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Strip Cutting in Shallow-soil Upland Black Spruce near Nipigon, Ontario V. Regeneration in 12 to 18 year-old Stripcuts

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The views, conclusions, and recommendations contained herein are those of the authors and should be construed neither as policy nor endorsement by Natural Resources Canada or the Ontario Ministry of Natural Resources.

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NODA REPORT:

**STRIP CUTTING IN SHALLOW-SOIL UPLAND BLACK SPRUCE
NEAR NIPIGON, ONTARIO**

V. REGENERATION IN 12 TO 18 YEAR-OLD STRIPCUTS

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ABSTRACT

Regeneration performance of black spruce (Picea mariana [Mill.] B.S.P.) in 12 to 18 year old stripcuts located near Nipigon, in the Central Plateau Section of northern Ontario is documented. Other tree species were included to follow changes in forest composition. Regeneration in both the first-cut and second-cut strips was examined. The first-cut strips contained 62.1% and second-cut strips 37.9% of the total number of stems of all species. The average densities for black spruce were 8371 and 5111 stems/ha in the first- and second-cut strips, respectively. Overall, 88% of the strips achieved acceptable (40 to 59%) or desirable (> 60%) levels of stocking in 2-m x 2-m quadrats for black spruce. Stand composition at the time of harvesting (1975 -1977) was mainly of black spruce with a conifer to hardwood ratio of 82:18. The current ratio of conifers to hardwoods was 74:26 overall, after 12 to 18 years. Additionally, the overall density of conifer seedlings and saplings was 4.3 stems/quadrat in the first-cut strips and 2.8 stems/quadrat in the second-cut strips (3.6 stems/quadrat overall). Receptive seedbed, strip width, leave period and site type, individually, all had significant effects on the density of black spruce. A regression equation for stocking and density is presented based upon percentage receptive seedbed, strip width and seeding period.

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INTRODUCTION

Frequent failures in natural regeneration of black spruce (Picea mariana [Mill.] B.S.P.*) have been explained by: (1) an inadequate supply of seed, (2) unfavourable seedbed conditions, and (3) exposure of the ground surface to excessive heating and drying (cf. Roe et al. 1970; Fraser et al, 1976). At this time it is apparent that, in Ontario, it is not possible to artificially regenerate all the area that is being harvested (Jeglum 1987). Therefore, regeneration studies are being conducted near Nipigon, located north of Lake Superior in Ontario, to determine the feasibility of the alternate stripcut method of harvesting, to facilitate natural regeneration in shallow-soil upland black spruce.

In 1973, an assessment to compare regeneration in clearcuts with stripcuts was made in the Central Plateau and Northern Clay Sections of Ontario (Fraser et al. 1976). This survey revealed that strip clearcutting yielded better regeneration of black spruce, but it was not clear what factors were important to regeneration. Consequently, a long-term study was initiated near Nipigon, Ontario, to study the biological and economic feasibility of alternate-strip clearcutting to regenerate black spruce on shallow-soil upland sites (Jeglum 1980). The method entailed cutting alternate strips (first-cut strips), leaving the forested, intermediate strips (second-cut strips) as a seed source to reseed the cut-over areas and to maximize natural regeneration. The intermediate strips were cut two to four years after the first-cut strips. Regeneration in the second-cut strips was based on any survival of advance growth, or

* The scientific names for species cited in the text have been compiled in Appendix 2. Where no common name exists the scientific name has been used in its place.

seeding in from standing uncut forests located in the vicinity and, in one of three areas, groups of seed trees left as seed sources.

The biological studies centred around a large strip cutting experiment, which was designed to study the influence of three strip widths (20 m, 40 m, and 80 m), and two leave times (2 and 4 years) on natural regeneration in the first-cut strips. Assessment of the first of three study areas indicated that regeneration was desirable or acceptable in all strip widths, but that 4 years of leave time was preferable to 2 years (Jeglum 1982).

Further work on the biology of strip clearcutting, in comparison to clearcutting, indicated that higher proportions of black spruce relative to broadleaf species are maintained (Jeglum 1983), and that it is essential to site prepare to provide a receptive seedbed for the successful regeneration of black spruce (Jeglum 1984). Another study considered the losses of timber to windfall and mortality (Fleming and Crossfield 1983). A workshop held in 1986 represented a 10-year review of this project, including studies of regeneration, economics, environmental impacts, and planning and implementation (Nicolson 1987, Robinson 1987).

One of the most important considerations for the use of strip clearcutting is costs. Several reports have been published on the additional harvesting costs associated with strip clearcutting by Ketcheson (1977, 1979, 1982; Ketcheson and Smyth 1978). Subsequent to this work, it was realized that one should combine the costs of harvesting with the costs of regeneration to derive the net costs of the whole system. Work was done by Johnson and Smyth (1987, 1988) and Johnson et al. (in press) making cost comparisons of several systems. If one compares clearcutting and planting with strip clearcutting and regeneration of the second cut strip with any other method, one can achieve savings of up to \$700/ha with strip

clearcutting. However, whenever a clearcut is regenerated by seeding it is always cheaper than any strip clearcutting option.

This project, and other research and operational trials over several decades in Ontario, have yielded many reports and papers on the subject of modified harvesting and natural regeneration (e.g. Fleming and Groot 1984; Haavisto et al. 1988; Jeglum and Leblanc 1988; Jeglum et al. 1983; Jeglum 1990a, b). Recently, a comprehensive guide to strip clearcutting in black spruce has been published (Jeglum and Kennington 1993).

