

FOREST RESEARCH REPORT



Nova Scotia Department of Natural Resources
Forest Management Planning

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The long-term branching and diameter response of pre-commercially thinned hardwood stands in Nova Scotia.

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Abstract

Several hardwood trials were established during the 1980's and 1990's to determine the affect of pre-commercial thinning (PCT) on growth and quality. These trials were examined for their long-term branching and growth response 4-35 years after PCT. The number of branches and twigs in the lowest 5 m of the tree bole and the height of the lowest live branch were measured to assess treatment impact on quality. Diameters at Breast Height (Dbh) were measured to determine growth responses. Various species (sugar maple, yellow birch, white ash, white birch, red maple, and red oak), spacings (1.8-3.7 m) and treatment timings (4-10 m tall when thinned) were examined.

All species responded favorably to PCT in growth, resulting in increased diameters of 8-132% over controls. Wider spacings generally produced greater diameter gains. On the other hand, wider spacings resulted in more branching. For example, at a yellow birch site thinned when 5 m tall, the number of branches for each spacing (Control, 1.8 m, 2.4 m, 3 m) are as follows respectively (1, 2, 4, 6) 25-years after PCT. Overall, white ash and white birch were good self-pruners and branch retention and twig development after PCT were minimal. The other species retained more branches, but quality can still be maintained when they are PCT'ed. Overall, a balance between growth and quality can be achieved through pre-commercially thinning to moderate timings (6-9 m tall) and spacing (2.4 m).

Introduction

Pre-commercial thinning (PCT) in hardwood stands can be used to improve the proportion of desired species and to accelerate individual tree growth. This reduces the time required for trees to reach merchantable size. However, there is concern that the potential of these stands to produce sawlog quality stems could be compromised. Releasing hardwood trees too early before they've had a chance to self-prune promotes branch retention. This results in knots which can potentially reduce quality and value of sawlogs.

Since 1998, approximately 2000 ha of hardwood PCT has taken place in Nova Scotia (through Sustainability Regulations). The growth aspects of PCT in hardwoods has been well documented (Smith and Lamson 1983, Voorhis 1990, Heitzman and Nyland 1991, Zarnovican 1998, O'Keefe and McGrath 2006), but little is known about the long term effects of PCT on quality, which is paramount in hardwoods. Some studies have examined the effects of PCT on quality in hardwoods but mainly cover a short period after release (5-10 years) (Voorhis 1990, Lees 1995, Wood *et al.* 1996). The hardwood PCT trials described in this report were established in the 1980's and early 1990's, providing 4-35 years of post-treatment data. The long-term nature of these trials makes them quite valuable from a research stand point.

This report examines the impact that pre-commercial thinning has on branching in hardwoods. More specifically the effect of various treatment timings (height when thinned), spacings, and species were examined. The intent is to provide forest managers with the necessary information to make informed decisions concerning pre-commercial thinning in hardwoods that balances both quality and diameter growth.

Site Locations

Nine pre-commercially thinned sites were examined for this report. Three are located in Kings county, three in Pictou county, one in Lunenburg county, one in Guysborough county, and one in Colchester county (Figure 1).

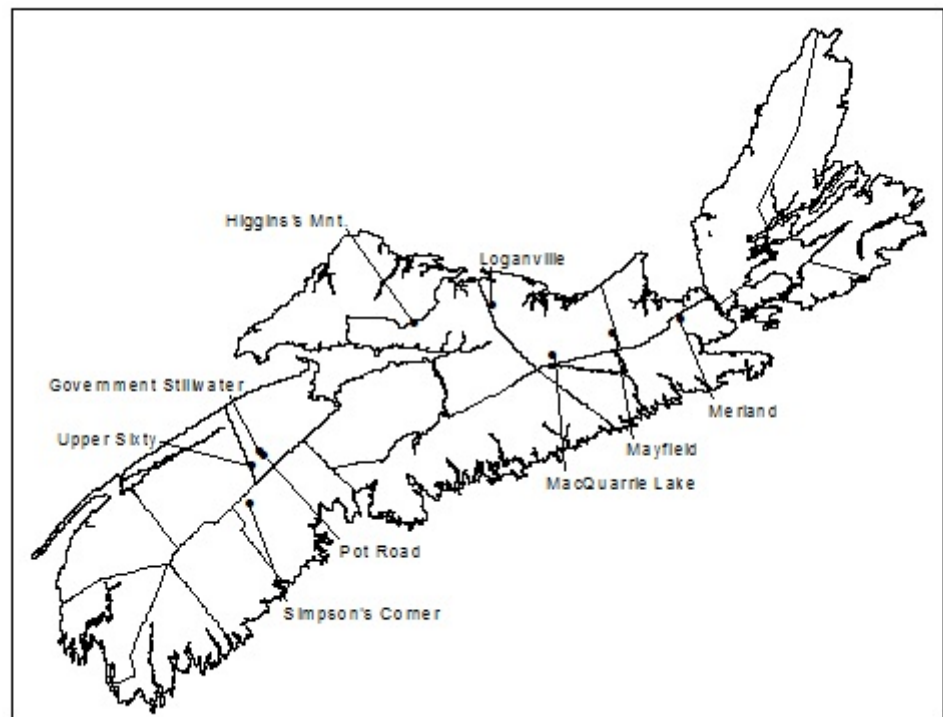


Figure 1. The locations of the trials in Nova Scotia.

Site Descriptions

Stands that were pre-commercially thinned as part of the trial are shown in Table 1. The species included are sugar maple (*Acer saccharum* Marsh.), red maple (*Acer rubrum* L.), yellow birch (*Betula alleghaniensis* Britton), white ash (*Fraxinus americana* L.), white birch (*Betula papyrifera* Marsh.), and red oak (*Quercus rubra* L.). The stands were between 4-10 m (13-33 ft) in height when they were thinned. The spacings ranged from 1.8-3.7 m (6-12 ft).

Table 1. Site Descriptions							
Location	Stand ID	Major Species	Vegetation type according to FEC ¹	Site Index ² (m)	LC ³ (m ³ ha ⁻¹ yr ⁻¹)	Height when PCT'ed ⁴	Spacing
Government Stillwater	8282	Red Maple Sugar Maple	IH7:Red maple / Hay-scented fern - Wood sorrel	16	2.5	10 m	3 m, 3.7 m Control
Higgin's Mountain	8701	Yellow Birch Sugar Maple	TH1:Sugar maple / Hay-scented fern	16	2.7	5 m	1.8 m, 2.4 m 3 m, Control
Loganville	8806	White Ash	TH3:Sugar maple - White ash / Christmas fern	15	2.6	10 m	2.1 m, Control
MacQuarrie Lake	9217	Yellow Birch	MW1:Red spruce - Yellow birch / Evergreen wood fern	14	2.2	4 m	2.4 m, 3 m Control
Mayfield	1011	Sugar Maple	TH1:Sugar maple / Hay-scented fern	16	2.7	9 m	1.8 m, 2.4 m, Control
Merland	8601	Yellow Birch	TH8: Red maple - Yellow birch / Striped maple	12	1.8	10 m	1.8 m, 2.4 m 3 m, Control
Pot Road	9225	Sugar Maple	TH1:Sugar maple / Hay-scented fern	17	3	7 m	2.4 m, 3 m, Control
Simpson's Corner	1711	Red Oak	IH2a:Red oak - Red maple/ Witch-hazel	11	1.5	9 m	1.8 m, 2.4 m, 2.7 m, Control
Upper Sixty Lake	8274	Sugar Maple White Birch White Ash	TH3:Sugar maple - White ash / Christmas fern	18	3.2	6 m	2.4 m, 3 m, 3.7 m, Control

¹Vegetation type according to FEC Guides (see Neily *et al.* 2011)

²Site Index - A relative measure of forest site quality based on the height of the dominant trees (m) at the breast height age of 50.

³Land Capability (LC) - A relative measure of forest site quality used in Nova Scotia based on the volume produced by 1ha of land in one year (m³ ha⁻¹yr⁻¹) for a fully stocked stand (NSDNR 1993) at peak mean annual increment.

⁴PCT'ed = Pre-commercially thinned

Assessment Procedures

The following features were used as indicators of quality (Figure 2);

- The number of live branches within the first 5 m (16 ft) section.
- The number of dead branches within the first 5 m (16 ft) section.
- The number of live adventitious twigs¹ (Figure 3) within the first 5 m (16 ft) section.
- The height of the lowest live branch.

For a visual representation of the assessment procedures see Figure 2. The focus on the first 5 m (16 ft) section of stem is because this area frequently contains the most suitable portion of the tree for sawlog production. The aim is to keep this portion of the tree free of branches, twigs (Rast *et al.* 1990), rot, cankers and other imperfections that can reduce quality for sawlog production.

The interval between re-measurements was approximately five years. There are presently four re-measurements ranging anywhere from 4 years to 35 years after PCT depending on the study site. The species and diameter at breast height of each tree were also recorded.



Figure 3. Example of a twig.

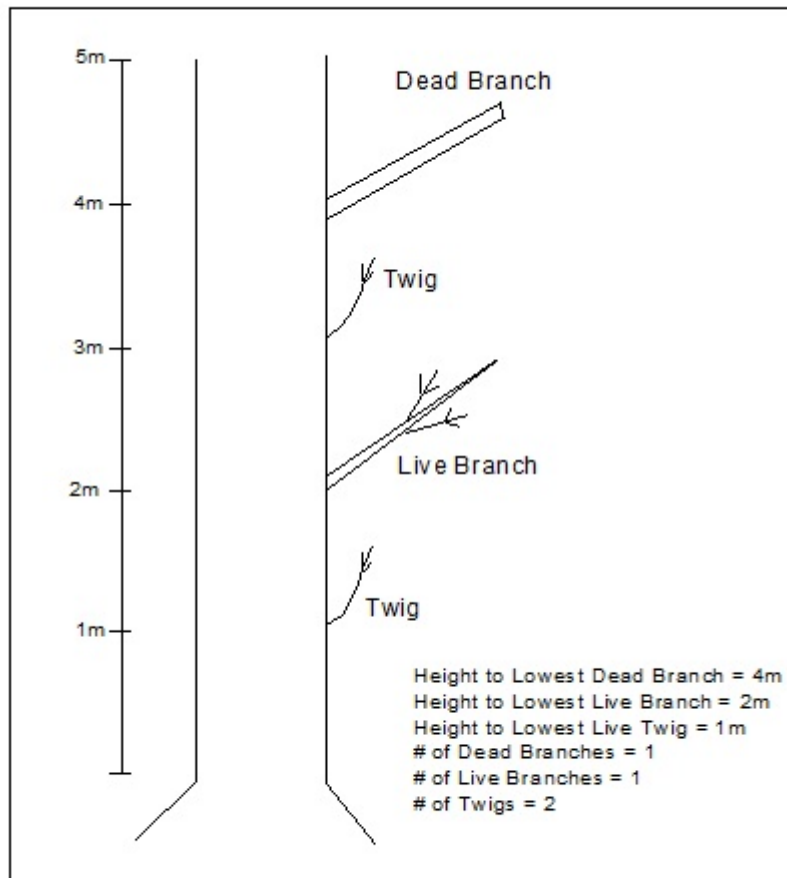


Figure 2. Example of Assessment Procedures

¹Adventitious twigs are small branches originating from dormant buds on the stem of a tree. They are defined as being 3/8 inch (~1 cm) or less in diameter, once they reach a diameter greater than 3/8 inch they are tallied as branches. (Calvert and Petro 1993).

