FOREST
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Nova Scotia Department of Natural Resources
Forest Management Planning

Contents

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The 30 year post-thinning assessment of 45 year old red spruce stands pre-commercially thinned at various intensities in Nova Scotia.

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Introduction

Dense natural regeneration of balsam fir (*Abies balsamea* (L.) Mill.) and spruce (*Picea* spp.) commonly develops after disturbances such as harvest, fire, and windthrow in Nova Scotia and often the fir component dominates. Densities in the tens of thousands of stems per hectare are common. Excess density can delay and reduce individual tree and stand growth. In Nova Scotia, pre-commercial thinning (PCT) is commonly prescribed to reduce the density of excess stems thereby concentrating the growth on the remaining stems and also to increase the proportion of preferred species, namely spruce.

Between 1975-2005, 183,374ha have been pre-commercially thinned in Nova Scotia. PCT has been on an increasing trend and is one of the most widely used silvicultural treatments in the province (Figure 1). It presently rivals planting in terms of abundance. With PCT forming such a large portion of our provincial silvicultural strategy, there is a need for long-term growth and yield data concerning this treatment.

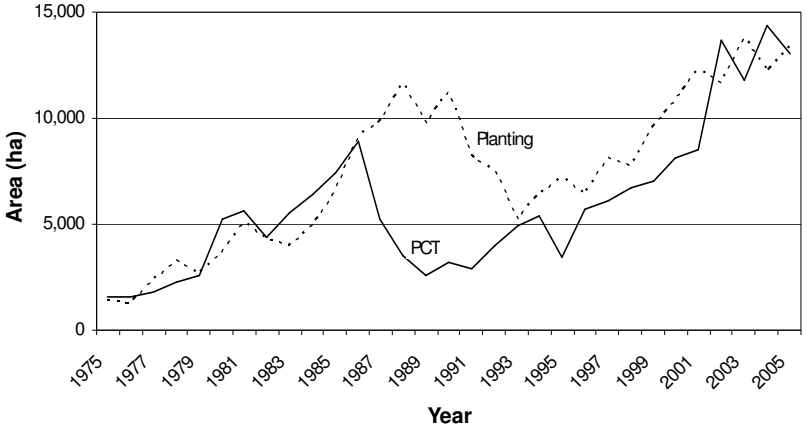

Figure 1. The area of pre-commercial thinning in both natural and planted stands and the area of planting in Nova Scotia on private and crown lands between 1975-2005.

In 1968, a pre-commercial thinning trial exploring different spacings was established in naturally regenerated 15 year old mixed red spruce (*Picea rubens* Sarg.)/balsam fir stands favouring the spruce. The 30 year post-thinning results are presented in this report.

Site Description

Two stands approximately 5km apart were pre-commercially thinned in 1968. The two study sites are located north of St. Margaret's Bay in central Nova Scotia (Figure 2). The land is owned by Bowater Mersey Paper Company Limited. Site A ranges in elevation from 95-100m and site B from 125-135m. Both sites have an average site index of 15 m @ 50 years or a land capability of 5 m^3/ha/yr (NSDNR 1993). Both stands occur on the Gibraltar Soil Series on fresh to moist sites (MacDougall *et al.* 1963).

Both study sites originated after a hurricane in 1954, which caused extensive damage to the mature red spruce stands that were present at the time. Salvage operations were carried out shortly afterwards releasing the advanced regeneration. The Canadian Forest Service of Natural Resources Canada established the pre-commercial thinning trial when the stands were approximately 15 years of age and 3.5m in height. For further information regarding the establishment of this trial and the site and stand conditions at the time of establishment refer to Meikle and Hughes (1969) and NSDLF (1988). The latter reference provides 15 year post-thinning results of this trial.

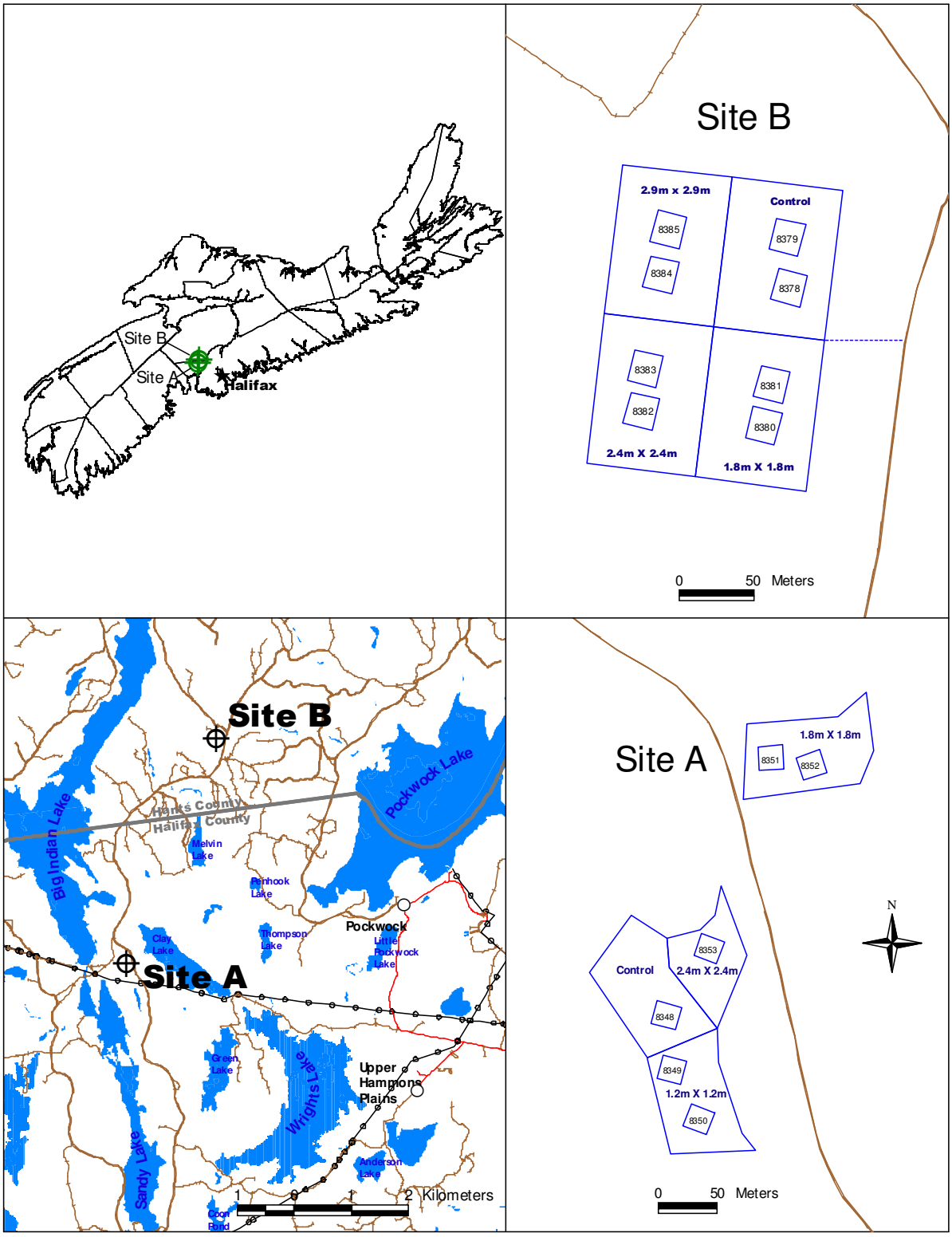

Figure 2. The locations of sites A and B and the block layouts.