The present study, reports a reassessment of the regeneration 12 to 18 years after harvesting (completed in 1992). Black spruce was the main target species in this study, but regeneration data were collected on all tree species. Regeneration was examined in both the first-cut and second-cut strips. The objectives of this study were to: 1) determine stocking and density for all species in both first-cut and second-cut strips, 2) to assess the relative success of the regeneration for black spruce and all species combined, and 3) to determine the importance of the main factors included in the trial -- strip width, leave (seeding) period and receptive seedbed.

METHODS

Study Areas

A strip cut experiment was established and replicated in each of three successive years (Jeglum 1980) located 20 - 40 km south-east of Beardmore and east of Lake Nipigon, in the Central Plateau Section of the Boreal Forest Region (Rowe 1972; Figure 1). The location of

the three study areas is shown in Figure 1. The layout of Areas 1, 2 and 3 are presented in Figures 2, 3 and 4, respectively. Area 1 is located approximately 26 km south of Jellicoe on the Leopard Lake/Thimble Creek Road. Area 2 is located approximately 30 km east of Highway 11 on the translimits road near Peck Lake. Area 3 is located approximately 10 km east of Highway 11 (access road 5 km south of Beardmore) near Phoney Lake on the Domtar Camp 93 access road.

Each of the study areas contained 56 strips of 3 different widths; 20-meters, 40-meters and 80-meters. In each area there were 16 strips of each width. An additional eight 40-meter strips were included to act as controls; they were not scarified. Initially, each strip had 25, 2-m x 2-m quadrats, systematically placed, for a total of 1400 quadrats in each of the three areas. An additional 50 quadrats were added to each of the first-cut control strips to provide a larger control sample. More details are provided in Jeglum (1980) and contractors reports.

The location of the strips was determined according to varying criteria including: dominance to black spruce, local topography, drainage, grade, etc. (Jeglum 1980). The original intent was to conduct the experiment on sites with very shallow-soil over bedrock. However, this type of site was not scheduled for harvesting, so sites that were not the most extreme shallow soils were accepted. Areas 1 and 3 had about 10% of their original forest classified as mixedwood or hardwood, and jack pine was present in small amounts in mixture with the black spruce. Area 2 had no jack pine (*Pinus banksiana* Lamb.) present, but there were scattered individuals or clumps of trembling aspen (*Populus tremuloides* [Michx.]) and white birch (*Betula papyrifera* [Marsh.]) present.

The first-cut strips were mechanically site prepared to create seedbed conditions

favourable to seedling regeneration. Two of the strips were treated by prescribed burning. The areas were initially assessed one year prior to cutting. After cutting, assessments were performed at one, three and five years.

Site Conditions

In the original design of the study, each quadrat had been assigned a topographic site

Table 1. The number (N) and proportion (%) of site types in the first-cut, and all strips, in Areas 1, 2 and 3.

Site Type*		First-cut Strips			All Strips		
		Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
1	N	124	95	27	145	210	72
	%	15.1	10.9	3.0	10.3	11.6	5.1
2	N	323	419	224	552	756	269
	%	39.3	48.3	24.8	39.4	42.0	19.2
3	N	271	324	493	586	692	795
	%	33.0	37.3	54.7	41.8	38.4	56.8
4	N	102	31	156	117	130	264
	%	12.4	4.0	17.3	8.4	7.2	18.8
1+2	N	447	514	251	697	966	341
	%	54.5	59.2	27.8	49.8	53.6	24.4
3+4	N	373	355	639	703	822	1059
	%	45.5	40.8	71.0	50.2	45.6	75.6
Totals	N	820	868	900	1400	1800	1400
	%	100	100	100	100	100	100

type: 1 - drainageway, 2 - lower slope, 3 - upper slope and 4 - crest. Table 1 shows the number and proportion of site types in the first-cut and all strips in Areas 1, 2 and 3. In Areas 1, 2 and 3 the proportion of areas occupied by lowland drainageways or lower slopes in the first-cut strips was 54.5, 59.2, and 27.8% and in all strips was 49.8, 53.6 and 24.4% respectively. The proportion of bedrock hits in a depth survey (maximum depth was 75 cm) was 40, 14 and 29% in Areas 1, 2 and 3 respectively (Jeglum 1980).

Data Collection

A partial regeneration survey of Area 1 (first-cut strips) was conducted in 1989. In 1992 the remainder of the quadrats in Area 1, and Areas 2 and 3 were surveyed. A computer program, 'REGEN', was written using Borland's Turbo Pascal 5.0, and transferred to the DAP Microflex PC1000, a hand held computerized data collector, to facilitate data collection¹.

An example is given below of the sequence of 14 attributes collected in the field. In each 2-m X 2-m quadrat the presence and numbers of seedlings of each tree species were recorded according to their height or diameter class. Each species present in a quadrat was recorded in a full line of attributes; for example, quadrat 10 had information gathered for three species. After data was collected for five quadrats, it was saved and named. During the evening these files were combined into files for complete strips representing 25 quadrats e.g.

¹Tenhagen, M. D. 1992. Strip-cutting in shallow-soil upland black spruce near Nipigon, Ontario. V. Collection of regeneration, vegetation and seedbed data in 16 to 18 year-old strip-cuts. Contractor's Rep., Sault Ste. Marie, Ont. Rep. 4Y050-2-0459/01-XE.

R(strip number).dat. In this way data could be inspected for errors and return trips were made, if necessary, for reassessments².