Results

The number of live branches, the number of live and dead branches combined, the height of the lowest live branch (LLB), the diameter, and the number of twigs on six hardwood species (sugar maple, yellow birch, white ash, white birch, red maple, and red oak) after pre-commercial thinning is shown in Figures 4-12. Some have a small sample size (represented with a dashed line) so caution should be used when interpreting these results (to view sample sizes refer to Appendix 1).

Sugar Maple

There are five sites containing sugar maple. They are arranged on two pages in this report from earliest to latest thinning (Figure 4). Generally, the results show that the thinned sugar maple stems are self pruning over time. There is a reduction in the number of branches (Figure 4: 1ab,2ab,3ab) and the height of the lowest live branch is moving further up the stem (Figures 4:1c,2c,3c,4c,5c). The average diameter of thinned trees was between 8-79% greater than controls (Figure 4:1d,2d,3d,4d,5d).

Higgin's Mountain was thinned when it was 5 m in height. At the last measurement, thinned trees were larger in terms of diameter than controls, with the widest spacings having the greatest diameter gains; 35% diameter gain (1.8 m spacing), 59% diameter gain (2.4 m spacing), 65% (3 m spacing) (Figure 4:1d). However, the trees that were wider spaced have more branches (Figure 4:1ab- last measurement). The spacing also affected the height of the lowest live branch. Trees that were more widely spaced have branches starting lower on the stem which reduces the length of clear bole (Figure 4:1c).

Upper Sixty Lake and Pot Road show many of the same trends as those mentioned above (Figures 4: 2abcd, 3abcd). Thinned trees, especially the wider spacings, start out with many live branches, however by the last measurement even the most widely spaced have 2 or less live branches (Figure 4: 2a, 3a); however, Upper Sixty still has a number of dead branches (Figure 4:2b). Both Upper Sixty Lake (site index=18) and Pot Road (site index=17) are productive sites (Table 1) which could be a factor in them self-pruning quickly. Pot Road has a very large sample size (Appendix 1: n=55(control), n=124(2.4 m), n=53(3 m) compared to the other sites.

The two sites that were treated later (Mayfield and Gov. Stillwater) have few branches ~20 years after pre-commercial thinning (Figure 4:4ab,5ab). The later treatment timing in conjunction with age of the stands when they were measured contributed to the low numbers of branches. All spacings have 2 or less branches (live+dead combined) (Figure 4:4b, 5b). Also, most spacings no longer have live branches within the portion of the stem that is likely to produce sawlogs (Figure 4:4c,5c). See Figure 5 for a visual representation of the average tree for each of the spacings at Mayfield. There is little difference between thinned and control trees in terms of branches, but the diameter of thinned trees is greater.

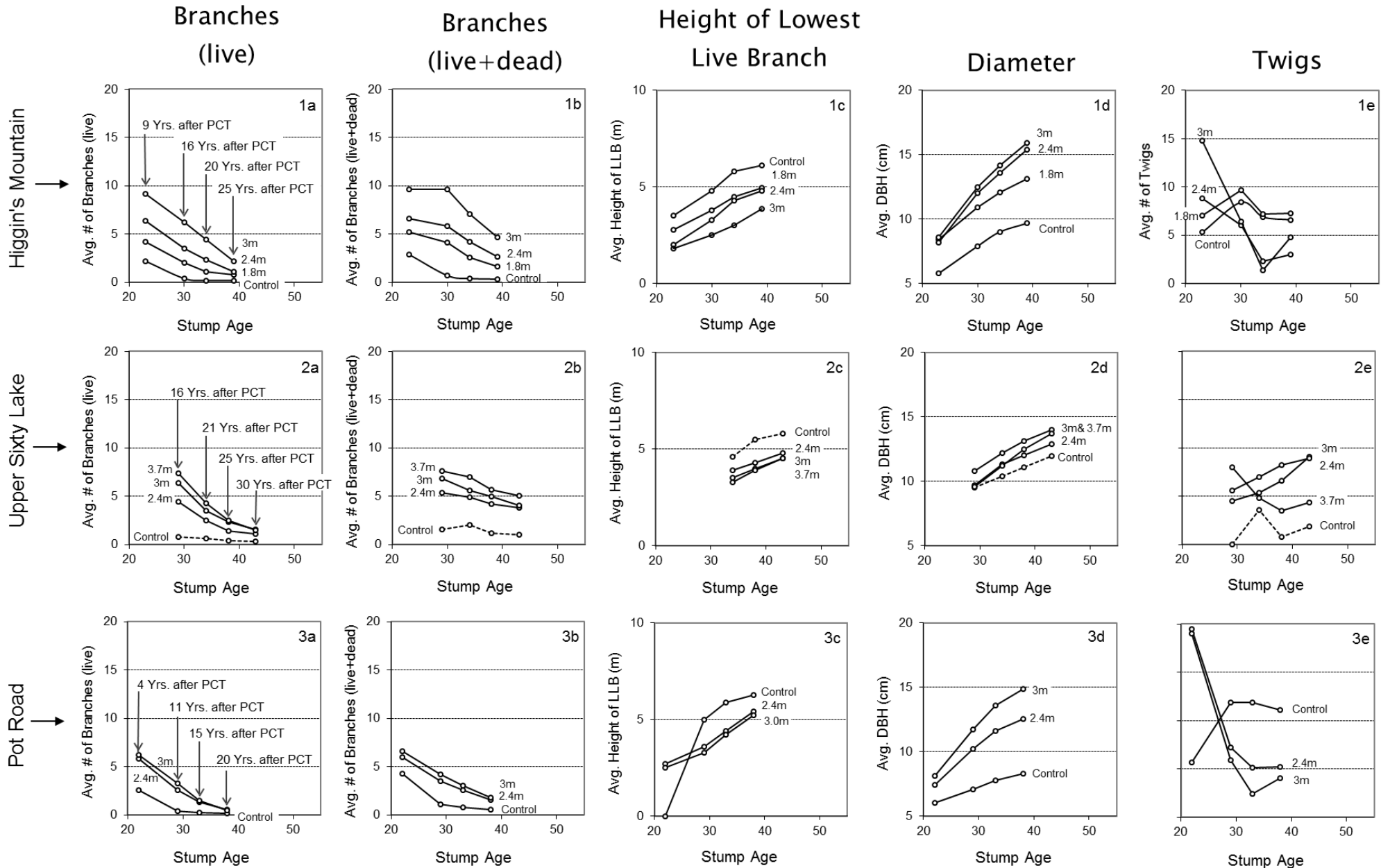
Twigs were abundant on sugar maple soon after thinning, but drop off quickly (Figure 4:1e,3e). The sites which were observed soon after thinning include Higgins's Mountain (9 years after PCT) and Pot Road (4 years after PCT). Sugar maple spaced to 3 m at Pot Road went from having 19 twigs four years after thinning to only 4 twigs sixteen years later (Figure 4: 3e). In some cases there are more twigs on control trees and the lightly thinned than on the more heavily thinned (Figure 4: 1e,3e). This is counter-intuitive to what one might think would happen. Wilson (1970) describes a process in trees whereby vigorous terminal growth in the crown inhibits the growth of twigs lower on the stem. This could explain why released trees, which

have vigorous crowns, have fewer twigs than control trees. Some sites and spacings have numerous twigs, these could affect quality if they do not die back (Figure 4: 2e, 1e-1.8 m spacing). The sites with older trees (Mayfield, Government Stillwater) for the most part had few twigs (Figure 4: 4e,5e).

The sample size of the controls from Gov. Stillwater (1), Mayfield (6), and Upper Sixty Lake (5) are very small so caution should be used when interpreting these results (Appendix 1). However, the results are in line with other sites that have a larger sample size.

Sugar Maple

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----- Small Sample Size (<10)