Experimental Design

Site A is divided into 4 experimental units varying in size from 0.6-1.3 ha (Figure 2). Three thinning intensities (1.2x1.2m, 1.8x1.8m, 2.4x2.4m) plus an unthinned control were randomly assigned to each experimental unit. Originally, the experimental design had also included a spacing of 2.9x2.9m, but this portion of the trial on site A was harvested during road construction. Site B is divided into 4 experimental units each approximately 0.8 ha in size. Three thinning intensities (1.8x1.8m, 2.4x2.4m, 2.9x2.9m) plus an unthinned control were randomly assigned to each experimental unit.

The thinning intensity that was applied on the ground (actual spacing) did not always match what had been prescribed as shown in Table 1. The actual spacing is a more accurate description of the growing conditions, therefore this measurement is used rather than the prescribed spacing. Plots with the same or similar thinning intensities were combined (different shading) and these categories are used throughout the report (Site A = control, 1.4x1.4m, 1.8x1.8m, 2.3x2.3m; Site B = control, 2.0x2.0m, 2.65x2.65m, 2.8x2.8m).

Table 1. The spacing categories used in the report (different shading) and the actual spacing and prescribed spacing for each PSP.

	Site A						Site B							
Spacing used in Report (m)	Control	1.4		1.8		2.3	Control		2.0		2.65		2.8	
PSP #	8348	8349	8350	8351	8352	8353	8378	8379	8380	8381	8382	8383	8384	8385
Actual (m)	0.7	1.4	1.4	1.8	1.8	2.3	0.8	0.9	1.9	2.1	2.6	2.7	2.8	2.8
Prescribed (m)	Control	1.2	1.2	1.8	1.8	2.4	Control	Control	1.8	1.8	2.4	2.4	2.9	2.9

Methods

In 1968, the Canadian Forest Service established a pre-commercial thinning trial using lightweight power-saws favouring red spruce. Where spruce was absent at the desired location, balsam fir or hardwood was chosen in that order. In 1983, permanent sample plots (PSP's) were re-established in each thinning intensity by the Nova Scotia Department of Natural Resources. PSPs located in thinned areas were 400m^2, while PSPs in controls were 100m^2 due to the high density of stems. The PSPs were re-measured every 5 years. The data per plot is provided in Appendix 1.

Initial Stand Conditions

The growth response after thinning is dependent on factors such as species, site, unthinned density, and age at time of thinning (Karsh *et al.* 1994). The report produced by Meikle and Hughes (1969) provides some preliminary information on the pre-thinning and post-thinning conditions of the two study sites. Figure 3 is derived from the aforementioned report and describes the diameter class distribution of the trees within the different plots prior to thinning and following thinning in 1968.

Site B contained a greater proportion of larger diameter trees compared to site A before thinning and after thinning (Figure 3). The trees on site B are on average 4 years older (Appendix 1) than site A which may explain the dbh[1] differences. Furthermore, site A was considerably more dense prior to release than site B (Figure 5). The variability in initial stand conditions between the two sites can affect the post-thinning growth response and for this reason the two sites were not combined for analysis.

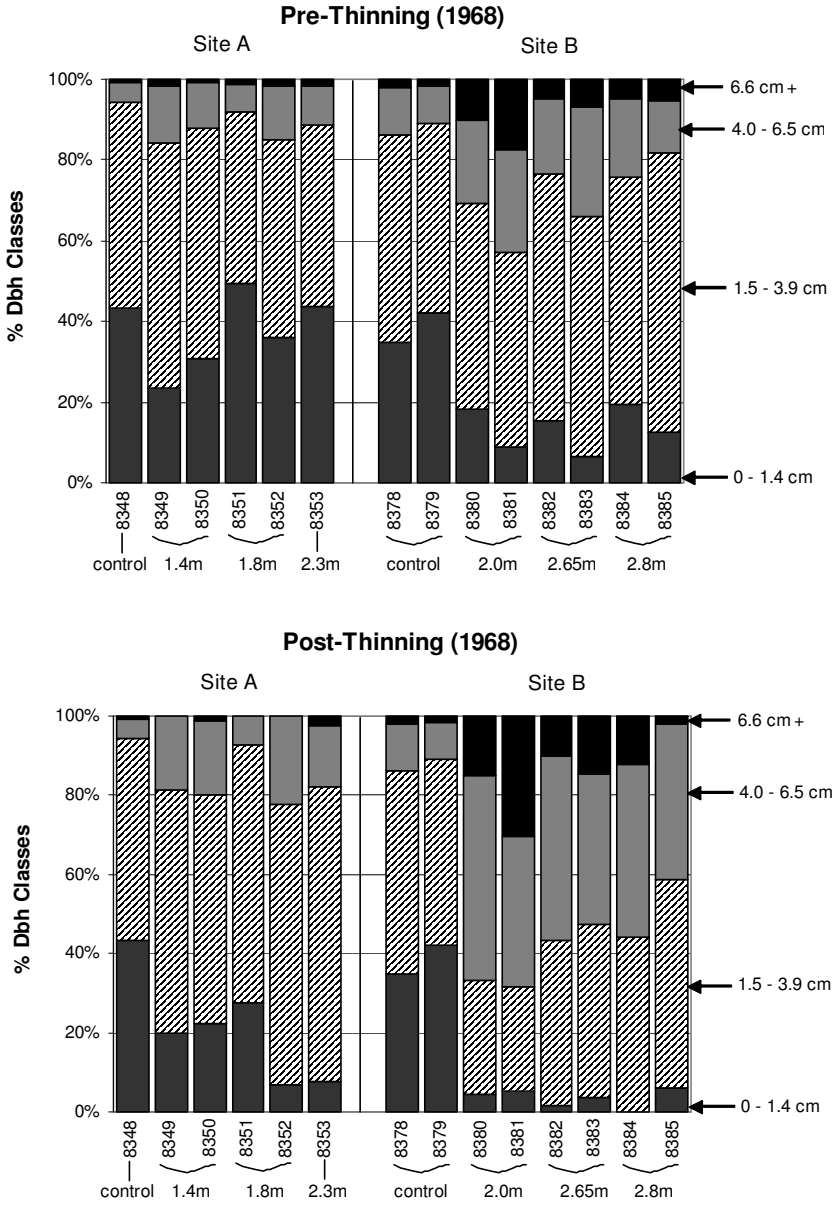

Figure 3. The diameter class distribution per plot prior to pre-commercial thinning and following pre-commercial thinning in 1968 on sites A & B.

[1]Diameter Breast Height (dbh) is the diameter of a tree measured at 1.3m above the ground.

Results

Species Composition

Pre-commercial thinning can be an effective silvicultural tool for manipulating species composition. All thinned plots showed an increase in the percent composition of red spruce and a reduction in balsam fir and red maple (*Acer rubrum* L.) (Figure 4). A 7-37% increase in red spruce with a proportional reduction in balsam fir and red maple was achieved.

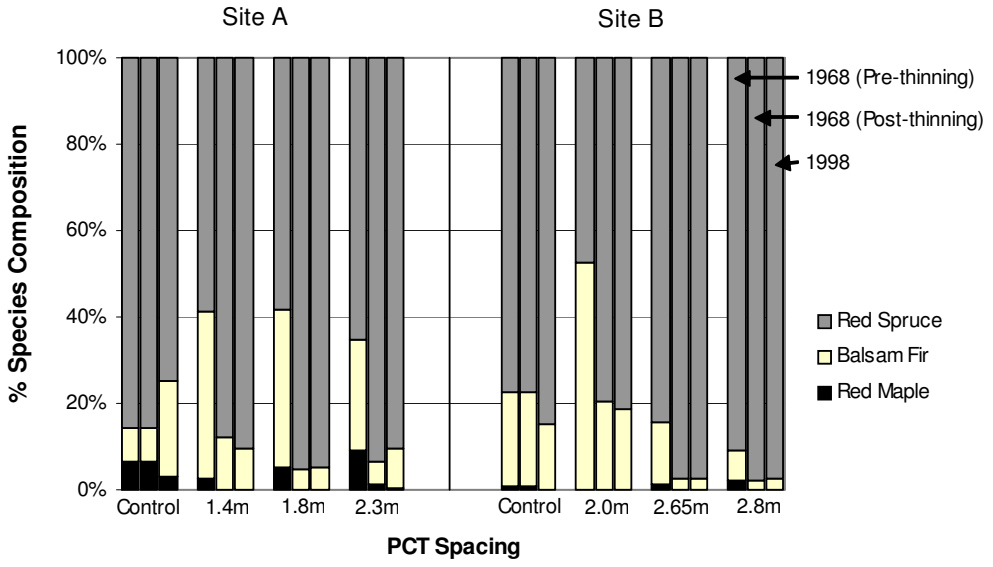

Figure 4. The % species composition (based on density) at different PCT spacings on sites A and B in 1968 prior to thinning and after thinning, and thirty years later in 1998.