Example 1. Example of attributes collected using the hand-held computer and REGEN program

```

      *
      8 1 0 0 0 6 3 1 0 0 0 0 0 3
      9 3 0 0 1 2 0 0 0 0 0 0 0 0
     10 1 1 0 0 1 0 0 0 0 0 0 0 1
     10 7 0 0 4 3 2 0 0 0 0 0 0 0
     10 8 0 0 0 4 5 0 0 0 0 0 0 0
     11 0 0 0 0 0 0 0 0 0 0 0 0 0
     12 1 0 1 0 0 2 0 0 0 0 0 0 3

```

* the first number identifies the quadrat,
the second identifies the species code, and so on to
the last number, which is a free-to-grow rating (see below).

Data were collected for the following categories:

Attribute	Column Numbers	
1	1-3	Quadrat no.
2	4-6	Species code
3	7-8	Height Class 1(H1) Presence/Absence - 1 or 0 to indicate the presence, or absence, of seedlings under 10 cm in the 2 m x 2 m quadrat
4	9-11	Height Class 1(H1) - total number of seedlings (0 - 9.9 cm tall) in the 50 cm x 2 m quadrat
5	12-14	Height Class 2 (H2) - (seedlings 10 - 49 cm tall) total number of seedlings in the 2 m x 2 m quadrat

²Tenhagen, M. D. 1992. Strip-cutting in shallow-soil upland black spruce near Nipigon, Ontario. V. Collection of regeneration, vegetation and seedbed data in 16 to 18 year-old strip-cuts. Contractor's Rep., Sault Ste. Marie, Ont. Rep. 4Y050-2-0459/01-XE.

6	15-17	Height Class 3 (H3) - (seedlings 50 - 199 cm tall) total number of seedlings in the 2 m x 2 m quadrat
7	18-20	Height Class 4 (H4) - (seedlings 2 m - 2.4 cm diameter at breast height (dbh) total number of seedlings in the 2 m x 2 m quadrat)
8	21-22	Diameter Class 1 (D1) - (2.5 - 4.9 cm dbh) total number of seedlings in the 2 m x 2 m quadrat
9	23-24	Diameter Class 2 (D2) - (5 - 9.9 cm dbh) total number of seedlings in the 2 m x 2 m quadrat
10	25-26	Diameter Class 3 (D3) - (10 -14.9 cm dbh) total number of seedlings in the 2 m x 2 m quadrat
11	27-28	Diameter Class 4 (D4) - (15 - 19.9 cm dbh) total number of seedlings in the 2 m x 2 m quadrat
12	29-32	Diameter at Breast Height (DBH1) -dbh, in centimetres of the tree, greater than or equal to 20 cm dbh
13	33-36	Diameter at Breast Height (DBH2) - dbh, in centimetres of the tree, greater than or equal to 20 cm dbh
14	37-40	Free-to-grow rating 0 - for species other than Sb, no condition given,or the following ratings for the tallest Sb present 1 - overtopped by other tree or vegetation, will not mature into a marketable tree 2 - some degree of shading but may mature into a marketable tree 3 - little or no shading, strong probability will mature into a dominant individual, marketable tree

These files were concatenated to form REGAREA1.DAT, REGAREA2.DAT, and

REGAREA3.DAT. Copies of these files were created for safekeeping³.

In the experimental design the first-cut strips were even-numbered, the second-cut were odd-numbered. Observations from 1989 and 1992 were combined and the files were edited to eliminate the quadrats in strips that had not been cut. Reasons for not cutting included 1) terrain limitations to skidder access, 2) inaccurate cutting of strips to the marked line between strips, 3) operational constraints (deep snow, lack of time at end of operation, etc.), and 4)

³Tenhagen, M. D. 1992. Strip-cutting in shallow-soil upland black spruce near Nipigon, Ontario. V. Collection of regeneration, vegetation and seedbed data in 16 to 18 year-old strip-cuts. Contractor's Rep., Sault Ste. Marie, Ont. Rep. 4Y050-2-0459/01-XE.

Table 2. Quadrats classified as uncut and the number of remaining quadrats.

Area		Strip Number	Uncut Quadrat Number(s)	Total No. of Cut Quadrats	
				Odd	Even
Even	1	26	11 - 25		
	1	28	1 - 2 + 6 - 25		
	1	36	16 - 20 + 25		
	1	54	20 - 21		
	1	56	4 - 6		652
Odd	1	25	21 - 25		
	1	27	6 - 25		
	1	31	21 - 25		
	1	39	11 - 25		
	1	55	22 - 25	651	
Even	2	62	21 - 25		
	2	98	24		894
Odd	2	57	1 - 25		
	2	59	1 - 25		
	2	61	1 - 25		
	2	63	1 - 25		
	2	65	1 - 25		
	2	77	1 - 25		
	2	79	1 - 25		
	2	97	21 - 25		
	2	99	21 - 25		
	2	105	1 - 25		
	2	107	1 - 25		
	2	109	1 - 25		
	2	111	1 - 25	615	
Even	3	--	--	0	900
	3	159	1 - 25		675
Totals				1941	2446 4387

chance location of quadrats in uncut seed tree groups (Area 1). The uncut quadrats in even and odd numbered strips and the remaining sample quadrats, are listed in Table 4.

