by age 56.

Two economic evaluations provided a basis for evaluating the efficacy of these early treatments. One evaluation was made by projecting the 5-year growth results over a 20-year period to stand age 45 (McCauley and Marquis 1972). This evaluation estimated that the species-removal and light thinning treatments could produce return rates on the initial investment of 9 to 10 percent. The heavy treatment was too costly to provide a positive economic benefit. The authors suggested that lower numbers of crop trees—200 or less—would boost the economic returns due to lower initial costs.

Based on a remeasurement in 1990 (stand age 56), a second economic analysis provided return-rate estimates of 3.5 percent for the light thinning and a negative return for the heavy. Based on a 2003 remeasurement, the comparable rates of return were 2.3 and 0.2 percent for light and heavy thinnings, respectively (Sendak and Leak 2008). Again, the authors suggested that greater returns would likely be achieved by releasing no more than 200 crop trees and by applying a commercial harvest at about age 45.

THE 1959 STUDY: COMMERCIAL HARVEST

In the spring of 2003 (stand age 69 years), all the plots and buffer zones except for five control plots were commercially thinned by removing most of the aspen and paper birch. These species were the largest in the stand, so the operation was referred to as a dominant-tree thinning (Leak 2007). Basal area per acre was reduced to an average of 74 square feet per acre (4-inch class and larger) ranging from 54 to 126 square feet. The goal was to leave at least 50 square feet on each plot, which necessitated leaving a few paper birches (4.6 square feet/acre). The controls averaged 141 square feet.

Logging damage from this commercial operation was higher than expected or desirable. Light damage was defined as a wound that extended less than ¼ the way around the girth at the point of damage; heavy damage was defined as more than ¼ girth. Damage levels (light and heavy combined) ranged from 8 percent for white

Table 5.—Percent of trees (4 in. d.b.h and over) with light and heavy logging damage from the 2003 thinning

Damage	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Other
			Percent				
Light[a]	12	9	9	13	9	4	12
Heavy	18	8	14	12	4	4	17
No. samples	208	192	209	89	23	95	24

[a] Light damage was a wound less than ¼ girth; heavy was more than ¼ girth.

Table 6.—Annual d.b.h growth (inches) for four thinning scenarios

Scenario	Growth period (yrs.)	Beech (in.)	Yellow birch (in.)	Sugar maple (in.)	Red maple (in.)	White ash (in.)	No. samples
Thinned 2003	7	0.17	0.13	0.20	0.19	0.17	59
Unthinned 2003	7	0.16	0.06	0.17	0.19	0.13	15
PCT 1959	31	0.09	0.08	0.15	0.14	0.18	128
Thinned 1936	10	0.16	0.11	0.15	0.13	0.12	--

Table 7.—Annual net basal area growth (sq. ft.) per acre (trees 4.5 inches plus) over a 7-year period following the 2003 commercial thinning and the 1936 thinning

Regime	All species	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Aspen	Other
					Sq. ft.				
Thinned 2003	1.5	0.8	-0.2	0.8	0	-0.4	0.4	--	0.1
Unthinned 2003	-1.9	0.4	0.1	0.8	0.1	-3.9	0.1	0.5	--
Thinned 1936	2.6	0.4	0.1	0.7	0.7	0.1	0.5	--	0.1

ash up to 30 percent for beech (Table 5). The majority of the wounds were in smaller trees—below 7 to 8 inches d.b.h. This level of damage could be reduced by more attention to layout of the skid trails, choice of equipment, and supervision of the operation.

After the thinning, 84 randomly selected residual sample trees (63 on thinned plots and 21 on the controls—roughly equal numbers of each major species) were designated for diameter growth measurements. Results after 7 years were compared with the 31-year growth rates from the 1959 precommercial treatments (all thinning treatments combined excluding the control) and the 10-year rates from the 1936 study (Table 6). Following the commercial operation in 2003, thinning increased diameter growth of white ash and yellow birch as compared to the unthinned, and maintained or slightly increased growth of the other species. The rates are appreciably greater (except for white ash) than the 31-year rates following the 1959 precommercial treatments and moderately better than the rates following the commercial thinning in 1936. The conclusion is that the dominant tree removal in 2003 was a successful operation. A second conclusion is that current diameter growth rates are at least as good now as in the past despite atmospheric/environmental concerns.