The species composition resulting from PCT in 1968 was relatively unchanged over 30 years. The ability to modify species composition is not important when the stand is almost purely composed of the desired species. However, with mixed-species stands (spruce/balsam fir) pre-commercial thinning has proven to be effective at reducing the less desirable species (balsam fir). This is especially significant in Nova Scotia and much of Northeastern Canada and the United States where balsam fir regeneration is prolific. Balsam fir is less desirable than spruce for a number of reasons including its susceptibility to spruce budworm *(Choristoneura fumiferana* (Clemens)) (Frank 1990), windthrow, and rot in pre-commercially thinned stands (O'Keefe *et al.* 2004) as well as its shorter life span. The longer lived spruce provides a larger window of opportunity for additional tending operations and harvesting before stand decline.

Density

Figure 5 represents the density per treatment for sites A and B over time. Each cluster of bars follows a chronological order beginning with the earliest; 1968 pre-thinning, 1968 post-thinning, 1983, 1988, 1993, and 1998. The first bar in each series represents the density prior to thinning, site A was more dense than site B before release. For the controls, the general trend is a gradual reduction in stems as self-thinning occurs. At a spacing of 1.4m, the period of release produced by the pre-commercial thinning is short lived as self-thinning starts to occur shortly after treatment as is evidenced by the gradual reduction in stems over time. On site B at a spacing of 2.0m, there is a drop in density between 1968 and 1983. This reduction in stems is not due to self-thinning, but is a result of porcupine induced mortality (NSDLF 1988).

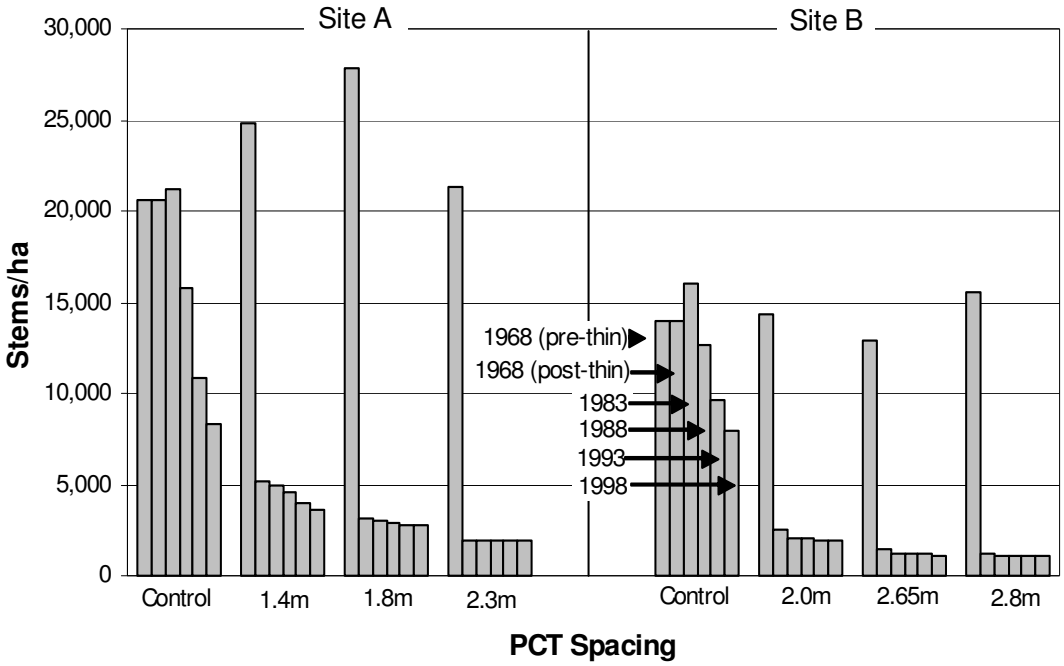

Figure 5. The density (stems/ha) at different PCT spacings on sites A and B over time.

Diameter

Pre-commercial thinning resulted in an increase in average diameters[2]. All thinning intensities resulted in an average diameter greater than the controls (Figure 6). Thirty years after treatment, the average diameter of pre-commercially thinned plots increased by 43%-124% at spacings ranging between 1.4m and 2.65m respectively.

Diameter growth is proportional to the spacing width, meaning the more space allotted to each individual tree the greater the growth response. Therefore, the widest spacings produced the greatest increases in average diameter. Trees spaced at 2.65m and 2.8m were on average more than double the size (124%, 120% respectively) of the controls (Figures 6 and 7).

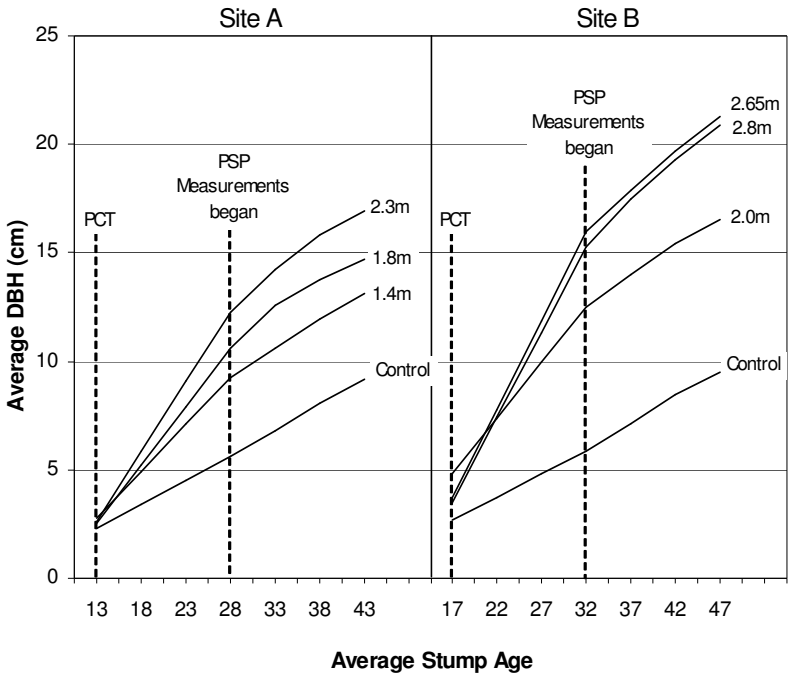

Figure 6. The average DBH resulting from different PCT spacings on sites A and B.

[2]Quadratic mean diameter was used and is defined as the diameter at breast height (dbh) of the tree of average basal area based on trees greater than 1 cm at dbh (Husch *et al*. 2003).

Control (Plot 8379)

2.6x2.6m spacing (Plot 8382)

Figure 7. The featured tree in each photo represents the tree of average dbh for each plot. On the left is a control plot and on the right is a plot spaced to 2.6x2.6m both from site B.