Only data for Height Class 1 (H1) through Diameter Class 2 (D2) were used. In this way, trees with diameters greater than 10 centimetres were not included in the analysis as these might have been present at the time of harvesting and left uncut for unknown reasons. The number of seedlings counted in H1 (ie. seedlings less than 10 cm tall occurring in the 2-m x 0.5-m quadrats) were multiplied by four in order to equate their numbers to the other size classes which were counted in 2-m x 2-m quadrats.

Programs written in Borland's Turbo Pascal, Version 6.0 manipulated the ASCII data files and performed the analysis. The results were then imported into Quattro Pro. Due to the difference in file formats between the data files from data collection performed in 1989 and 1992, two versions of every program were required.

RESULTS

Regeneration for Black Spruce

Regeneration by Areas

Tables 3 to 5, and Figure 5, present summaries of the number of stems of black spruce. The greatest number of stems occurred in height classes 2 and 3. Area 2 produced the most stems in both first and second-cut strips, followed by Area 3 and then Area 1. The total number of stems in the first-cut strips in Area 1 was approximately 1/2 the number of stems in the first-cut strips in both Areas 2 and Area 3. The total number of stems in the first-cut strips in Area 1, from data collected in 1989, was approximately the same as the total number

of stems in the second-cut strips in Area 1 from the data collected in 1992 whereas in Areas 2 and 3 first-cut strips produced nearly double that in the second-cut strips. Also, the numbers of seedlings in the fifth year assessment were over three times as great as those in the 1989 assessment of the first-cut strips. For these reasons we cannot accept the density values from the 1989 assessment as being accurate.

For the second-cut strips, Area 2 produced the greatest total number of stems for black spruce for all three areas (Tables 3-6, Fig. 5). This might be explained by the predominance of lower slope and drainageway topographic site types in Area 2 providing generally moister seedbed conditions. In addition, the presence of numerous uncut, second-cut leave strips may have provided a seed source for those strips that were cut.

Table 4 shows the number of stems produced, per height class, and their proportions, in the first- and second-cut strips. In both the first- and second-cut strips approximately 50% of the total number of stems were in height class 3. The next highest densities were in height class 2. The proportion of each height class is similar in both first- and second-cut strips.

Table 3. The number of stems of black spruce per hectare (#) and density per 2-m x 2-m quadrat (D) for each height and diameter class for first- and second-cut strips. All data were collected in 1992 except for the first-cut strips in Area 1, which were collected in 1989.

	H1	H2	H3	H4	D1	D2	Total
Area 1							
First-cut							
#	30.6	755.4	2864.3	605.8	268.4	53.7	4578
D	0.01	0.3	1.15	0.24	0.1	0.02	1.8
Second-cut							
#	245.7	1063.7	2288.8	514.5	222.7	103.7	4439
D	0.1	0.4	0.9	0.2	0.09	0.04	1.8
Area 2							
First-cut							
#	64	3716.4	4952.5	1057	321.6	78.3	10,730
D	0.2	1.5	2.0	0.4	0.1	0.03	4.3
Second-cut							
#	292.7	2256.1	3016	516.3	158.5	30.7	6272
D	0.12	0.9	1.2	0.2	0.06	0.01	2.5
Area 3							
First-cut							
#	177.8	2661.1	5241.7	1166.7	475.0	83.3	9806
D	0.07	1.06	2.09	0.47	0.19	0.03	3.9
Second-cut							
#	74.0	1359.3	2551.9	351.9	225.9	59.3	4622
D	0.03	0.54	1.02	0.14	0.09	0.02	1.8

Note: All assessed quadrats were used.

The number of stems in the first-cut strips represent 62.1%, and the stems in the

second-cut strips are 37.9% of the total. These totals were converted to 'number of stems per hectare'

Table 4. The average number of stems, of black spruce, per hectare (N = the number of 2-m x 2-m quadrats) for all areas.

	H1	H2	H3	H4	D1	D2	Total	%	N
First-cut Strips	90.8	2377.6	4352.8	943.2	355	71.8	8712		
Frequency (%)	3.2	26.7	45.4	17.9	5.2	1.4	100	52	2456
Second-cut Strips	204.1	1559.2	2617.7	460.9	202.4	64.6	5128		
Frequency (%)	4.1	30.4	51.3	8.9	4.0	1.3	100	48	1941
Total	277.6	2178.7	3693.4	1131.4	370.1	106.9	7758.2		
Frequency (%)	3.7	28.6	48.4	13.4	4.6	1.4	100	100	4397

* Area 1 data collected in 1989

(mean number of stems per 2-m x 2-m quadrat x 2500). Densities ranged from 4,439 per hectare in the second-cut strips of Area 1, to 10,730 in the first-cut strips of Area 2 (Table 5, Fig. 5).

Figure 5 presents a visual summary of the number of stems of black spruce per hectare, and the percent stocking within the quadrats in the first and second-cut strips, in all areas. Note that regeneration was not assessed in the first-cut strips in Area 1 in 1992. For black spruce, stocking in the first-cut strips was 60% in Area 1 (1989 data), 68% in Area 2 and 65% in Area 3. In the second-cut strips, stocking in Area 1 was 54% (1992 data) in Area 2 was 53% and 48% in Area 3.

Stocking Levels

For the purpose of this study we define stocking as the percentage occurrence of 1 species, or a group of species, in a number of 2-m x 2-m quadrats. The level of stocking of black spruce, divided into failure (0-39.9%), acceptable (40-59.9%) and desirable (60-100%) levels is summarized in Table 6 and shown in Figure 7. For all strips, 54.5% achieved a desirable (> 60%) level of stocking for black spruce, 33.3% achieved an acceptable (40 - 59.9%) level, and 12.2% were failures (< 40%). The first-cut strips had higher proportions of strips with acceptable or desirable levels than the second-cut strips, 96% versus 78%, respectively.