Sugar Maple

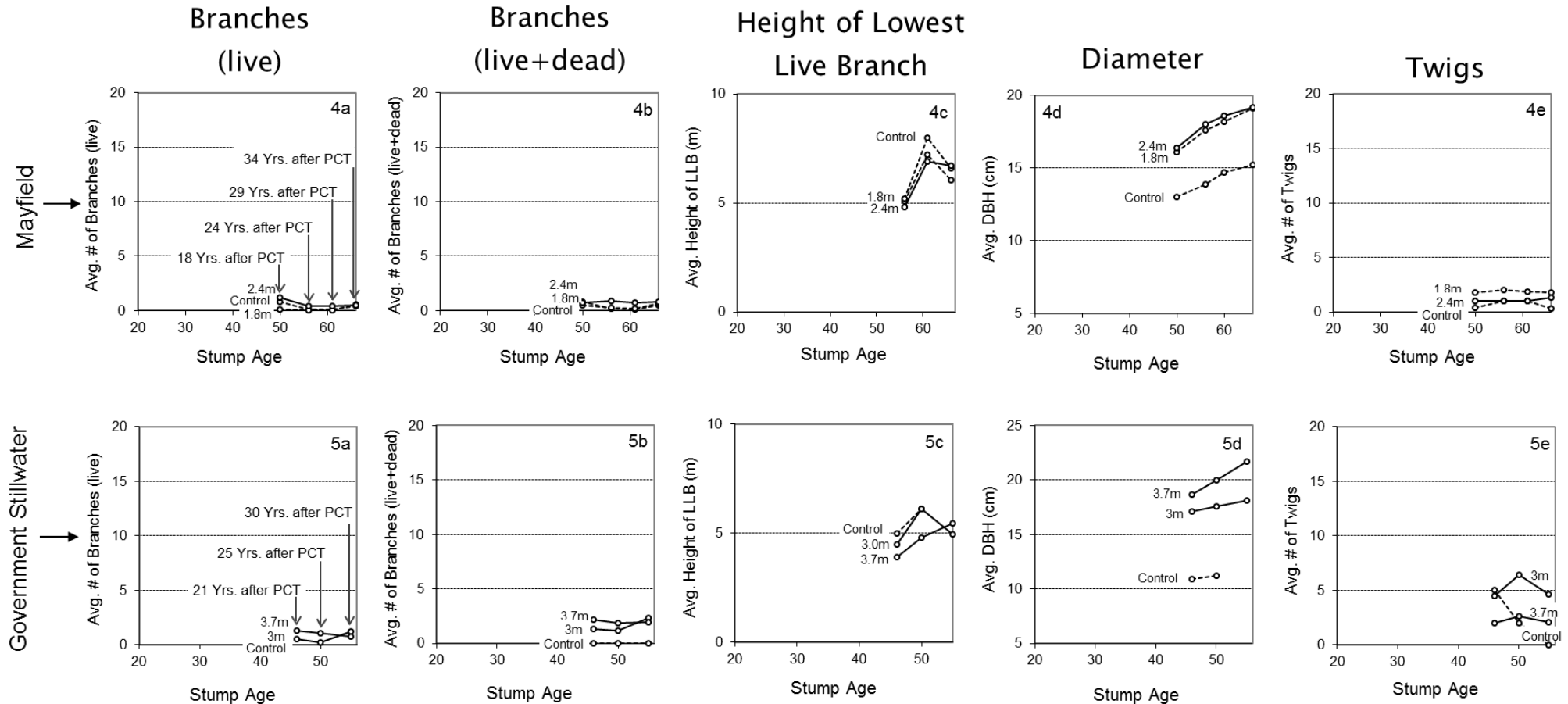


Figure 4. The number of live branches, the number of live+dead branches, the height of the lowest live branch (LLB), the diameter at breast height (DBH), and the number of twigs on sugar maple after pre-commercially thinning five sites (Higgin's Mountain, Upper Sixty Lake, Pot Road, Mayfield, Government Stillwater). The sites are arranged from earliest to latest thinning based on the height of the stand when pre-commercially thinned (PCT'ed).

----- Small Sample Size (<10)

- Higgin's Mountain (1abcde): PCT'ed when 5m tall and 14 years old, measured 9-25 years after PCT, FEC=TH1,TH2.
- Upper Sixty Lake (2abcde): PCT'ed when 6m tall and 13 years old, measured 16-30 years after PCT, FEC=TH3.
- Pot Road (3abcde): PCT'ed when 7m tall and 18 years old, measured 4-20 years after PCT, FEC=TH1.
- Mayfield (4abcde): PCT'ed when 9m tall and 32 years old, measured 18-34 years after PCT, FEC=TH1,TH2.
- Gov. Stillwater (5abcde): PCT'ed when 10m tall and 25 years old, measured 21-30 years after PCT, FEC=IH7.

Mayfield – Sugar Maple

Height when PCT'ed = 9 m

Age when PCT'ed = 32 years

Results: 34 years after PCT @age 66



Control

Avg. # Live Branches = 0.4

Avg. # Dead Branches = 0
0.4

Avg. # Live Twigs = 0.3

Avg. Height of Lowest Live Branch = 6.1 m

Avg. Diameter = 15.2 cm



1.8x1.8 m Spacing

Avg. # Live Branches = 0.6

Avg. # Dead Branches = 0.1
0.7

Avg. # Live Twigs = 1.8

Avg. Height of Lowest Live Branch = 6.6 m

Avg. Diameter = 19.1 cm



2.4x2.4 m Spacing

Avg. # Live Branches = 0.5

Avg. # Dead Branches = 0.3
0.8

Avg. # Live Twigs = 1.3

Avg. Height of Lowest Live Branch = 6.7 m

Avg. Diameter = 19.2 cm

Figure 5. A photo of the average tree for control, 1.8x1.8 m, and 2.4x2.4 m spacings for sugar maple at Mayfield 34 years after PCT (Age=66).

Mayfield: PCT'ed when the stand was 9m tall and 32 years old, site index = 16, FEC = TH1: Sugar maple / Hay-scented fern, TH2: Sugar maple / New York fern-Northern beech fern.

Yellow Birch

Three different sites are represented, two were thinned relatively early (4 m and 5 m tall) and one later (10 m tall) (Figure 6). Yellow birch had high numbers of branches when released early. The site that was released when it was 4 m tall (MacQuarrie Lake) to a spacing of 3 m had 13 live branches twenty years after PCT (Figure 6:1a). Even the moderate spacing of 2.4 m had 8 live branches. Figure 7 shows a photo of the average tree for each spacing at MacQuarrie Lake. The 3 m spacing has many branches low on the stem. In terms of diameter, thinned trees were more than double the size of controls (Figure 7).

Higgin's Mountain which was thinned when it was 5 m tall shows better results. It has considerably fewer live branches compared to MacQuarrie Lake for equivalent spacings (Figure 6: 2a). The 5 m treatment timing resulted in many branches early on, especially the 3 m spacing, but they did decrease quite considerably in the following 16 yr period. Twenty-five years after PCT the wider spacings have more branches (Figure 6: 2b); 1 branches (control), 2 branches (1.8 m spacing), 4 branches (2.4 m spacing), 6 branches (3 m spacing). Diameter gains of thinned vs controls are as follows; 25% (1.8 m spacing), 48% (2.4 m spacing), 58% (3m spacing) (Figure 6:2d). Compared to sugar maple, yellow birch at Higgin's Mountain did not produce as many twigs following PCT (9 years after PCT) (Figure 6:2e and Figure 4:1e). Twenty-five years after PCT, all spacings have 3 or less twigs (Figure 6:2e).

The Merland site thinned at 10 m tall contained yellow and white birch, many of the white birch trees and some of the yellow birch trees were killed by the bronze birch borer (*Agrilus anxius* Gory). Due to the unhealthy condition of the stand it did not respond as well to the PCT (Figure 6:3d). The mortality caused the stand to open up and branch retention was promoted across all spacings (Figure 6: 3ab). This site had very few twigs compared to the other sites (Figure 6:1e,2e,3e). It was observed during field measurements that some of the twigs in the heavily thinned plots developed into branches.

Yellow Birch

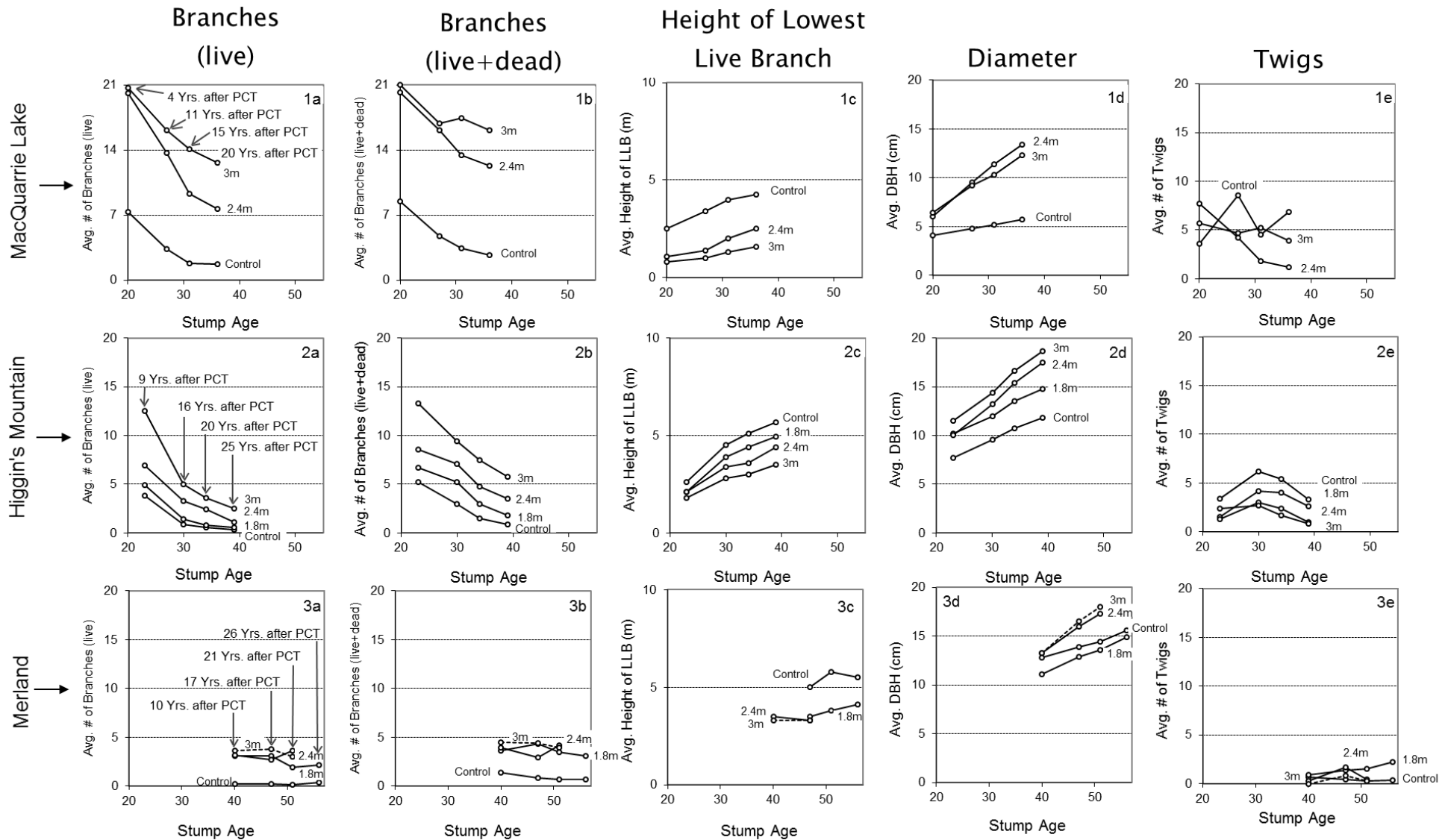


Figure 6. The number of live branches, the number of live+dead branches, the height of the lowest live branch (LLB), the diameter at breast height (DBH), and the number of twigs on yellow birch after pre-commercially thinning three sites (MacQuarrie Lake, Higgin's Mountain, Merland). The sites are arranged from earliest to latest thinning based on the height of the stand when pre-commercially thinned (PCT'ed).