Figure 8 shows the diameter class distributions of the controls and pre-commercially thinned stands thirty years after treatment. All the PCT'ed stands have a greater proportion of stems in the larger diameter classes compared to the controls. The wider spacings have the greatest proportion of stems in the larger diameter classes.

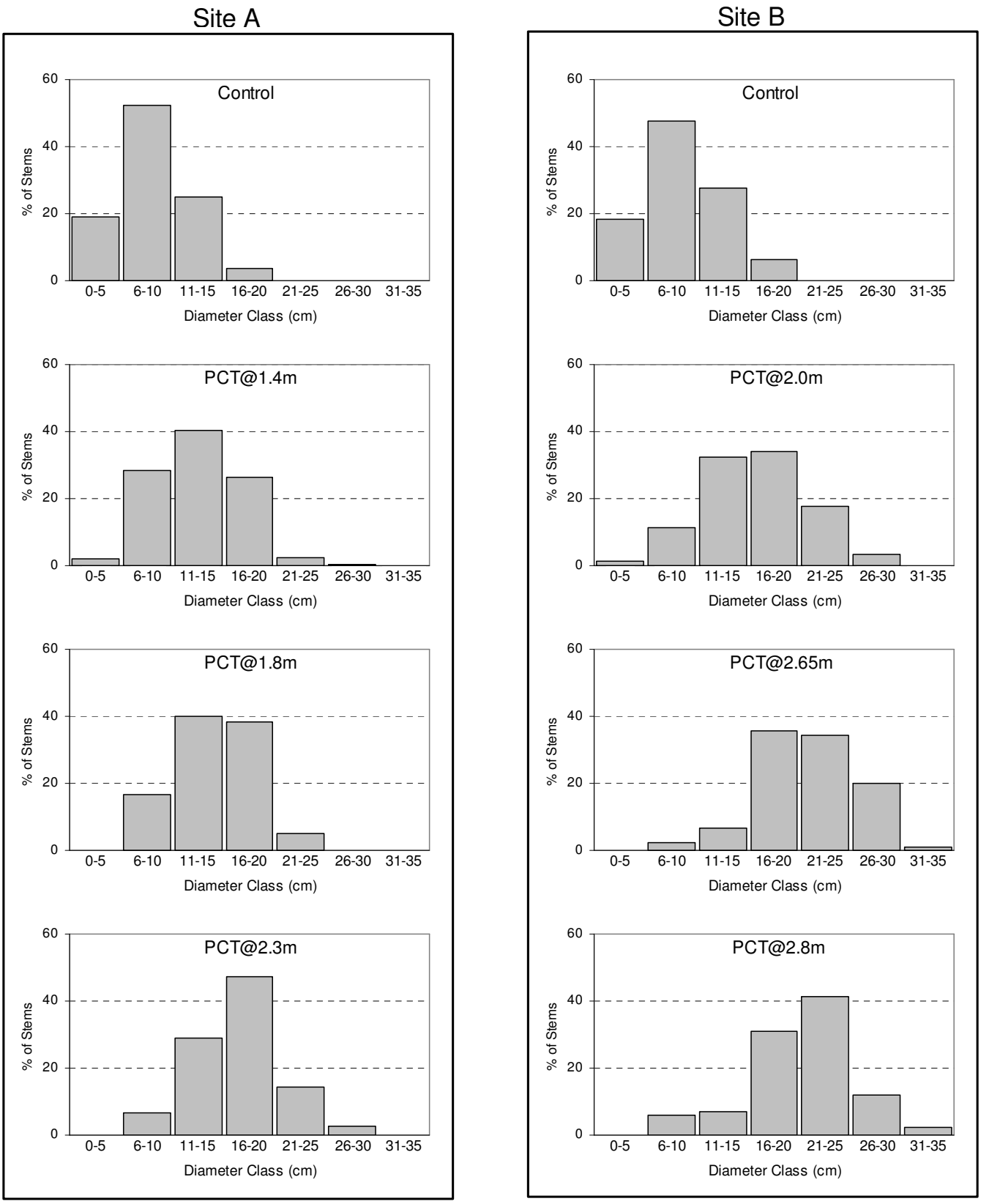

Figure 8. The diameter class distribution of the controls and different PCT spacings on sites A and B thirty years after pre-commercial thinning.

Height

At site B, there is a substantial difference in the average tree height[3] between the thinned and control plots; the same is true for Site A, but to a lesser extent (Figure 9). On sites A and B respectively, thinned plots were on average 5% and 29% taller than controls. Generally, height growth is considered independent of density. However, other studies have also reported increased height growth of balsam fir, spruce and jack pine stands due to thinning (Brissette *et al.* 1999, Piene and Anderson 1987, Burns *et al*. 1996, Zhang *et al.* 2006). Other contributing factors to the magnitude of the difference on site B could include the size difference in the advanced regeneration between the controls and the other thinned plots starting out (Figure 3, Figure 6), and/or site quality differences between thinned and control plots. With respect to treated plots, the average height is relatively unaffected by the thinning intensity.

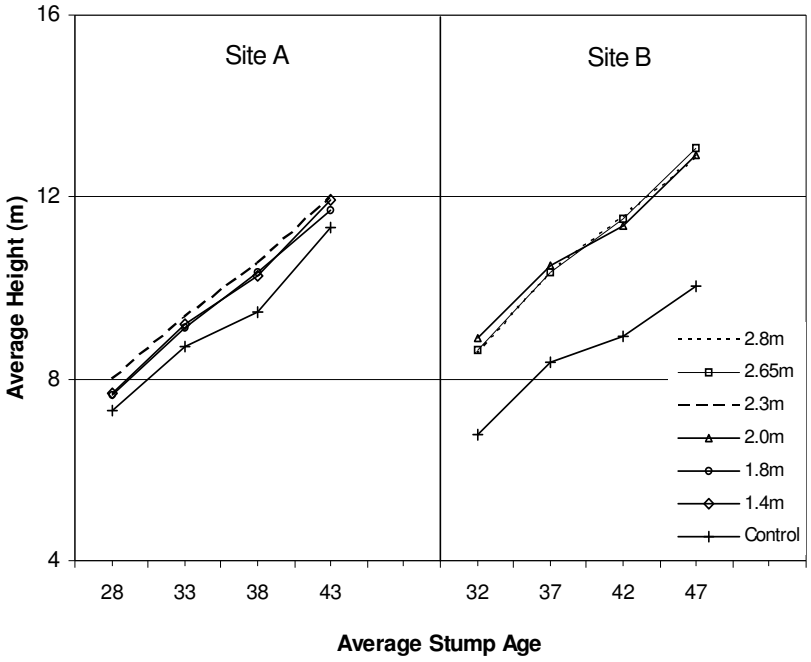

Figure 9. The average height resulting from different PCT spacings on sites A and B, 15-30 years after treatment.

[3]Total Lorey's height was used and is defined as the height of the tree of average basal area based on trees exceeding 1 cm diameter breast height (Husch *et al.* 2003).

Total number of trees/merchantable m^3

Pre-commercial thinning has concentrated the merchantable volume on fewer stems (Figure 10). For every tree harvested in the pre-commercially thinned stands (spacings: 1.4m - 2.65m), one would have to handle 6-21 trees respectively from the controls to produce an equivalent amount of merchantable volume fifteen years after thinning. Thirty years after thinning, one would have to handle 3-9x more trees from the controls. With respect to the different thinning intensities, the widest spacings produced the greatest piece size gains (Figure 10).