Table 5. The number of black spruce stems per hectare for first and second-cut strips and overall the strips. N = number of quadrats.

	First-Cut Strips		Second-Cut Strips	
Area 1	*4,578	N = 662	4,439	N = 651
Area 2	10,730	N = 894	6,272	N = 615
Area 3	9,806	N = 900	4,622	N = 675
All Areas	8,371	N= 2456	5,111	N = 1941

* From data collected in 1989

The numbers of strips achieving different levels of stocking by 10% classes is summarized in Figure 6. Sixty (71.4%) of the 84 first-cut strips achieved 60% or better regeneration while twenty-five (34.7%) of the 72 second-cut strips achieved 60% or better. Eighty-one (96.4%) of the first-cut strips achieved 40%, or better, regeneration while 56 (77.8%) of the second-cut strips achieved 40% or better. First-cut strips had a 3.6 %

failure rate (less than 40% frequency) whereas the second-cut strips had a 22.2 % failure rate. Twenty of the first-cut strips achieved 80%, or better, regeneration. Five of the second-cut strips achieved 80%, or better, regeneration.

Table 6. Levels of stocking for black spruce in first- and second-cut strips. N = number of strips.

Percent Stocking	First-cut Strips		Second-cut Strips		All Strips	
	#	%	#	%	#	%
0 - 39.9 %	3	3.6	16	22.2	19.1	12.2
40 - 59.9 %	21	25.0	31	43.1	52	33.3
60 - 100 %	60	71.4	25	34.7	85	54.5
N	84		72		156	

Free-to-grow Rating

A free-to-grow rating (Table 7) was developed to evaluate the potential for the tallest black spruce stem within the quadrat to reach maturity as a marketable tree. Values of 1 - 3 were assigned. This rating was not included in data collected in 1989. The rating is a subjective estimate of the relative exposure of the tallest black spruce to sunshine and freedom from shading by competing shrubs or other tree species. The rating also includes aspects of vitality and growth. Ordinarily, the most prolific non-tree species found overshadowing the black spruce were speckled alder (Alnus rugosa [Du Roi] Spreng) in the lower sites, and green alder (Alnus crispa [Ait.] Pursh.) in the higher sites .

Of the quadrats that had a presence of black spruce, Area 3 had higher proportions of quadrats with either 3, or 3 + 2 (Table 7). This was true for both first-cut and second-cut

strips. This suggested that Area 3 had less competition than Area 2, relative to black spruce. The second-cut strips in Area 1 had percentages similar to those of Area 3, suggesting that Areas 1 and 3 had similar levels of competition, less than those of Area 2.

Table 7. Percentage of quadrats with competition classes 3, and 3 + 2, for black spruce. These represent the more or less "free growing" black spruce.

	% of all quadrats			% of quadrats with Sb	
	First-cut	Second-cut		First-cut	Second-cut
Condition			Area 1		
3	*	47.7		*	81.2
3 + 2	*	52.2		*	98.27
			Area 2		
3	50.8	34.96		60.74	66.77
3 + 2	67.1	50.08		80.0	95.65
			Area 3		
3	58	38.4		88.8	79.3
3 + 2	64.5	47.06		98.6	97.24

* No free-to-grow ratings were collected in 1989.

Free-to-grow ratings:

- 1 - overtopped by other tree or vegetation
will not mature to into a marketable tree
- 2 - some degree of shading but may mature
into a marketable tree
- 3 - little or no shading, strong probability
will mature into a dominant individual,
marketable tree

Regeneration for Five Species

Calculations of the number of stems for all species per strip, was accomplished using

Quattro Pro for Windows worksheets using the method described in the previous section.

Table 8 summarizes the number of stems of the five species in the first and second-cut strips in all areas. This is portrayed as well in Figure 8.

Area 2 achieved the greatest number of stems of black spruce overall and in both the first- and second-cut strips; probably due to the predominance of lower topographic site types

Table 8. The number of stems per hectare of five species for first- and second-cut strips in all areas.

Species	Area 1		Area 2		Area 3	
	*First-Cut	Second-cut	First-cut	Second-cut	First-cut	Second-cut
Sb	4578	4439	10730	6272	9806	4622
Pj	836	380	0.0	12	717	367
Fb	1200	3172	1230	785	878	915
Pot	844	1071	1368	1972	617	530
Bw	1392	2078	3065	1423	2667	1367
Total	8850	11141	16393	10464	14683	7800

* 1989 data

and the absence of overshadowing jack pine. Area 2 also produced the highest number of hardwoods, trembling aspen (Populus tremuloides [Michx.]) and white birch (Betula papyrifera [Marsh.]) combined.

Figure 10 presents a summary of numbers of strips achieving failure, acceptable and

desirable stocking levels. For black spruce alone, about 55% of the strips achieved desirable levels, whereas for all species, about 90% of the strips achieved desirable. Correspondingly, for black spruce only, more of the strips were rated as acceptable or failures. Thus, if one is willing to count all species in the stocking of a stand, all of our strips were acceptably regenerated and presumably the stands will become fully stocked stands. However, if one is only willing to accept black spruce as a tree crop species, then there were 10% of the strips which were failures.