MacQuarrie Lake (1abcde): PCT'ed when 4m tall and 16 years old, measured 4-20 years after PCT, FEC=MW1.
 Higgin's Mountain (2abcde): PCT'ed when 5m tall and 14 years old, measured 9-25 years after PCT, FEC=TH1,TH2
 Merland (3abcde): PCT'ed when 10m tall and 30 years old, measured 10-26 years after PCT, FEC=TH8.

..... Small Sample Size (<10)

MacQuarrie Lake – Yellow Birch

Height when PCT'ed = 4 m
 Age when PCT'ed = 16 years

Results: 20 years after PCT @ age 36



Control

Avg. # Live Branches = 1.7
 Avg. # Dead Branches = $\frac{0.9}{2.6}$
 Avg. # Live Twigs = 6.8
 Avg. Height of Lowest Live Branch = 4.3 m
 Avg. Diameter = 5.8 cm



2.4x2.4 m Spacing

Avg. # Live Branches = 7.6
 Avg. # Dead Branches = $\frac{4.7}{12.3}$
 Avg. # Live Twigs = 1.2
 Avg. Height of Lowest Live Branch = 2.5 m
 Avg. Diameter = 13.4 cm



3x3 m Spacing

Avg. # Live Branches = 12.6
 Avg. # Dead Branches = $\frac{3.5}{16.1}$
 Avg. # Live Twigs = 3.9
 Avg. Height of Lowest Live Branch = 1.6 m
 Avg. Diameter = 12.3 cm

Figure 7. A photo of the average tree for control, 2.4x2.4m, 3x3m spacings for yellow birch at MacQuarrie Lake 20 years after PCT (Age=36).

MacQuarrie Lake: PCT'ed when the stand was 4m tall and 16 years old, site index = 14, FEC = MW1:Red spruce - Yellow birch / Evergreen wood fern.

White Ash

There are two sites with white ash, Upper Sixty Lake which was thinned when it was 6 m tall and Loganville which was thinned when it was 10 m tall (Figure 8).

At Upper Sixty Lake, all spacings (2.4-3.7 m) have less than 1 live branch in the sawlog portion of the stem thirty years after PCT (Figure 8:1a), and these branches are located high on the stem (Figure 8:1c). However, there are still some dead branches; especially at the widest spacing (3.7 m) (Figure 8:1b). The total number of branches (live+dead) for each spacing are as follows; 2 branches (2.4 m spacing), 1 branch (3 m spacing), 4 branches (3.7 m spacing)(Figure 8:1b). There were no twigs for the last 3 measurements (Figure 8:1e).

At Loganville, the 2.1 m spacing is almost completely free of branches and twigs within the sawlog portion of the stem 8 years after PCT at age 38 (Figure 8:2abce). The average diameter of thinned trees was 54% greater than controls (Figure 8:2d). Figure 9 shows a photo of the average tree for control and trees spaced to 2.1 m at Loganville. Both show no branches or twigs, but the diameter gains of thinned trees over the control is quite apparent. White ash generally grows on better sites, therefore site may also be a factor in the quick self pruning that occurs in this species.

White Ash

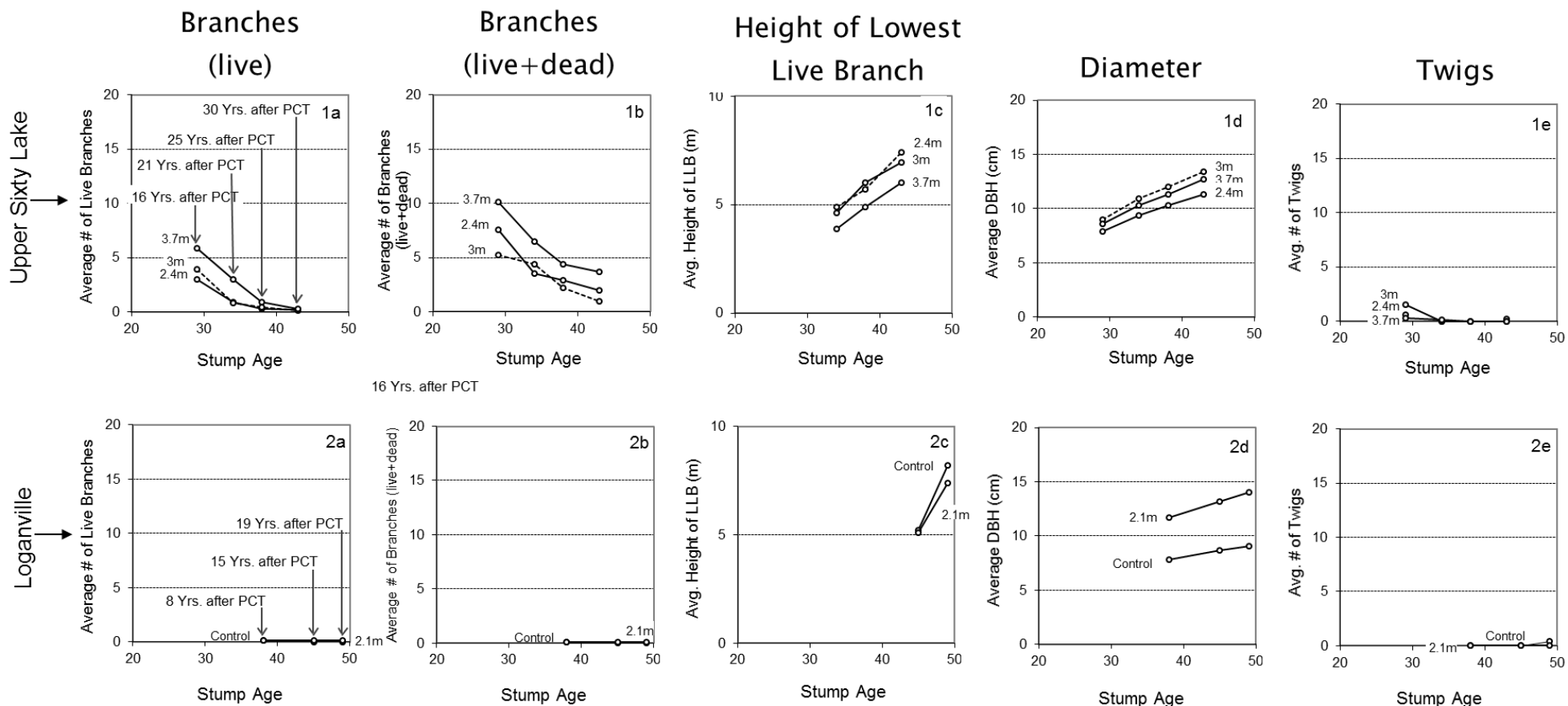


Figure 8. The number of live branches, the number of live+dead branches, the height of the lowest live branch (LLB), the diameter at breast height (DBH), and the number of twigs on white ash after pre-commercially thinning two sites (Upper Sixty Lake and Loganville). The sites are arranged from earliest to latest thinning based on the height of the stand when pre-commercially thinned (PCT'ed).

Upper Sixty Lake (1abcde): PCT'ed when 6m tall and 13 years old, measured 16-30 years after PCT, FEC=TH3. ----- Small Sample Size (<10)
 Loganville (2abcde): PCT'ed when 10m tall and 30 years old, measured 8-19 years after PCT, FEC=TH3.

Loganville – White Ash

Height when PCT'ed = 10 m

Age when PCT'ed = 30 years



Results: 19 years after PCT @ age 49

Control

Avg. # Live Branches = 0
 Avg. # Dead Branches = $\frac{0.2}{0.2}$
 Avg. # Live Twigs = 0.4
 Avg. Height of Lowest Live Branch = 8.2 m
 Avg. Diameter = 9.1 cm



2.1x2.1 m Spacing

Avg. # Live Branches = 0.1
 Avg. # Dead Branches = $\frac{0.3}{0.4}$
 Avg. # Live Twigs = 0
 Avg. Height of Lowest Live Branch = 7.4 m
 Avg. Diameter = 14 cm

Figure 9. A photo of the average tree for control and 2.1x2.1 m spacing for white ash at Loganville 19 years after PCT (Age=49).

Loganville: PCT'ed when the stand was 10m tall and 30 years old, site index = 15,

FEC = TH3: Sugar maple - White ash / Christmas fern

White Birch

White birch occurred at two sites shown in Figure 10 (Upper Sixty Lake and Pot Road). Upper Sixty Lake was PCT'ed when it was 6 m tall and Pot Road was PCT'ed when it was 7 m tall.

White birch shows similar results to that of white ash. Thirty years after thinning Upper Sixty Lake all spacings have no live branches (Figure 10:1a), no twigs (Figure 10:1e), but still has some dead branches (Figure 10:1b) especially the wider spacings. The total number of branches (live+dead) for each spacing are as follows; 0.3 branches (control), 1 branch (2.4 m spacing), 2 branches (3 m spacing), 4 branches (3.7 m spacing). Diameter gains of thinned trees over controls are as follows; 32% (2.4 m spacing), 43% (3 m spacing), 55% (3.7 m spacing) (Figure 10:1d). The wider spacings had greater diameter gains, but more dead branches.

Pot Road shows similar results, although it appears to have self pruned slightly sooner than Upper Sixty Lake following PCT (Figure 10:2a). The 2.4 m spacing went from having six live branches to zero over a span of 16 years. At age 38 (or 20 years after PCT), there are no live branches (Figure 10:2a), 1 dead branch (Figure 10:2b), and no twigs (Figure 10:2e). The average diameter of thinned trees was 42% greater than controls (Figure 10:2d).

There is another white birch site that is not displayed in the graphs; there were too few samples. However, the data can be found in the appendix (Appendix1: Sand River).

Red Maple

The one red maple site at Government Stillwater was PCT'ed when it was 10 m tall (Figure 11). Thirty years after PCT (Age=55), thinned trees have one branch (live+dead) (Figure 11:1b) and less than 1 twig (Figure 11:1e) in the sawlog portion of the stem. On average, the first live branch on PCT'ed trees starts at 6m (Figure 11:1c). The average diameter of thinned trees were 23-31% greater than controls (Figure 11:1d).

Red Oak

The red oak site (Simpson's Corner) experienced severe defoliation and mortality, and therefore did not respond to the PCT treatment (Figure 12:1d). This site is not the best example of the potential for thinning red oak. With this in mind, one can still garner some information from the trial. Red oak appears to be a naturally branchy species. The control has as many branches as some of the thinned treatments (Figure 12:1a). The most heavily thinned (2.7 m) produced many branches and maintained them for a long period of time (Figure 12:1ab).