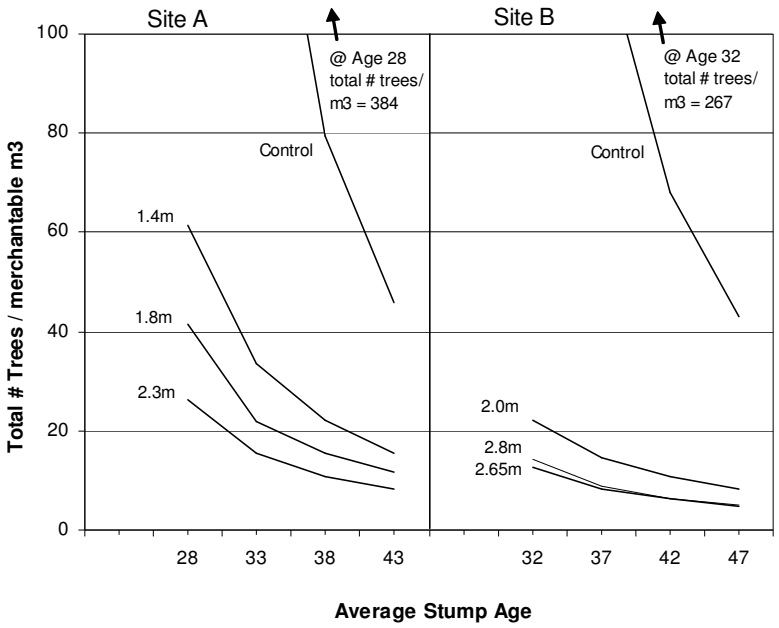

Figure 10. The total # of trees/merchantable m^3 resulting from different PCT spacings on sites A and B, 15-30 years after treatment.

White (1991) stated that tree size is the single most important factor affecting the productivity of harvest machinery. An operator must harvest several small trees to produce the same amount of wood as one large tree, thereby increasing the time that it takes to process an equivalent amount of wood. Dense natural stands containing many small stems take longer to harvest and are therefore less cost effective to harvest. In addition, these natural stands usually contain many unmerchantable stems and dead snags making harvesting more difficult. Therefore, either final harvest or further tending operations are more economically feasible in pre-commercially thinned stands compared to natural stands due to the increased piece size.

Volume

The volume by treatment over time was split into categories; total volume, merchantable volume[4], pulpwood volume[5], and sawlog volume[6] (Figure 11). This approach shows how the amount and proportion of forest products change over time at different thinning intensities. However, it should be noted that the sawlog category is based solely on size requirements and stems within this category do not necessarily meet quality requirements.

As shown in Figure 11, the benefit of pre-commercial thinning is that more merchantable volume and sawlog volume is available sooner. A 12-30% (23-54 m^3/ha) increase in merchantable volume, and a 143-239% (86-165m^3/ha) increase in sawlog volume was achieved thirty years after pre-commercial thinning (Figure 11, Table 2). For the thinned plots, 63-99% of the merchantable volume is of sawlog size compared to 33% and 37% for the controls on Sites A and B respectively (Table 2). When comparing thinning intensities, the more heavily thinned plots produce more sawlog volume sooner.

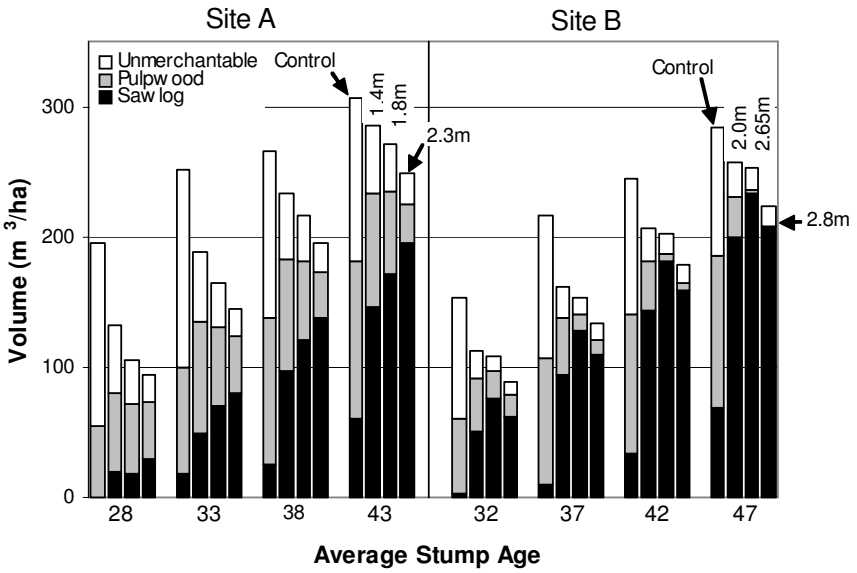

Figure 11. The volume (m^3/ha) by category (unmerchantable, pulpwood, sawlog) resulting from different PCT spacings on sites A and B, 15-30 years after treatment. (Total volume = entire bar; merchantable volume = pulpwood + sawlog)

[4]**Merchantable Volume**: The inside bark bole volume, per unit of area, of trees greater than 9 cm at diameter breast height, as determined from Honer's (1967) volume equations and converted to metric using conversion factors found in the Forestry Field Handbook (NSDNR 1993). The merchantable bole excludes the stump (15 cm height) and top portion of the bole (<7.6 cm diameter inside bark).

[5]**Pulpwood Volume =** merchantable volume - sawlog volume.

[6]**Sawlog Volume:** The inside bark bole volume, per unit of area, of trees greater than 14 cm at diameter breast height, as determined from Honer's (1967) volume equations and converted to metric using conversion factors found in the Forestry Field Handbook (NSDNR 1993). The sawlog bole excludes the stump (15 cm height) and top portion of the bole (<10 cm diameter inside bark).

Table 2. The increase in merchantable and sawlog volumes (m^3/ha) by thinning intensity compared to controls thirty years after pre-commercial thinning.

	Controls		PCT Spacings					
	Site A	Site B	Site A			Site B		
			1.4m	1.8m	2.3m	2.0m	2.65m	2.8m
Merchantable Volume (m^3/ha)	180.8	186.1	233.9	234.5	224.9	230.5	235.9	208.7
Increase (m^3/ha)			53.1	53.7	44.1	44.4	49.8	22.6
Increase (%)			29	30	24	24	27	12
Sawlog Volume (m^3/ha)	60.2	68.9	146.4	171.3	194.8	199.5	233.9	207.6
Increase (m^3/ha)			86.2	111.1	134.6	130.6	165.0	138.7
Increase (%)			143	185	224	190	239	201
% of Merchantable Volume	33	37	63	73	87	87	99	99

Mean Annual Increment (MAI)

The pre-commercially thinned plots showed greater mean annual increments (merchantable m^3/ha/yr) than the controls (Figure 12). Thirty years after treatment, the average mean annual increments ranged between 4.0 - 4.2 m^3/ha/yr for the controls and 4.4 - 5.5 m^3/ha/yr for the thinned plots which is an increase of 10%-31%.

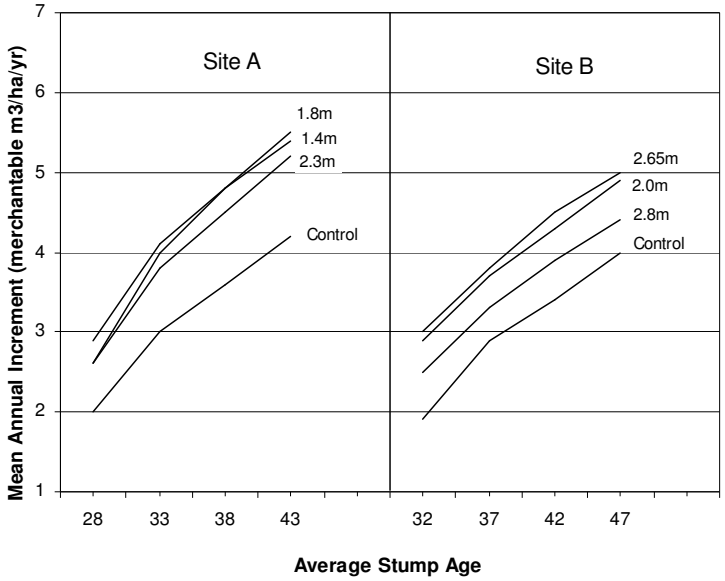

Figure 12. The MAI (merchantable m^3/ha/yr) resulting from different PCT spacings on sites A and B, 15-30 years after thinning.