Figure 9 shows the number of strips that achieved stocking frequency classes of 10% in the first-cut and second-cut strips and for all the strips. No strips were failures, achieving less than a 40% rate of stocking. Sixty-three out of 84 first-cut strips had 80% or better stocking while thirty-five out of 72 of the second-cut strips had 80% or better stocking.

Stand Composition

Table 9 and Figure 11 show the relative percentage values, based on density, of the five species in the first- and second-cut strips in all areas. First-cut strips (even-numbered) consistently had higher proportions of black spruce. The highest relative percentage of black spruce, 66.8%, was in the first-cut strips in Area 3. Black spruce always had the highest relative density for all treatment combinations; the relative densities ranged from 39.8 to 66.8%. The second most important species varied depending on the treatment and area, and was mostly white birch, followed by balsam fir and trembling aspen. The levels of white birch remained quite stable for all strips, whereas the levels of trembling aspen were

consistently higher in the second-cut strips.

At the time of harvesting the forest was composed mainly of black spruce with smaller components of jack pine, balsam fir, trembling aspen and white birch with a proportion, in density, of conifer to hardwood, of about 82:18 (Jeglum 1982). After five years, in the first-cut strips, this ratio was about 40:60 (ibid.). The data for the present study

Table 9. The relative percentage values for all species based on numbers per hectare.

Species	Area 1		Area 2		Area 3	
	* First-cut	Second-cut	First-cut	Second-cut	First-cut	Second-cut
Sb	51.7	39.8	65.5	59.9	66.8	59.3
Pj	9.4	3.4	0.0	0	4.9	4.7
Fb	13.6	28.4	7.5	7.4	6.0	11.7
Pot	9.5	9.6	8.3	18.8	4.2	6.8
Bw	15.7	18.6	18.6	13.6	18.2	17.5

* 1989 data

16 - 18 years for the first-cut strips and 12 - 16 years for the second-cut strips, the proportion of conifers to hardwoods, was about 74:26 overall (Table 10). The proportion of black spruce to all the other species in both the first and second-cut strips was about 58:42. In only one case (Area 1, second-cut strips), was black spruce less than all other species, 40:60. This was owing to the presence of high numbers of balsam fir.

The cumulative stocking of species, was calculated by including, sequentially, the presence one to five species as being acceptable for the quadrat to be considered stocked

(Table 11, Figure 12). The rules were set by conditional statements. For example, for all five species to be acceptable, the statement was 'if Sb or if Pj or if Fb or if Pot or if Bw is present within a quadrat, then presence is true'. The overall frequency for black spruce was 57.7% while the overall frequency for all species was 78.7%. By allowing jack pine and balsam fir to count, the stocking increased by 11 percentage points, and if trembling aspen

Table 10. The ratios of numbers of black spruce to all other species and conifers to hardwoods in first- and second-cut strips in all areas based on density values.

Species	Area 1		Area 2		Area 3		Overall
	* First-cut	Second-cut	First-cut	Second-cut	First-cut	Second-cut	
Pj, Fb, Pot, Bw							
Sb	52:48	40:60	66:34	60:40	67:33	59:31	58:42
Pot, Bw							
Sb, Pj, Fb	75:25	72:28	73:27	67:33	78:22	76:24	74:26

* 1989 data

and white birch are counted, stocking increased over 20 percentage points. The greatest frequency for black spruce was found in the first-cut strips in Area 2 while the lowest was in the second-cut strips in Area 3.

The greatest stocking for all species was achieved in the first-cut strips in Area 2 and the lowest was achieved in the second-cut strips in Area 3 (Table 11, Fig. 12). First-cut strips had a mean cumulative frequency for all species of 83.3% while the second-cut strips had a

Table 11. The cumulative stocking (%) based on increasing numbers of species being acceptable for counting quadrats as "stocked".

	Sb	Pj	Fb	Pot	Bw
Area 1					
* First-cut	59.7	63.8	75.0	80.1	82.7
Second-cut	53.8	57.1	77.9	81.0	85.0
Area 2					
First-cut	67.8	67.8	74.5	81.8	86.4
Second-cut	52.9	52.9	58.2	71.5	73.5
Area 3					
First-cut	64.6	67.6	71.1	75.4	78.0
Second-cut	47.7	51.6	59.1	63.6	66.7
Mean	57.7	60.1	69.3	75.6	78.7

* 1989 data

mean stocking for all species of 75.1%.

Temporal Changes in Stocking in Area 1

Table 12 summarizes the levels of stocking of black spruce in the first-cut strips from 1974 to 1992. In the 2-year leave strips (first-cut strips with adjacent leave strips left as a seed source for 2 years) the level of stocking dropped slightly between the year before harvesting, 1974 (54%), and the final year of assessment, 1989 (48%). In the 4-year leave strips, the pre-harvest level of 58% dropped in the first year after harvesting to 51%, then increased in 1978 to 65%, and finally to 69% in 1989. Most of the new regeneration therefore

Table 12. Changes in black spruce stocking in Area 1 from pre-harvest year (1974), to the final assessment in 1992.