Although diameter growth following the 2003 thinning was somewhat better than rates after the 1936 thinning, annual basal area growth per acre was poorer: 1.5 square feet as compared to 2.6 square feet, respectively (Table 7). Sugar maple, beech, and white ash were the most productive in basal area growth. Growth on the 2003 control plots was negative. The reason for the differences in the thinned rates in 2003 vs 1936 is the species composition (Table 8). After thinning, the 1936 stand had less yellow birch, much more red maple, and the paper birch in the slightly younger 1936 stand had not quite reached the point of overmaturity and decline.

Table 8.—Basal areas per acre (sq. ft.) after thinning (trees 4.6 inches plus) by species for the 2003 and 1936 thinning studies

Regime	All species	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Aspen	Other
	----------	----------	----------	----------	Sq. ft.	----------	----------	----------	----------
2003 thinning	69.7	7.5	13.0	13.9	10.9	5.0	18.4	--	1.0
1936 thinning	79.7	2.5	3.2	10.9	24.8	11.6	25.0	--	1.7

CONCLUSIONS

1. Based on the 1936 and 2003 thinnings at Bartlett in 60- to 70- year-old stands, commercial thinning proves to be a productive operation in the northern hardwoods. Both thinnings, the 2003 thinning especially, removed large volumes of mature/overmature paper birch and aspen, still retaining sufficient stocking of long-lived species. Diameter growth remained high, basal area production was adequate, and mean annual increment was maintained. At about age 70, paper birch and—to a lesser degree—aspen are becoming overmature and should be removed. Yellow birch did not respond very well and individual trees of this species should be carefully screened for vigor and quality. The one downside to the commercial operation was the excessive damage—up to 30 percent for beech, much of it in the smaller trees. Better layout, equipment, and supervision could readily reduce the damage.

2. Precommercial release treatments, as applied during the 1959 study in a 25-year-old stand, produced adequate growth responses on the retained crop trees (385 per acre). However, the economic returns at ages 56 and 69 were only 3.5 percent or less. To make precommercial work more feasible, it would be advisable to identify less than 200 crop trees—possibly 50 to 100 per acre would be sufficient. This would allow for an adequate release at much less cost. The one downside is that fewer crop trees allow less opportunity to mold the species composition and less room for poor choices—a real possibility in young stands.

Northern hardwood stands provide a somewhat unique opportunity for commercial thinning since most evenaged stands, originating from a clearcutting, contain a significant proportion of intolerant species, mainly aspen and paper birch. These species mature in about 50 to 70 years and provide a profitable commercial thinning for pulpwood and small logs (depending on local markets). Usually there is sufficient residual stocking (50 square feet/acre plus) of longlived species (sugar and red maples, yellow birch, white ash) to continue stand management until a final regeneration harvest at age 100-120 years. Without this commercial thinning of intolerant species, total stand productivity declines, and the opportunity to release the long-lived species is lost.

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Appendix Table 1.—Common and scientific names of tree species referred to in this report

Common Name	Scientific Name
Beech	*Fagus grandifolia*
Yellow birch	*Betula alleghaniensis*
Sugar maple	*Acer saccharum*
Red maple	*Acer rubrum*
Paper birch	*Betula papyrifera*
Eastern hemlock	*Tsuga canadensis*
Red spruce	*Picea rubens*
Pin cherry	*Prunus pensylvanica*
Striped maple	*Acer pensylvanicum*
Aspen	*Populus spp.*

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KEY WORDS: commercial thinning, precommercial thinning, northern hardwoods

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