White Birch

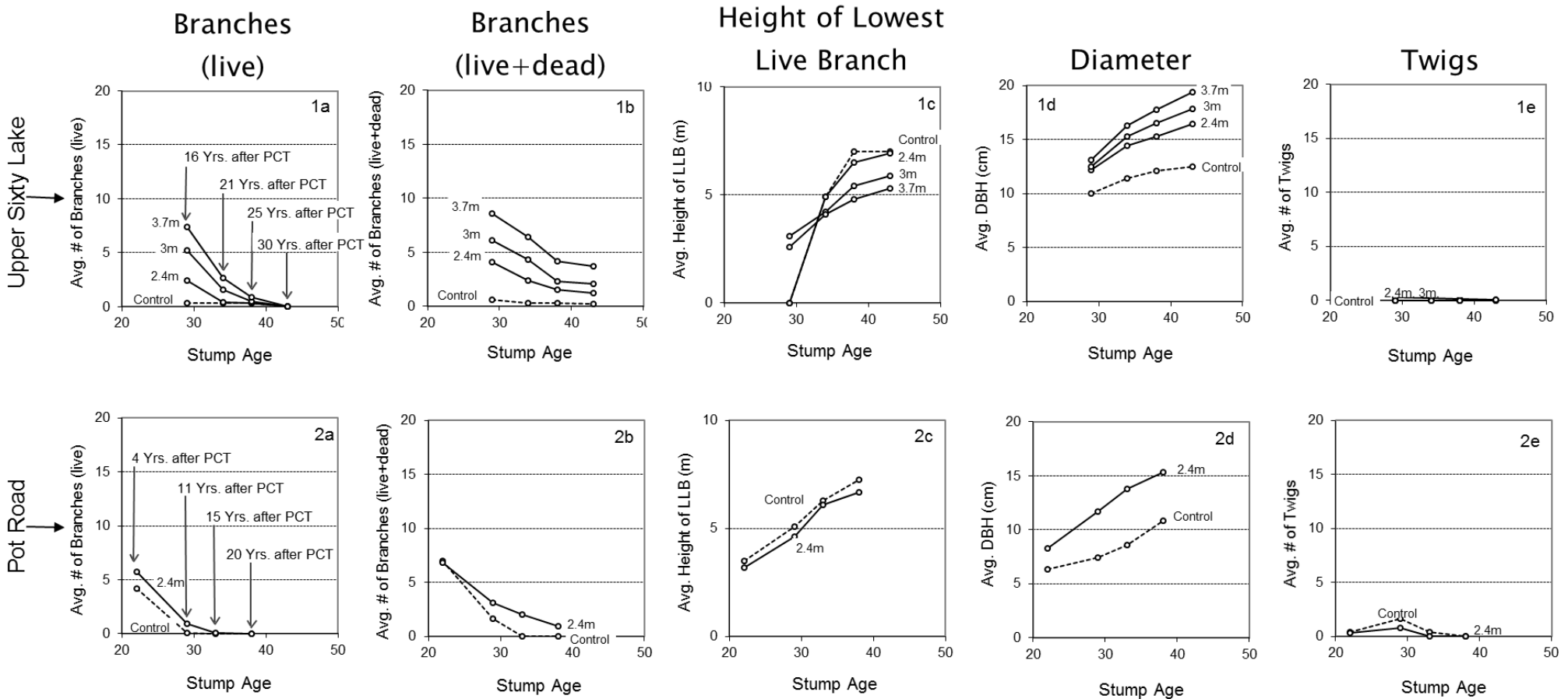


Figure 10. The number of live branches, the number of live+dead branches, the height of the lowest live branch (LLB), the diameter at breast height (DBH), and the number of twigs on white birch after pre-commercially thinning two sites (Upper Sixty Lake and Pot Road). The sites are arranged from earliest to latest thinning based on the height of the stand when pre-commercially thinned (PCT'ed).

Upper Sixty Lake (1abcde): PCT'ed when 6m tall and 13 years old, measured 16-30 years after PCT, FEC=TH3. ----- Small Sample Size (<10)
 Pot Road (2abcde): PCT'ed when 7m tall and 18 years old, measured 4-20 years after PCT, FEC=TH1.

Red Maple

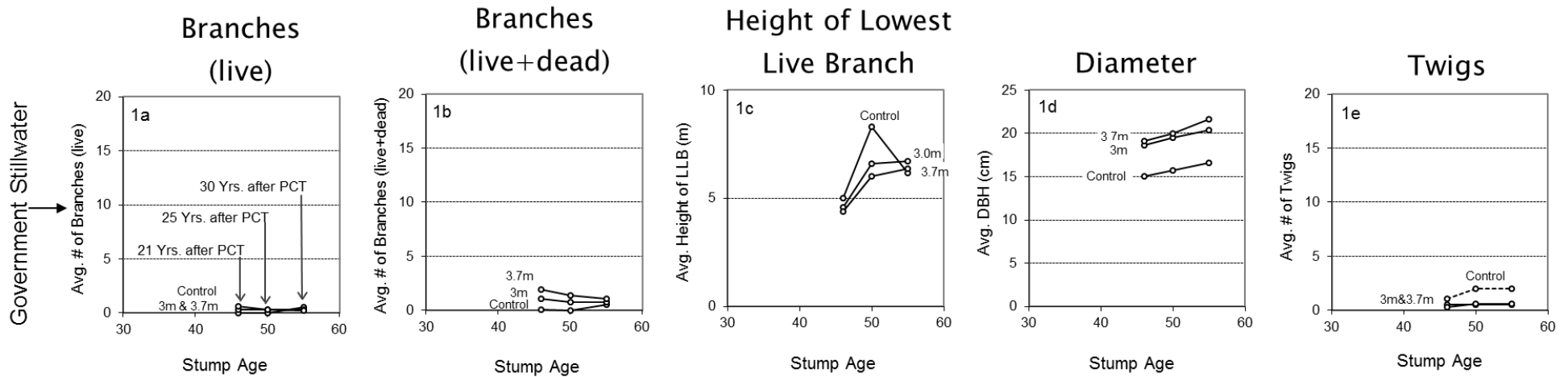


Figure 11. The number of live branches, the number of live+dead branches, the height of the lowest live branch (LLB), the diameter at breast height (DBH), and the number of twigs on red maple after pre-commercial thinning at Government Stillwater.

Government Stillwater (1abcde): PCT'ed when 10m tall and 25 years old, measured 21-30 years after PCT, FEC=IH7.

Red Oak

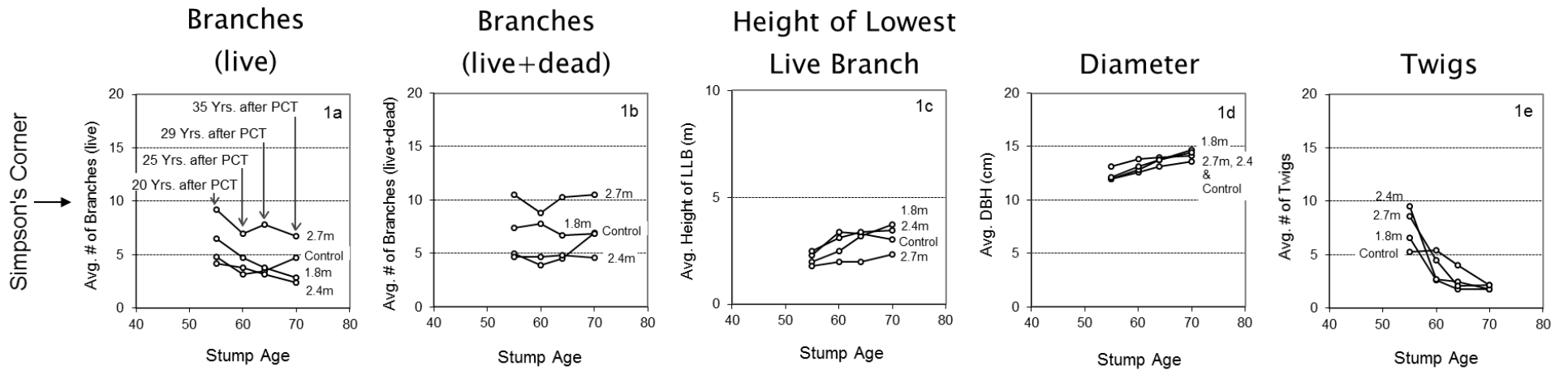


Figure 12. The number of live branches, the number of live+dead branches, the height of the lowest live branch (LLB), the diameter at breast height (DBH), and the number of twigs on red oak after pre-commercial thinning at Simpson's Corner.

Simpson's Corner (1abcde): PCT'ed when 9m tall and 35 years old, measured 20-35 years after PCT, FEC=IH2a.

Sprouting

Figure 13 shows the sprouting of hardwoods that occurred after PCT. Generally, there appears to be a greater abundance of sprouts in wider spaced plots. For example at Higgin's Mountain; 0 stems/ha (control), 0 stems/ha (1.8m spacing), 630 stems/ha (2.4m spacing), 1065 stems/ha (3m spacing) (Figure 13). The greater sprouting in wider spaced plots could be due to the greater abundance of stumps to sprout from and/or the greater abundance of space to grow. Generally, a wide spacing in conjunction with an early release seemed to promote the most sprouting (Figure 13: McQuarrie Lake, Higgin's Mountain, Upper Sixty Lake). However, the species composition of the stand prior to PCT can greatly influence this as well (i.e. more maple).

Mayfield had no sprouting even though it consisted of almost pure sugar maple. It was older when it was PCT'ed which likely resulted in lower sprouting vigor (Figure 13). Sugar maple and red maple were by far the most common species to sprout. There were minor amounts of white ash, yellow birch, and white birch sprouts. Sites which contained a high proportion of yellow birch prior to PCT, such as Higgin's Mountain and MacQuarrie Lake, had few yellow birch stems of sprout origin remaining in the stand as of the last measurement. Lees (1995) observed similar results with respect to yellow birch sprouts.

The height of the sprouts in relation to the crop trees is shown in Table 2. For the most part they are not interfering with crop trees. At MacQuarrie Lake the sprouts are the closest to the height of the crop trees of any site. This site was the shortest (4 m) when it was thinned, this could explain the competitiveness of the sprouts. On the other sites, the sprouts are at least 3 m below the height of crop trees and in no position to compete. Gov. Stillwater was thinned when the crop trees were quite tall (10 m) so sprouts could not overcome the height differential.

In this study it was found that sprouts for the most part never reached the main canopy except when the stand was PCT'ed relatively early. In a similar PCT trial with many of the same species Lees (1995) also found that sprouts never reached the main canopy.