Strip width.		Year of harvest (C1 - C3) and assessments													
2 yr and 4 yr leave		and years of natural seeding (+1, ... +4)													
periods	Pre-harvest	First-cut strips									Second-cut strips				
		75	'76 (+1)	'77	'78 (+2)	'78 (+3)	'79	'80 (+2)	'80 (+4)	'89 (+2)	'89 (+4)	'83	'89	'92	
No. of quadrats	600		565		300	265		300	265	300	265		275	300	300
20 - m scarified strips															
2-yr leave	59	C1	59	C2	50	-	51		53				-	50	62
4-yr leave	52		53		-	67	C3	69		75			49**	49**	49**
40 - m scarified strips															
2-yr leave	49		48		49	-	50		55				-	32	37
4-yr leave	49		38		-	63		61		67.5			53**	48**	61**
80 - m scarified strips															
2-yr leave	65		34		59	-	52		36				-	38	46
4-yr leave	66		56		-	65		63		65			42**	48**	61**
All scarified strips															
2-yr leave	54		47		53	-	51		48				-	41	48
4-yr leave	58		51		-	65		65		69			47**	48**	57**

* Source: Pre-1989 data from previous assessments (Jeglum 1980, 1983)

** Natural seeding from groups of seed trees.

was established in the first three years after harvesting. There was an increase in stocking of 11% between pre-harvest and 13 year post-harvest levels. Of the strips that had the benefit of four years of seeding, the 20-m strips achieved the highest level of stocking (75%) and the 40- and 80-m strips achieved similar levels of 67.5 and 65, respectively. For the strips with two years of seeding, the stocking level was acceptable for 20-m and 40-m strips (53%, 55%) but a failure level (36%) for the 80-m strips.

The second-cut strips were cut either two years or four years after the first-cut strips. The 4-year leave strips were regenerated by leaving groups, usually two, of seed trees within each strip (Matcam Forestry Consultants Inc. 1983). By 1992 both the 2- and 4-year leave

strips achieved an overall acceptable level (40 - 59.9%) of stocking, 48% for the 2-year and 57% for the 4-year leave strips. These levels were similar to stocking in the pre-harvest state, 54 and 58% for the 2-year and 4-year, respectively.

The 40-m and 80-m 4-year leave strips both achieved desirable rates of stocking (61%) and, overall, were 20% higher than the 40-m and 80-m 2-year leave strips (Table 12). The higher stocking in the 4-year leave strips was probably due to the presence of groups of seed trees. However, the relationship was reversed for the 20-m strips, which is difficult to explain. The 20-m 2-year leave strips achieved a marginally desirable level (62%) while the 20-m 4-year leave strips achieved an acceptable level of stocking (49%).

Table 13 summarizes the levels of stocking and density in Area 1 for five main tree species, from 1974 to 1992. Stocking and density calculations are based on data collected by different contractors and employees.

For the first-cut strips, the level of stocking decreased from 57% to 49% after harvesting. Then it increased from 49%, in 1976 (+1 year of natural seeding) to 69% in 1989 (+4 years). The level of 65% was achieved with only three years of seeding in 1978. Stocking of black spruce in 1978 (+2 years) was 53%, and this decreased to 48% in 1989 (+2 years).

For the second-cut strips, the level of stocking of black spruce in 1989 and 1992, 10 to 15 years after harvests, was from 40 to 57% (Table 13). The 4-year leave strips had a higher stocking on average than the 2-year (44% vs. 53%). The level of stocking of second-cuts, around 50%, was acceptable, but was 19% lower than achieved by the first-cut strips with 4 years of natural seeding.

Table 13. Changes in stocking (%) and density (no./quad.) of five tree species in Area 1 from pre-harvest year, 1974,* to the final assessment in 1992.

Species/ stocking/ density (per 2-m x 2-m quad.)	Pre- harvest year 1974	Year of harvest (C1 - C3) and assessments and years of natural seeding (+1, ... +4)										Second-cut strips			
		First-cut strips													
		75	'76	'77	'78	'78	'79	'80	'89	'89		'89	'92	'89*	92*
			(+1)	(+2)	(+3)			(+4)	(+2)	(+4)		(2yr)	(2yr)	(4yr)	(4yr)
No. of quadrats	600		565	300	265			265	300	265		300	300	300	300
Black spruce															
Stocking	57	C1	49	C2	53	65	C3	65	48	69		40	48	48	57
Density	4.2		3.4		3.2	5.4		4.1	1.4	2.2		1.3	1.5	1.1	2.1
Jack pine															
Stocking	1		32		13	20		19	17	18		11	10	5	7
Density	<0.5		2.6		0.8	0.8		0.6	0.4	0.3		0.2	0.2	0.1	0.1
Balsam fir															
Stocking	70		48		32	33		32	26	24		44	44	34	45
Density	7.2		2.9		1.0	1.6		1.4	0.5	0.5		1.1	1.2	1.0	1.5
Trembling aspen															
Stocking	8		44		44	51		38	21	12		22	24	13	16
Density	0.3		4.5		2.2	3.1		1.7	0.4	0.2		0.4	0.5	0.2	0.3
White birch															
Stocking	36		37		58	58		54	23	40		29	30	18	30
Density	2.5		3.4		8.2	7.7		6.4	0.5	0.8		0.9	0.9	0.3	0.9
Total Species combined															
Stocking	88		87		88	88		87	80	86		83	84	74	87
Density	14.3		16.8		15.5	18.7		14.4	3.2	4.1		3.9	4.2	2.7	4.9

* Source: Pre-1989 data (Jeglum 1982a).

Note: Strip widths are not differentiated.

Density for black spruce was 4.2 stems per 2-m x 2-m quadrat (10,500/ha) in the pre-harvest forest (Table 13). For the first-cut strips, the level dropped in years 1 and 2 after harvesting (3.2 to 3.4) but then rose in years 3 and 4 to pre-harvest levels (4.1 to 5.4). However, by 1989 levels had dropped considerably, to 1.4 and 2.2 seedlings per quadrat, suggesting that considerable mortality occurs after the early wave of new seedlings. For the second-cut strips, densities of black spruce were consistently low, 1.1 to 2.1 (Table 13).