Summary

- ***Species Composition:*** All thinned plots showed an increase in the percent composition of red spruce (7-37% increase) and a proportional reduction of balsam fir and red maple.

- ***Density:*** Control plots showed an incremental reduction in stems over time as self-thinning occurs. At a spacing of 1.4m, self-thinning starts to occur soon after treatment indicating that the period of release produced by this thinning intensity was short lived.

- ***DBH:*** Thirty years after treatment, the average diameter of pre-commercially thinned plots increased by 43%-124% at spacings ranging between 1.4m - 2.65m respectively. The widest spacings produced the greatest gains.

- ***Height:*** On sites A and B respectively, thinned plots were on average 5% and 29% taller than controls. The explanation for the magnitude of the difference on site B is unclear. Other contributing factors could include the difference in the size of the advanced regeneration between controls and thinned plots starting out and/or differences in site quality. With respect to treated plots, the average height is relatively unaffected by the thinning intensity.

- ***Total # of Trees/Merchantable m^3:*** For every tree harvested from the PCT stands (spacings:1.4m - 2.65m), one would have to handle 6-21 trees respectively from the controls to produce an equivalent amount of merchantable volume fifteen years after thinning. Thirty years after thinning, one would have to handle 3-9x more trees from the controls. The widest spacings produced the greatest piece size gains.

- ***Volume*****:** A 12-30% (23-54 m^3/ha) increase in merchantable volume, and a 143-239% (86-165m^3/ha) increase in sawlog volume was achieved thirty years after pre-commercial thinning at spacings ranging between 1.4m-2.8m. For the thinned plots, 63-99% of the merchantable volume is of sawlog size compared to 33% and 37% for the controls on sites A and B respectively. The more heavily thinned plots produced the greatest sawlog volume gains.

- ***Mean Annual Increment:*** Thirty years after thinning, the average merchantable mean annual increments ranged between 4.0 - 4.2 m^3/ha/yr for the controls and 4.4 - 5.5 m^3/ha/yr for the thinned plots which is an increase of 10%-31%.

Discussion

The results of this PCT trial show considerable improvement in the proportion of preferred species, merchantable and sawlog volumes, mean annual increments, average diameter, average height, and piece size as a result of pre-commercial thinning.

Thirty years after thinning, the percent composition of red spruce increased by 7-37%, merchantable volumes increased by 12-30%, sawlog volumes increased by 143-239%, merchantable mean annual increments increased by 10-31%, average diameters increased by 10-30%, average heights increased by 4-30%, and the merchantable volume is distributed on 3-9x fewer stems. The above is the range of results for all thinning intensities (1.4x1.4m-2.8X2.8m). The widest PCT spacings produced the greatest sawlog volume, stand diameter, and piece size gains.

However, these advantages must be weighed against the potential for reductions in quality and strength. There is concern that products manufactured from pre-commercially thinned material have diminished quality and mechanical properties (Barbour *et al.*1992, Shepard and Shottafer 1990, Zhang *et al.*1998, Zhang *et al.* 2006).

The benefits of pre-commercial thinning are numerous. Tending and harvest operations would be more cost effective in pre-commercially thinned stands compared to unmanaged stands as one has to handle fewer stems to produce a unit of merchantable wood. In addition, achieving higher merchantable and sawlog volumes sooner reduces rotation age and increases the profitability of tending and harvest operations. Pre-commercial thinning also has the potential to increase the proportion of preferred species across the landscape, namely spruce. In the Acadian forest this is significant as balsam fir regeneration often dominates but is less desirable.

Acknowledgements

I would like to acknowledge all present and former staff of the forest management planning section (formerly the forest research section) of the Nova Scotia Department of Natural Resources that were involved. In particular, Tim McGrath, Bob Murray, Troy Rushton, Dave Arseneau, and Rob O'Keefe. I would also like to acknowledge Bowater Mersey Paper Company Limited for providing access to their land for the purposes of trial re-measurement and also for their co-operation in preserving this trial. The Canadian Forest Service in Fredericton (formerly the Department of Fisheries and Forestry) is acknowledged for the initial establishment of this trial. Appreciation is given to Edwin Swift of the Canadian Wood Fibre Centre in Fredericton for reviewing this document.

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Appendix 1: PSP data

		Site A						Site B							
Spacing used in Report			Control	1.4m		1.8m		2.3m		Control		2.0m		2.65m		2.8m	
Plot #			8348	8349	8350	8351	8352	8353		8378	8379	8380	8381	8382	8383	8384	8385
Actual Spacing per Plot			0.7m	1.4m	1.4m	1.8m	1.8m	2.3m		0.8m	0.9m	1.9m	2.1m	2.6m	2.7m	2.8m	2.8m
Prescribed Spacing			Control	1.2m	1.2m	1.8m	1.8m	2.4m		Control	Control	1.8m	1.8m	2.4m	2.4m	2.9m	2.9m
Stump Age in 1998			43	44	44	41	42	43		46	46	49	58	44	46	47	43
DBH Age in 1998			39	40	39	37	38	38		42	40	43	50	39	42	41	38
DBH (cm)	Year Measured	Avg. Stump Age							Avg. Stump Age								
Total																	
Pre-thinning	1968	13	2.3	2.9	2.7	2.3	2.7	2.6	17	2.8	2.6	4.3	5.3	3.4	3.9	3.6	3.5
	1983	28	5.6	9.5	9.0	11.1	10.1	12.3	32	5.9	5.8	12.2	12.9	16.2	15.7	15.1	15.4
	1988	33	6.8	10.8	10.5	13.2	11.9	14.3	37	7.0	7.2	13.6	14.4	18.0	17.7	17.4	17.6
	1993	38	8.1	12.3	11.7	14.6	13.0	15.8	42	8.4	8.5	15.0	15.9	19.7	19.6	19.3	19.3
	1998	43	9.2	13.3	12.9	15.6	13.9	16.9	47	9.4	9.6	16.2	16.8	21.4	21.1	20.7	21.1
Merchantable																	
	1983	28	10.7	12.0	11.7	12.7	11.8	13.0	32	10.9	10.7	13.3	13.9	16.7	15.8	16.0	15.7
	1988	33	11.6	12.7	12.7	14.3	12.8	14.6	37	11.5	11.4	14.6	15.4	18.5	17.9	18.1	18.0
	1993	38	11.9	13.6	13.6	15.5	13.6	16.1	42	12.3	12.2	15.7	16.8	19.9	19.6	20.1	19.7
	1998	43	12.4	14.4	14.1	16.5	14.5	17.1	47	12.9	12.7	16.7	17.6	21.6	21.1	21.4	21.3
Sawlog																	
	1983	28		16.7	15.4	15.2	15.0	16.3	32	14.4		16.5	16.8	18.6	17.5	17.4	17.4
	1988	33	14.7	16.5	15.9	16.2	15.7	16.9	37	15.1	15.4	17.0	17.7	19.3	18.9	19.0	18.7
	1993	38	15.8	16.3	16.2	17.1	16.3	17.7	42	15.0	15.3	18.1	18.2	20.8	20.2	20.6	20.2
	1998	43	15.5	17.1	16.7	18.0	16.8	18.4	47	16.0	15.2	18.7	18.8	22.2	21.8	21.8	21.8
Height (m)	Year Measured	Avg. Stump Age							Avg. Stump Age								
Total																	
	1983	28	7.3	7.8	7.6	7.9	7.4	8.0	32	7.0	6.5	8.2	9.6	8.7	8.5	8.5	8.6
	1988	33	8.7	9.5	8.9	9.5	8.8	9.4	37	8.7	8.1	9.9	11.1	10.4	10.2	9.9	10.7
	1993	38	9.5	10.3	10.2	10.7	10.0	10.5	42	9.3	8.6	10.9	11.8	11.7	11.4	11.4	11.7
	1998	43	11.3	12.1	11.7	12.0	11.4	12.0	47	10.4	9.7	12.3	13.5	13.1	13.1	12.7	13.0
Merchantable																	
	1983	28	8.7	8.3	8.1	8.1	7.8	8.1	32	8.3	8.0	8.5	9.8	8.8	8.5	8.6	8.7
	1988	33	10.1	9.8	9.3	9.6	9.0	9.4	37	9.9	9.5	10.1	11.2	10.5	10.2	10.0	10.8
	1993	38	10.5	10.6	10.6	10.8	10.2	10.6	42	10.4	9.8	11.0	11.9	11.7	11.4	11.5	11.7
	1998	43	12.1	12.3	11.9	12.1	11.5	12.0	47	11.3	10.8	12.4	13.6	13.1	13.1	12.7	13.0
Sawlog																	
	1983	28		9.2	9.2	8.1	8.9	8.9	32	10.2		9.5	10.5	9.1	8.8	8.8	9.2
	1988	33	11.2	10.6	10.1	9.9	10.0	9.8	37	12.4	10.1	10.8	11.8	10.5	10.5	10.2	10.9
	1993	38	11.8	11.2	11.3	11.1	11.2	10.8	42	11.2	10.6	11.6	12.2	11.8	11.4	11.6	11.8
	1998	43	12.8	13.0	12.3	12.2	11.9	12.1	47	12.4	11.5	13.0	13.8	13.1	13.2	12.8	13.1