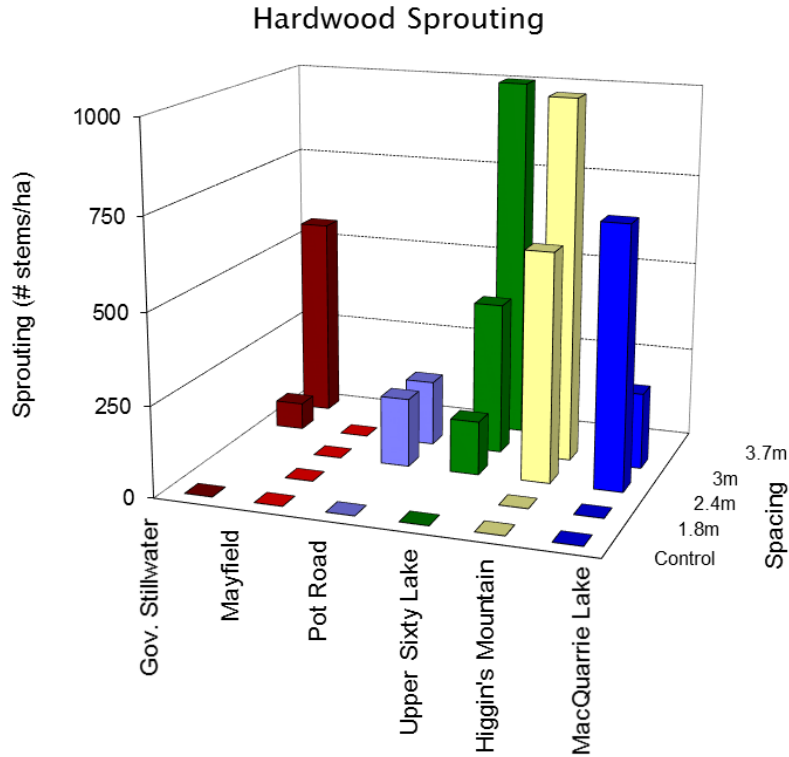


Figure 13. The re-sprouting of hardwoods on 6 sites after pre-commercial thinning. The number of re-sprouts includes only those that reached 4cm at diameter breast height. Shown in the graph is the last measurement for each site.

	Gov. Stillwater	Mayfield	Pot Road	Upper Sixty Lake	Higgin's Mountain	MacQuarrie Lake
Height when PCT'ed	10 m	9 m	7 m	6 m	5 m	4 m
Age When PCT'ed	25	32	18	13	14	16
Species Composition of Sprouts	sM=56% rM=44%	0 Sprouts	rM=80% sM=20%	sM=78% wA=13% rM=9%	sM=99% rM=1%	rM=52% yB=26% sM=10% wB=6% Other=6%
Height ¹ of Sprouts	10 m		10 m	10 m	9 m	8 m
Height ¹ of Crop Trees	15 m		13 m	14 m	12 m	9 m

¹Height = Total Lorey's height: The height of the tree of average basal area.

Discussion

All species responded favourably to pre-commercial thinning as long as they remained healthy. Thinned trees are larger in terms of stem diameter than controls, and in some cases double the size. Diameter gains ranged between 8-132%. This reduces the time needed to bring trees to merchantable and sawlog size.

Spacing greatly influenced the outcome of the pre-commercial thinning treatments. Generally, the wider spacings produced greater diameter gains. For example, diameter gains of PCT'ed yellow birch trees compared to control trees at Higgin's Mountain were as follows; 25% (1.8 m spacing), 48% (2.4 m spacing), 58% (3 m spacing) 25 years after PCT. However, on the negative side, the number of branches (live+dead) retained also increased with a wider spacing; 1 branch (control), 2 branches (1.8 m spacing), 4 branches (2.4 m spacing), 6 branches (3 m spacing). In addition, the wider spacings generally promoted the retention of branches lower on the stems, which means a shorter section of clear bole.

A wider spacing in combination with an early release promoted the most branch retention, but also some of the best diameter gains. For example, yellow birch at MacQuarrie Lake was PCT'ed when it was 4 m tall, with the following results 20 years after thinning.

	<u>Control</u>	<u>2.4 m spacing</u>	<u>3 m spacing</u>
Branches (live+dead)	3	12	16
Diameter Gains (%)		132%	115%

In this case, the diameter gains may not be worth the costs in terms of quality. These tradeoffs between diameter gains and branch retention must be considered when choosing the treatment that best suits your objectives. However with hardwoods, much of the value is in quality. A treatment that favors quality, such as a moderate treatment timing and/or a moderate spacing, is likely to produce the best results. Also, the better quality sites should be selected for PCT, because they tend to self-prune quicker.

Based on the work of Boyce and Carpenter (1968), four surface defects (branches, twigs) can be present when a tree is undersized and still have over an 80% chance to produce a high-grade log (G-1) in the future. The trees used in the Boyce and Carpenter (1968) study were older so their system is not entirely applicable². Regardless, it still provides a basis upon which to establish the maximum number of branches that can be present and still produce high-grade logs.

It appears from this study that white ash and white birch can be PCT'ed without compromising quality. These species were PCT'ed when they were 6 m tall to a spacing of 3 m with the following results; 2 or less branches (live+dead), no twigs, and white birch was 43% larger in terms of diameter than controls 30 years after treatment (Age 43). Increasing the thinning intensity of white birch to 3.7 m resulted in greater diameter gains (55%), but also resulted in more branches (4 live+dead branches). Based on the results of this study, the development of adventitious

² Trees used in the Boyce and Carpenter (1968) study were between 18-38 cm (7-15 inches) dbh. Most of the trees from this report haven't reached the lower limit of 18 cm yet and are therefore not at the same developmental stage. Some of the features present now, such as twigs and branches, could self-prune by the time they reach the size used in the Boyce and Carpenter (1968) study.

twigs was not an issue when these species were PCT'ed. Other researchers have reported similar results (Marquis 1969).

Loganville, a white ash site that was PCT'ed when it was 10 m tall to a spacing of 2.1 m, is relatively free of branches after only 8 years post-thinning and is virtually identical to the control. It was released after its lower branches had already self pruned, therefore branch retention was not an issue. The scenarios mentioned above are all well within the Boyce and Carpenter (1968) standard of four surface defects.

Red maple PCT'ed at 10 m tall to a spacing of 3 m had on average 1 branch (live+dead) and 1 twig 30 years after thinning. Unfortunately, there are no data on earlier treatment timings for red maple. This scenario is also within the Boyce and Carpenter (1968) standard of four surface defects.

Sugar maple is not as good a self pruner as white ash and white birch and also tends to produce twigs. Regardless, it does appear that quality can still be maintained when this species is PCT'ed. For example, the sugar maple sites that were thinned later (when they were 9 m and 10 m tall) to spacings that ranged between 1.8-3 m, had on average 2 branches (live+dead) and anywhere from 1-5 twigs 30 years after thinning. These results are positive especially if the twigs die-back.

Sugar maple that was thinned when it was 7 m tall (Age 18) to a spacing of 2.4 m also shows positive results in terms of quality. Twenty years after PCT (Age 38), the sugar maple had on average 2 branches and 5 twigs within the sawlog portion of the stem and live branches started at 5.4 m. Presently, it is not within the Boyce and Carpenter (1968) standard of four surface defects. However, over time some of the twigs and branches will likely self prune.

Trees self-pruned better over the long-term than might have been predicted from early results. Studies with a much shorter observation period would have a less favorable outlook of pre-commercial thinning in hardwoods in regards to being able to produce quality stems. For example, four years after pre-commercial thinning sugar maple (treatment timing=7 m, spacing=3 m) the trees averaged 19 twigs, 16 years later this was reduced to 4 twigs. The same is true of branches, the same sites went from having 7 branches to 2 over the same time period.

Treatment timing, being the height of a stand when it is PCT'ed, seemed to have a bearing on branch retention in hardwoods. There appeared to be better results for later treatment timings in terms of less branches. However, no definitive conclusions can be made as the different treatment timings are on different sites which makes them difficult to compare. The Nova Scotia Department of Natural Resources has established PCT treatment timing trials which could address this issue.

The Nova Scotia forestry field handbook recommends that a hardwood stand be between 6-9 m tall before pre-commercial thinning operations take place (NSDNR 1993). The former also recommends a spacing of 2.4 m. The results of this study support these recommendations. The stands that were PCT'ed earlier than 6 m tall retained an excessive number of branches. For example, yellow birch that was thinned when it was 4 m tall to a moderate spacing of 2.4 m still had 12 branches 20 years after PCT. By waiting a few more years you can substantially reduce the number of branches in the bottom portion of the stem due to self-pruning. Thinning

between 6-9 m strikes a balance between releasing early to realize diameter gains, but not too early to cause excessive branching.

The better self pruners such as white ash (Schlesinger 1990) and white birch can be thinned anywhere within the operability range of 6-9 m to spacings up to 3 m without much concern about branching. Sugar maple and yellow birch should be limited to 2.4 m spacing to produce quality logs. The majority of stands in Nova Scotia are mixed to some degree, so the silvicultural prescription should be based on the most abundant or treatment timing/spacing sensitive species.

Another consideration is the cost and ease of the pre-commercial thinning operation. As trees get taller it becomes more difficult to conduct a PCT. Taller trees are more difficult to fell and often get hung up. Also, a chain saw may be needed as trees get taller and larger, instead of a traditional spacing saw.

Summary

- Relative to controls, the average diameters of pre-commercially thinned trees were 8-132% greater.
- All species (sugar maple, red maple, yellow birch, white birch and white ash) responded favourably to pre-commercial thinning as long as they remained healthy.
- The spacing greatly influenced the outcome of the PCT treatments. Trees that were spaced wider had larger diameters, but on the negative side they also had more branches that occurred lower on the stem. See Example below.

<u>Example</u> - Higgin's Mountain: Yellow birch thinned when it was 5 m tall and 14 years old. Results at age=39 (25 years after PCT)				
Spacing	Control	1.8x1.8 m	2.4x2.4 m	3x3 m
# Branches (live+dead)	1	2	4	6
Height of Lowest Live Branch	5.7 m	5.0 m	4.4 m	3.5 m
Diameter gain (%)		25%	48%	58%

- Yellow birch appears susceptible to branching when released early. The site that was PCT'ed when it was 4 m tall (MacQuarrie Lake) retained many branches (live+dead) 20 years after treatment (Age 36). Control = 3 branches, 2.4 m spacing = 12 branches, 3 m spacing = 16 branches.

- Comparing species, white ash and white birch were good self pruners (see example below). Compared to sugar maple, they have fewer branches, a lower proportion of live branches, no twigs, and live branches occur farther up the stem leaving a longer section of clear bole.