		Site A						Site B							
Spacing used in Report		Control	1.4m		1.8m		2.3m		Control		2.0m		2.65m		2.8m	
Plot #		8348	8349	8350	8351	8352	8353		8378	8379	8380	8381	8382	8383	8384	8385
Actual Spacing per Plot		0.7m	1.4m	1.4m	1.8m	1.8m	2.3m		0.8m	0.9m	1.9m	2.1m	2.6m	2.7m	2.8m	2.8m
Prescribed Spacing		Control	1.2m	1.2m	1.8m	1.8m	2.4m		Control	Control	1.8m	1.8m	2.4m	2.4m	2.9m	2.9m
Stump Age in 1998		43	44	44	41	42	43		46	46	49	58	44	46	47	43
DBH Age in 1998		39	40	39	37	38	38		42	40	43	50	39	42	41	38
Basal Area (m2/ha)	Year Measured	Avg. Stump Age						Avg. Stump Age								
Total																
	1983	28	51.7	34.8	31.3	28.9	24.0	22.9	32	41.1	45.5	25.1	24.8	24.0	24.8	20.4	20.2
	1988	33	57.2	41.0	39.3	37.1	33.3	30.4	37	46.2	55.0	31.4	30.5	29.0	29.9	25.2	25.9
	1993	38	55.8	46.4	44.1	44.0	38.8	36.9	42	47.8	60.3	38.0	35.8	35.4	35.2	31.0	31.2
	1998	43	55.0	49.2	47.9	49.6	43.9	42.3	47	51.9	61.3	42.1	40.1	39.9	39.0	35.9	35.3
Merch.																	
	1983	28	17.9	26.4	22.8	25.7	18.1	21.4	32	20.4	20.3	22.8	23.9	23.8	24.7	20.0	20.0
	1988	33	26.2	35.4	33.1	35.0	30.4	30.0	37	27.6	30.4	29.6	29.6	28.7	29.8	24.8	25.7
	1993	38	34.0	42.3	39.3	42.2	37.1	36.4	42	31.9	37.9	36.8	35.0	35.3	35.2	30.6	31.0
	1998	43	38.4	46.0	45.3	48.2	42.6	42.0	47	38.7	44.0	41.2	39.6	39.8	39.0	35.6	35.1
Sawlog																	
	1983	28	0.0	5.9	4.2	9.0	2.6	8.3	32	1.6	0.0	10.5	13.8	18.8	19.1	17.0	15.3
	1988	33	5.0	11.1	11.3	22.8	12.9	19.3	37	1.8	1.8	19.7	20.1	27.4	27.0	23.0	23.9
	1993	38	5.8	23.3	20.5	32.5	20.1	29.7	42	8.8	5.5	27.4	29.0	34.3	33.9	29.7	30.0
	1998	43	13.0	28.4	28.8	40.2	27.4	37.4	47	14.0	14.4	34.1	35.6	39.0	37.7	35.2	34.1
Volume (m3/ha)	Year Measured	Avg. Stump Age						Avg. Stump Age								
Total																	
	1983	28	194.7	139.7	124.0	118.5	92.6	94.2	32	150.1	155.5	105.7	120.6	107.4	109.1	89.2	88.7
	1988	33	252.1	197.2	178.7	178.3	149.7	144.8	37	203.6	228.4	156.2	167.4	151.7	154.5	126.9	138.9
	1993	38	265.7	239.5	226.8	235.0	197.2	195.2	42	225.8	263.2	206.2	207.6	204.6	199.6	176.3	179.9
	1998	43	306.1	293.7	277.6	293.3	249.6	249.5	47	269.7	299.5	254.0	260.3	254.0	250.6	223.8	223.5
Merch.																	
	1983	28	55.1	87.8	73.0	86.7	57.1	73.5	32	62.4	58.1	82.7	100.0	96.2	97.3	79.0	78.6
	1988	33	99.8	142.5	127.0	146.9	114.4	123.8	37	104.4	109.9	130.0	145.1	138.3	141.7	115.6	126.6
	1993	38	137.1	188.7	175.3	202.2	161.6	172.6	42	133.5	148.5	179.1	184.2	189.4	185.4	162.8	166.3
	1998	43	180.8	240.5	227.3	257.8	211.2	224.9	47	178.5	193.6	226.1	234.8	237.2	234.6	208.6	208.7
Sawlog																	
	1983	28	0.0	22.4	15.6	27.3	9.6	30.0	32	5.6	0.0	40.6	60.2	76.8	73.7	64.4	60.1
	1988	33	18.7	50.4	46.8	90.9	50.8	80.5	37	13.5	7.0	89.8	99.2	129.2	126.1	105.4	114.6
	1993	38	25.8	103.0	91.9	151.4	89.7	137.7	42	40.7	26.7	135.4	151.6	184.8	176.8	157.9	160.0
	1998	43	60.2	151.2	141.5	210.2	132.4	194.8	47	66.8	71.1	191.5	207.4	237.2	230.7	208.6	206.6