Upper Sixty Lake: A white ash, white birch, and sugar maple stand thinned when it was 6 m tall (Age=13) to a spacing of 3 m. Results at age 43 (30 years after PCT)				
	# Branches (live+dead)	% of branches which are alive	Height of Lowest Live Branch	# Twigs
White ash	1	10%	7.4 m	0
White birch	2	22%	5.9 m	0
Sugar maple	4	38%	4.5 m	9

- White ash and white birch that were thinned relatively early (6 m tall, Age=13) and at a fairly wide spacing (3 m) show positive results in terms of quality (see example above). Thirty years after PCT, they have 2 or less branches and 0 twigs within the sawlog portion of the stem.
- White ash that was PCT'ed later (10 m tall) to a spacing of 2.1 m also shows positive results (see example below). The sawlog portion of the stem is virtually free of defects (branches and twigs) and the diameters of thinned trees were 54% greater than unthinned.

Loganville: White ash PCT'ed when it was 10 m tall and 30 years old. Results at age 49 (19 years after PCT)			
	# Branches (live+dead)	# Twigs	Diameter Gain (%)
2.1x2.1 m spacing	0.4 branches	0	54%

- Sugar maple that was thinned when it was 7 m tall (Age 18) to a spacing of 2.4 m shows positive results in terms of quality. Twenty years after PCT (Age 38), the sugar maple had on average 2 branches and 5 twigs within the sawlog portion of the stem and live branches started at 5.4 m. The diameters of PCT'ed trees were 51% greater than controls.
- Sugar maple that was thinned later (9 m and 10 m tall) to spacings ranging between 1.8-3 m showed positive results in terms of quality. Thirty years after PCT, there was 2 branches within the sawlog portion of the stem. The twigs ranged between 1-5 depending on the site and spacing, and live branches started at 5 m. The diameters of PCT'ed trees were 26% greater than controls (9 m treatment timing site). There were too few control trees to make a diameter comparison for the 10 m treatment timing site.
- Sugar maple is prone to producing many twigs following PCT, however they die off quickly. For example, four years after pre-commercial thinning sugar maple (treatment timing 7 m, spacing 3 m) the trees averaged 19 twigs, 16 years later this was reduced to 4 twigs.
- White birch and white ash were not prone to producing twigs following PCT.
- Wider spacings promoted increased sprouting, however it was found that sprouts rarely attained a competitive position in the canopy except when the stand was PCT'ed relatively early (4 m tall).

Management Recommendations

Spacing greatly influenced branch retention in pre-commercially thinned hardwoods. Trees in stands that were spaced more tightly had fewer branches, but also less diameter growth. The tradeoffs between diameter gains and branch retention must be considered when choosing the treatment that best suits your objectives. Presently, Nova Scotia recommends that a hardwood stand be between 6-9 m before pre-commercial thinning takes place and be spaced to 2.4 m. The results of this study supports this recommendation. White ash and white birch can be thinned anywhere within the operability range of 6-9 m to spacings up to 3 m without much concern about branching. Sugar maple and yellow birch can be thinned within the same operability range, but should be limited to 2.4 m spacing to produce quality logs. Tighter spacings will realize less diameter growth response.

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Appendix 1. Data Summary

	Location	Stand #	Height	Age	Yrs.	Stump Age	Sample Size							Avg. Diameter (cm)						
			w hen PCT'ed	w hen PCT'ed	Since PCT		Con	18m	2.1m	2.4m	2.7m	3m	3.7m	Con	18m	2.1m	2.4m	2.7m	3m	3.7m
Sugar Maple	Higgin's Mountain	8701	5m	14	9	23	15	44		27	11			5.8	8.4		8.2	8.6		
					16	30	14	44		27	10		7.9	10.9		12	12.5			
					20	34	15	44		27	10		9	12.1		13.6	14.2			
					25	39	15	43		27	10		9.7	13.1		15.4	15.9			
	Upper Sixty Lake	8274	6m	13	16	29	5			46	29	42		9.5			9.7	10.8	9.6	
					21	34	5			46	28	41		10.4			11.3	12.2	11.2	
					25	38	5			47	26	39		11.1			12	13.1	12.5	
					30	43	6			46	26	39		12.0			12.9	14.0	13.7	
	Pot Road	9225	7m	18	4	22	59			138	54			6			7.4	8.1		
					11	29	57			132	54		7.1			10.2	11.7			
					15	33	56			127	54		7.8			11.6	13.6			
					20	38	55			124	53		8.3			12.6	14.9			
	Mayfield	1011	9m	32	18	50	8	9		42				13	16.1		16.4			
					24	56	8	9		42			13.9	17.6		18				
					29	61	7	9		42			14.7	18.2		18.6				
34					66	6	9		42			15.2	19.1		19.2					
Government Stillwater	8282	10m	25	21	46	1					13	25	10.9				17.1	18.7		
				25	50	1					13	25	11.2				17.6	20		
				30	55						13	25					18.2	21.7		
Red Maple	Government Stillwater	8282	10m	25	21	46	11					39	35	15				18.6	19.1	
					25	50	11					39	35	15.7				19.5	20.3	
					30	55	10					38	35	16.6				20.4	21.7	
Red Oak	Simpson's Corner	1711	9m	35	20	55	17	10		13	34			12	13.1		12	12.1		
					25	60	17	10		12	32		12.6	13.8		12.8	13.1			
					29	64	17	10		11	31		13.1	14.0		13.7	13.8			
					35	70	11	9		8	26		13.6	14.1		14.7	14.5			
Yellow Birch	MacQuarrie Lake	9217	4m	16	4	20	25			35	34			4.1		6	6.4			
					11	27	22			33	31		4.8		9.5	9.2				
					15	31	21			29	27		5.2		11.4	10.3				
					20	36	19			28	27		5.8		13.4	12.3				
	Higgin's Mountain	8701	5m	14	9	23	41	31		50	38			7.7	10.2		10	11.5		
					16	30	36	27		33	28		9.6	12		13.2	14.4			
					20	34	35	23		28	24		10.7	13.5		15.4	16.6			
					25	39	32	20		25	22		11.8	14.8		17.5	18.7			
	Merland	8601	10m	30	10	40	10	16		22	8			12.8	11.1		13.3	13.3		
					17	47	10	16		21	8		13.9	12.9		16	16.5			
21					51	9	16		21	8		14.4	13.6		17.3	18				
26					56	9	16					15.6	14.9							
White Ash	Upper Sixty Lake	8274	6m	13	16	29				20	8	29				7.9	9	8.6		
					21	34				20	8	29				9.4	10.9	10.3		
					25	38				20	8	29				10.3	12	11.3		
					30	43				20	8	29				11.3	13.4	12.7		
	Loganville	8806	10m	30	8	38	12		17				7.8	11.7						
				15	45	12		17				8.7	13.2							
				19	49	11		17				9.1	14							
White Birch	Upper Sixty Lake	8274	6m	13	16	29	3			32	20	19		10		12.2	12.5	13.1		
					21	34	3			31	19	19		11.4		14.4	15.3	16.3		
					25	38	3			30	19	19		12.1		15.3	16.5	17.8		
					30	43	4			30	19	19		12.5		16.4	17.9	19.4		
	Sand River	211	6m	22	18	40		7		7	4			12.4	12.6		14.8	12.4		
					24	46		7		7	4		13.8	13.8		15.5	14.2			
					29	51	3	6		7	4		15	14.9		15.6	14.8			
Pot Road	9225	7m	18	4	22	13			19				6.3			8.3				
				11	29	8			17			7.4			11.7					
				15	33	5			15			8.6			13.8					
				20	38	4			15			10.8			15.3					

	Location	Stand #	Height when PCTed	Age when PCTed	Yrs. Since PCT	Stump Age	Avg. # of Live Branches							Avg. # of Dead Branches						
							Con	1.8m	2.1m	2.4m	2.7m	3m	3.7m	Con	1.8m	2.1m	2.4m	2.7m	3m	3.7m
Sugar Maple	Higgin's Mountain	8701	5m	14	9	23	2.2	4.2		6.4		9.2	0.7	1		0.2		0.4		
					16	30	0.4	2		3.5		6.2	0.3	2.1		2.3		3.4		
					20	34	0.2	1.1		2.3		4.4	0.2	1.5		1.9		2.7		
					25	39	0.2	0.8		1.1		2.2	0.1	0.9		1.6		2.5		
	Upper Sixty Lake	8274	6m	13	16	29	0.8			4.4		6.4	0.8			1		0.4	0.2	
					21	34	0.6			2.5		3.5	1.4			2.4		2.1	2.7	
					25	38	0.4			1.4		2.3	0.8			2.8		2.7	3.2	
					30	43	0.3			1.1		1.6	0.7			2.7		2.5	3.5	
	Pot Road	9225	7m	18	4	22	2.6			5.8		6.2	1.7			0.2		0.4		
					11	29	0.4			2.6		3.3	0.7			0.9		0.9		
					15	33	0.2			1.3		1.5	0.6			1.3		1.5		
					20	38	0.1			0.5		0.4	0.4			1		1.4		
	Mayfield	1011	9m	32	18	50	0.8	0.1		1.2			0	0.4		0.5				
					24	56	0.1	0		0.4			0.1	0.3		0.5				
					29	61	0.1	0		0.4			0	0.2		0.3				
34					66	0.4	0.6		0.5			0	0.1		0.3					
Government Stillwater	8282	10m	25	21	46	0					0.5	1.3	0				0.8	0.9		
				25	50	0					0.2	1.1	0				1	0.8		
				30	55						1.2	0.8					1.1	1.2		
Red Maple	Government Stillwater	8282	10m	25	21	46	0				0.3	0.6	0.1				0.8	1.3		
					25	50	0				0.3	0.3	0				0.5	1.1		
					30	55	0.5				0.3	0.2	0				0.5	0.9		
Red Oak	Simpson's Corner	1711	9m	35	20	55	4.8	6.5		4.2	9.2	0.2	0.9		0.5	1.3				
					25	60	3.2	4.7		3.8	7	0.7	3.1		0.9	1.8				
					29	64	3.5	3.8		3.2	7.8	1	2.9		1.6	2.5				
					35	70	4.7	2.9		2.4	6.8	2.2	4		2.3	3.7				
Yellow Birch	MacQuarrie Lake	9217	4m	16	4	20	7.3			20.1	20.7	1.2			0.1		0.4			
					11	27	3.3			13.7	16.1	1.4			2.4		0.8			
					15	31	1.8			9.3	14.1	1.6			4.1		3.3			
					20	36	1.7			7.6	12.6	0.9			4.7		3.5			
	Higgin's Mountain	8701	5m	14	9	23	3.8	4.9		6.9		12.5	1.4	1.8		1.7		0.8		
					16	30	0.9	1.4		3.3		5	2.1	3.8		3.8		4.4		
					20	34	0.6	0.8		2.4		3.6	0.9	2.2		2.4		3.9		
					25	39	0.4	0.6		1.1		2.5	0.5	1.3		2.4		3.3		
	Merland	8601	10m	30	10	40	0.2	3.1		3.2		3.6	1.2	0.5		0.6		0.9		
					17	47	0.2	3.1		2.7	3.8	0.6	1.1		0.1		0.6			
					21	51	0.1	1.9		3.6		3	0.6	1.6		0.6		0.9		
					26	56	0.3	2.1					0.3	0.9						
White Ash	Upper Sixty Lake	8274	6m	13	16	29				3	3.9	5.9				4.6	1.3	4.2		
					21	34				0.9	0.8	3			2.6		3.6	3.5		
					25	38				0.3	0.4	0.9			2.6		1.8	3.5		
					30	43				0.2	0.1	0.3			1.8		0.9	3.4		
	Loganville	8806	10m	30	8	38	0.1	0.1					0.3	0.3						
					15	45	0	0.1					0.5	0.4						
				19	49	0	0.1					0.2	0.3							
White Birch	Upper Sixty Lake	8274	6m	13	16	29	0.3			2.4	5.2	7.4	0.3			1.7	0.9	1.2		
					21	34	0.3			0.4	1.6	2.7	0			2		2.7	3.7	
					25	38	0.3			0.3	0.5	0.9	0			1.2		1.8	3.3	
					30	43	0			0	0.1	0.1	0			1		1.6	3.1	
	Sand River	211	6m	22	18	40	0	0		0.6		3.3		0.6		1.3		1.3		
					24	46	0	0		1	1.5			0.3		1.1		2.5		
					29	51	0	0		0.9	1			0.3	0	1.3		3		
	Pot Road	9225	7m	18	4	22	4.2			5.7			2.8			1.1				
					11	29	0.1			0.9			1.5			2.2				
					15	33	0			0.1			0			1.9				
				20	38	0			0			0			0.9					