		Site A						Site B							
Spacing used in Report		Control	1.4m		1.8m		2.3m		Control		2.0m		2.65m		2.8m	
Plot #		8348	8349	8350	8351	8352	8353		8378	8379	8380	8381	8382	8383	8384	8385
Actual Spacing per Plot		0.7m	1.4m	1.4m	1.8m	1.8m	2.3m		0.8m	0.9m	1.9m	2.1m	2.6m	2.7m	2.8m	2.8m
Prescribed Spacing		Control	1.2m	1.2m	1.8m	1.8m	2.4m		Control	Control	1.8m	1.8m	2.4m	2.4m	2.9m	2.9m
Stump Age in 1998		43	44	44	41	42	43		46	46	49	58	44	46	47	43
DBH Age in 1998		39	40	39	37	38	38		42	40	43	50	39	42	41	38
MAI (m3/ha/yr)	Year Measured	Avg. Stump Age						Avg. Stump Age								
Total																
	1983	28	7.0	5.0	4.4	4.2	3.3	3.4	32	4.7	4.9	3.3	3.8	3.4	3.4	2.8	2.8
	1988	33	7.6	6.0	5.4	5.4	4.5	4.4	37	5.5	6.2	4.2	4.5	4.1	4.2	3.4	3.8
	1993	38	7.0	6.3	6.0	6.2	5.2	5.1	42	5.4	6.3	4.9	4.9	4.9	4.8	4.2	4.3
	1998	43	7.1	6.8	6.5	6.8	5.8	5.8	47	5.7	6.4	5.4	5.5	5.4	5.3	4.8	4.8
Merch.																	
	1983	28	2.0	3.1	2.6	3.1	2.0	2.6	32	1.9	1.8	2.6	3.1	3.0	3.0	2.5	2.5
	1988	33	3.0	4.3	3.8	4.5	3.5	3.8	37	2.8	3.0	3.5	3.9	3.7	3.8	3.1	3.4
	1993	38	3.6	5.0	4.6	5.3	4.3	4.5	42	3.2	3.5	4.3	4.4	4.5	4.4	3.9	4.0
	1998	43	4.2	5.6	5.3	6.0	4.9	5.2	47	3.8	4.1	4.8	5.0	5.0	5.0	4.4	4.4
Sawlog																	
	1983	28	0.0	0.8	0.6	1.0	0.3	1.1	32	0.2	0.0	1.3	1.9	2.4	2.3	2.0	1.9
	1988	33	0.6	1.5	1.4	2.8	1.5	2.4	37	0.4	0.2	2.4	2.7	3.5	3.4	2.8	3.1
	1993	38	0.7	2.7	2.4	4.0	2.4	3.6	42	1.0	0.6	3.2	3.6	4.4	4.2	3.8	3.8
	1998	43	1.4	3.5	3.3	4.9	3.1	4.5	47	1.4	1.5	4.1	4.4	5.0	4.9	4.4	4.4
Total # of Trees/m3	Year Measured	Avg. Stump Age						Avg. Stump Age								
Total																
	1983	28	108.6	35.2	40.1	25.0	32.3	20.5	32	100.7	109.4	20.3	15.8	10.8	11.8	12.7	12.3
	1988	33	62.7	22.8	25.6	15.2	20.0	13.1	37	58.2	59.3	13.8	11.2	7.5	7.8	8.4	7.7
	1993	38	40.9	16.4	18.1	11.3	14.9	9.6	42	38.1	40.2	10.4	8.7	5.7	5.8	6.0	5.9
	1998	43	27.1	12.0	13.3	8.8	11.6	7.5	47	27.9	28.4	8.1	6.9	4.4	4.4	4.7	4.5
Merch.																	
	1983	28	383.6	56.0	68.0	34.2	52.4	26.2	32	242.4	292.7	26.0	19.0	12.1	13.2	14.4	13.8
	1988	33	158.4	31.6	36.0	18.5	26.1	15.4	37	113.6	123.2	16.5	12.9	8.2	8.5	9.2	8.4
	1993	38	79.3	20.8	23.4	13.1	18.2	10.9	42	64.4	71.2	12.0	9.8	6.1	6.3	6.5	6.4
	1998	43	45.9	14.7	16.2	10.1	13.7	8.4	47	42.1	43.9	9.1	7.7	4.7	4.7	5.1	4.9
Sawlog																	
	1983	28		219.8	317.4	108.6	310.8	64.3	32	2723		53.0	31.6	15.1	17.4	17.6	18.1
	1988	33	845.6	89.3	97.6	29.9	58.9	23.6	37	876.6	1938.7	23.9	18.9	8.8	9.6	10.1	9.3
	1993	38	421.6	38.2	44.6	17.5	32.8	13.6	42	211.2	396.3	15.9	11.9	6.3	6.6	6.7	6.6
	1998	43	138.0	23.4	26.0	12.3	21.8	9.6	47	112.4	119.6	10.7	8.7	4.7	4.8	5.1	4.9

		Site A						Site B							
Spacing used in Report		Control	1.4m		1.8m		2.3m		Control		2.0m		2.65m		2.8m	
Plot #		8348	8349	8350	8351	8352	8353		8378	8379	8380	8381	8382	8383	8384	8385
Actual Spacing per Plot		0.7m	1.4m	1.4m	1.8m	1.8m	2.3m		0.8m	0.9m	1.9m	2.1m	2.6m	2.7m	2.8m	2.8m
Prescribed Spacing		Control	1.2m	1.2m	1.8m	1.8m	2.4m		Control	Control	1.8m	1.8m	2.4m	2.4m	2.9m	2.9m
Stump Age in 1998		43	44	44	41	42	43		46	46	49	58	44	46	47	43
DBH Age in 1998		39	40	39	37	38	38		42	40	43	50	39	42	41	38
Density (stems/ha)	Year Measured	Avg. Stump Age						Avg. Stump Age								
Total																
Pre-thinning	1968	13	20,633	25,699	23,994	28,046	27,725	21,276	17	15,889	12,059	13,443	15,321	18,483	7,314	18,731	12,232
Post-thinning	1968	13	20,633	5,214	5,263	3,138	3,212	1,952	17	15,889	12,059	2,817	2,273	1,483	1,359	1,236	1,260
	1983	28	21,151	4,917	4,967	2,965	2,990	1,927	32	15,122	17,000	2,150	1,903	1,161	1,285	1,137	1,087
	1988	33	15,814	4,497	4,571	2,718	2,990	1,903	37	11,861	13,541	2,150	1,878	1,137	1,211	1,063	1,063
	1993	38	10,872	3,929	4,102	2,644	2,940	1,878	42	8,599	10,576	2,150	1,804	1,161	1,161	1,063	1,063
	1998	43	8,302	3,533	3,682	2,594	2,891	1,878	47	7,512	8,500	2,051	1,804	1,112	1,112	1,063	1,013
Merch.																	
	1983	28	1,977	2,323	2,125	2,026	1,656	1,606	32	2,174	2,273	1,631	1,581	1,087	1,260	988	1,038
	1988	33	2,471	2,792	2,619	2,174	2,372	1,804	37	2,669	2,965	1,779	1,581	1,063	1,186	964	1,013
	1993	38	3,064	2,891	2,718	2,224	2,545	1,779	42	2,669	3,262	1,903	1,581	1,137	1,161	964	1,013
	1998	43	3,163	2,817	2,891	2,249	2,594	1,829	47	2,965	3,459	1,878	1,631	1,087	1,112	519	988
Sawlog																	
	1983	28	0	272	222	494	148	395	32	99	0	494	618	692	791	717	642
	1988	33	297	519	568	1,112	667	865	37	99	99	865	815	939	964	815	865
	1993	38	297	1,112	988	1,408	964	1,211	42	494	297	1,063	1,112	1,013	1,063	890	939
	1998	43	692	1,235	1,310	1,581	1,235	1,408	47	692	791	1,235	1,285	1,013	1,013	939	914

% Species Composition

Pre-thinning (1968)															
Spruce sp.	86	60	57	63	53	65		77	78	47	48	83	86	87	94
Balsam fir	8	39	38	30	44	26		23	20	53	52	16	13	10	4
Red maple	6	1	4	7	3	9		0	2	0	0	1	1	2	2
Post-thinning (1968)															
Spruce sp.	86	88	87	99	92	94		77	78	85	74	95	100	98	98
Balsam fir	8	12	13	1	8	5		23	20	15	26	5	0	2	2
Red maple	6	0	0	0	0	1		0	2	0	0	0	0	0	0
1998															
Spruce sp.	74	90	91	91	99	90		86	84	87	76	95	100	100	95
Balsam fir	22	10	9	9	1	9		14	16	13	24	5	0	0	5
Red maple	3	0	0	0	0	0		0	0	0	0	0	0	0	0