	Location	Stand #	Height	Age	Yrs.	Stump Age	Avg. # of Live and Dead Branches							Avg. # of Live Twigs						
			w hen	w hen	Since		Con	18m	2.1m	2.4m	2.7m	3m	3.7m	Con	18m	2.1m	2.4m	2.7m	3m	3.7m
			PCTed	PCTed	PCT															
Sugar Maple	Higgin's Mountain	8701	5m	14	9	23	2.9	5.2		6.6	9.6		5.3	7	8.8	14.8				
					16	30	0.7	4.1		5.8	9.6		8.4	9.7	6	6.4				
					20	34	0.4	2.6		4.2	7.1		6.9	7.2	2.3	1.4				
					25	39	0.3	1.7		2.7	4.7		6.6	7.2	3.0	4.8				
	Upper Sixty Lake	8274	6m	13	16	29	1.6			5.4	6.8	7.6	0		4.5	5.6	8			
					21	34	2			4.9	5.6	7	3.6		5.4	7	4.8			
					25	38	1.2			4.2	5	5.7	0.8		6.6	8.2	3.5			
					30	43	1.0			3.8	4.0	5.0	1.8		9.1	9.0	4.3			
	Pot Road	9225	7m	18	4	22	4.3			6	6.6		5.7		19.5	19.1				
					11	29	1.1			3.5	4.2		11.9		7.2	5.9				
					15	33	0.8			2.6	3		11.9		5.1	2.4				
					20	38	0.5			1.6	1.8		11.1		5.2	4.1				
	Mayfield	1011	9m	32	18	50	0.8	0.5		1.7			0.4	1.8	1					
					24	56	0.2	0.3		0.9			1	2	1					
					29	61	0.1	0.2		0.7			1	1.9	1					
34					66	0.5	0.7		0.8			0.3	1.8	1.3						
Government Stillwater	8282	10m	25	21	46	0				1.3	2.2	5			4.5	2				
				25	50	0					1.2	1.9	2		6.4	2.6				
				30	55						2.3	1.9			4.6	2.1				
Red Maple	Government Stillwater	8282	10m	25	21	46	0.1			1.1	1.9	1.1			0.5	0.3				
					25	50	0				0.8	1.4	2		0.5	0.6				
					30	55	0.5				0.8	1.1	2		0.5	0.6				
Red Oak	Simpson's Corner	1711	9m	35	20	55	5	7.4		4.7	10.5	5.3	6.6	9.5	8.6					
					25	60	3.9	7.8		4.7	8.8	5.4	2.6	2.7	4.5					
					29	64	4.5	6.7		4.8	10.3	4	1.8	2.5	2.1					
					35	70	6.9	6.9		4.6	10.5	2.2	1.8	1.8	2.2					
Yellow Birch	MacQuarrie Lake	9217	4m	16	4	20	8.5			20.2	21.1	3.6		7.7	5.7					
					11	27	4.7			16.1	16.9	8.6		4.2	4.7					
					15	31	3.4			13.4	17.4	4.5		1.8	5.2					
					20	36	2.7			12.3	16.1	6.8		1.2	3.9					
	Higgin's Mountain	8701	5m	14	9	23	5.2	6.7		8.6	13.3		3.4	1.5	1.3	2.4				
					16	30	3	5.2		7.1	9.4	6.2	4.2	3	2.7					
					20	34	1.5	3		4.8	7.5	5.4	4	2.4	1.7					
					25	39	0.9	1.8		3.5	5.8	3.3	2.6	1.0	0.9					
Merland	8601	10m	30	10	40	1.4	3.6		3.8	4.5		0.7	0.9	0.3	0					
				17	47	0.8	4.2		2.8	4.4	0.4	1.4	1.7	0.8						
				21	51	0.7	3.5		4.2	3.9	0.3	1.5	0.4	0.3						
				26	56	0.7	3.1				0.3	2.3								
White Ash	Upper Sixty Lake	8274	6m	13	16	29				7.6	5.2	10.1			0.6	1.5	0.3			
					21	34				3.5	4.4	6.5		0	0	0.1				
					25	38				2.9	2.2	4.4		0	0	0				
					30	43				2.0	1.0	3.7		0.2	0	0				
	Loganville	8806	10m	30	8	38	0.4	0.4				0	0							
15	45	0.5	0.5				0	0												
19	49	0.2	0.4				0.4	0												
White Birch	Upper Sixty Lake	8274	6m	13	16	29	0.6		4.1	6.1	8.6	0		0	0.3	0				
					21	34	0.3			2.4	4.3	6.4	0		0	0.2	0			
					25	38	0.3			1.5	2.3	4.2	0		0	0.1	0			
					30	43	0.3			1.2	2.1	3.7	0		0	0.1	0.1			
	Sand River	211	6m	22	18	40	0	0.6		1.9	4.6		0		0.9	1.3				
					24	46	0	0.3		2.1	4		0.1	1.3	0					
					29	51	0.3	0		2.2	4		0	0.2	0.9	0				
	Pot Road	9225	7m	18	4	22	7			6.8			0.4		0.3					
					11	29	1.6			3.1		1.6		0.8						
					15	33	0			2		0.4		0						
20	38	0			0.9		0		0											

	Location	Stand #	Height	Age	Yrs.	Stump Age	Avg. Ht of Low est Live Branch (m)							Avg. # of Sprouts								
			w hen PCTed	w hen PCTed	Since PCT		Con	18m	2.1m	2.4m	2.7m	3m	3.7m	Con	1.8m	2.4m	2.7m	3m	3.7m			
Sugar Maple	Higgin's Mountain	8701	5m	14	9	23	3.5	2.8		2	1.8											
					16	30	4.8	3.8		3.3	2.5											
					20	34	5.8	4.5		4.3	3					0	0	615		1005		
					25	39	6.1	4.9		4.8	3.9					0	0	630		1065		
	Upper Sixty Lake	8274	6m	13	16	29				3.9	3.5	3.3										
					21	34	4.6			4.3	4	3.9	0		111		334	717				
					25	38	5.5			4.8	4.5	4.5	0		148		420	1014				
	Pot Road	9225	7m	18	4	22				2.7	2.5											
					11	29	5			3.6	3.3											
					15	33	5.9			4.4	4.2	0		98		45						
Mayfield	1011	9m	32	18	50																	
				24	56	5.1	5.2		4.8													
				29	61	7.2	8		6.9			0	0	0								
Government Stillw ater	8282	10m	25	21	46					4.5	3.9											
				25	50	6.1			6.1	4.8	0				86	507						
				30	55				4.9	5.5	0				74	556						
Red Maple	Government Stillw ater	8282	10m	25	21	46	5			4.6	4.4											
					25	50	8.3			6.6	6	0				86	507					
					30	55	6.2			6.7	6.3	0				74	556					
Red Oak	Simpson's Corner	1711	9m	35	20	55	2.3	2		2.5	1.8											
					25	60	3.4	2.5		3.1	2											
					29	64	3.3	3.2		3.4	2											
					35	70	3.0	3.7		3.5	2.3											
Yellow Birch	MacQuarrie Lake	9217	4m	16	4	20	2.5		1.1	0.8												
					11	27	3.4			1.4	1											
					15	31	4			2	1.3	0		690		120						
					20	36	4.3			2.5	1.6	0		720		210						
	Higgin's Mountain	8701	5m	14	9	23	2.6	2.1		2.1	1.8											
					16	30	4.5	3.9		3.4	2.8											
Merland	8601	10m	30	10	40																	
				17	47	5	3.5		3.5	3.3												
				21	51	5.8	3.8		3.3	3.3												
				26	56	5.5	4.1															
White Ash	Upper Sixty Lake	8274	6m	13	16	29																
					21	34				4.6	4.9	3.9										
					25	38				6	5.7	4.9										
					30	43				6.9	7.4	6.0										
Loganville	8806	10m	30	8	38																	
				15	45	5.2		5.1														
				19	49	8.2		7.4														
White Birch	Upper Sixty Lake	8274	6m	13	16	29					3.1	2.6										
					21	34	4.9			4.9	4.2	4.1										
					25	38	7			6.5	5.4	4.8										
					30	43	7			6.9	5.9	5.3										
	Sand River	211	6m	22	18	40																
					24	46		5.2		4.7	4.2											
	Pot Road	9225	7m	18	4	22																
					11	29	3.5			3.2												
				15	33	5.1			4.6													
				20	38	6.3			6.1													
						7.3			6.7													