Levels of stocking and density for jack pine and trembling aspen were very low in the pre-harvest condition, but increased dramatically in one year (+1) after harvest (Table 13). Thereafter, their levels decreased. In the second-cut strips the levels of jack pine were lower, owing probably to less effective scarification (around seed tree groups), whereas the levels of trembling aspen were about the same as in the first-cut strips.

Balsam fir in the pre-harvest condition had 70% stocking, but this dropped to around 24 - 26% in 1989 in the first-cut strips and 34 to 45% in the second-cut strips. White birch had 36% in the pre-harvest but then increased to between 40 - 58% in the +4 strips. Second-cut strips showed lower levels of stocking (18 - 30%) than pre-harvest levels. These differences are again explained by the silvics of the species. Balsam fir invades mossy surfaces in older stands, and harvesting would kill much of the advance growth in the original stand. Higher levels of survival would be found in the second-cut strips where seed tree groups were left and there was less scarification. White birch and jack pine, on the other hand, regenerates well on exposed mineral soils, and effective scarification in the first-cuts would be expected to favour them. Trembling aspen regenerates both by seeding and root suckering, and so both of these must be taken into account to explain its regeneration

patterns.

Stocking and Density in the First- and Second-cut Strips

Table 14 summarizes the stocking and mean density per 2-m x 2-m quadrat for all five species, total conifers and total hardwoods in first-cut and second-cut strips, and overall.

Stocking for black spruce was about 66% in the first-cut strips and about 52% in the second-cut strips. The stocking for black spruce in all strips was about 60% overall.

Table 14. Mean stocking percentage (S) and mean density (D) for five species.

Species	First-cut Strips		Second-cut Strips		All Strips	
	S	D	S	D	S	D
Sb	66.3	3.6	52.3	2.0	59.8	2.9
Pj	8.6	.2	6.05	.1	7.4	.2
Fb	19.5	.4	25.4	.7	22.2	.6
Total Conifers	75.5	4.3	66.8	2.8	71.5	3.6
Pot	15.7	.3	18.0	.3	16.8	.4
Bw	31.7	1.1	20.3	.6	26.4	.9
Total Hardwoods	43.1	1.4	33.3	1.0	38.6	1.3

Note: Calculations based on all cut quadrats in 156 strips - 12 second-cut strips were not harvested.

Comparable figures for all conifers was about 12% higher at 72%. The stocking for total conifers in the first-cut strips was 75.5 while 66.8 in the second-cut strips. The stocking of balsam fir was higher in the second-cut strips whereas the other conifers had higher levels of stocking in the first-cut strips. The overall stocking for hardwoods was 38.6%. The

stocking for hardwoods was higher in the first-cut strips at 43.1% than for the second-cut strips at 33.3%. The level of stocking for trembling aspen was also higher in the second-cut strips than the first-cut strips whereas stocking for white birch was higher in the first-cut strips.

The density for black spruce was higher in the first-cut strips (3.6) than in the second-cut strips (2.0). The density for black spruce in all strips was 2.9 stems/quadrat. The density of all conifers was 3.6 overall, 4.3 in the first-cut strips, and 2.8 in the second-cut strips. The overall density for hardwoods was 1.3 stems/quadrat with the density in the first- and second-cut strips at 1.4 and 1.0 stems per quadrat respectively.

Effects of Strip Width and Leave Period on Stocking and Density in the First-cut Strips

Stocking for different strip widths are presented in Table 15 and Figure 13. Differences in stocking between first-cut 20-, 40- and 80-m strips were still apparent after the 16-18 years since harvest. For black spruce, stocking levels increased as strip width decreased. Stocking of 71.6% was achieved in the 20-m strips, 59.4% in the 40-m strips and 53% in 80-m strips (Table 15). Stocking of white birch, all conifers, all hardwoods, and all species showed the same trend to increased stocking in the narrower strips. Stocking for jack pine, balsam fir and trembling aspen were least affected by strip width and did not show the same trend with all levels below 21% in the three strip widths.

Density levels for different strip widths are presented in Table 15 and Figure 14. Only all species, all conifers and black spruce clearly show the trend of decreasing values with increasing strip width. White birch and all hardwoods showed slightly lower densities in the

80-m strips. Densities of jack pine, trembling aspen and balsam fir were relatively unchanged over strip width, with all under 0.5 stems/quadrat.

The original experimental design allowed for 2- and 4-year leave periods, but due to

Table 15. Levels of stocking and density in first-cut strips of five species, all conifers, all hardwoods and all species for three strip widths (24 strips of each width). Areas 2 and 3 were assessed in 1992 and Area 1 was assessed in 1989. Only cut quadrats in scarified strips (less controls) were included (n=2446).

Species	Strip width					
	20-m		40-m		80-m	
	S	D	S	D	S	D
Black spruce	71.6	4.4	59.4	3.5	53	2.4
Jack pine	6.6	0.1	9.7	0.2	8.4	0.2
Balsam fir	20.9	0.4	16.3	0.4	18.6	0.5
All conifers	78.7	5.3	70.9	4.28	66.7	3.1
Trembling aspen	12.8	0.2	15.4	0.3	12.1	0.3
White birch	41.5	1.4	31.4	1.1	25.5	0.9
All hardwoods	50	1.6	42.6	1.64	33.8	1.2
All species	85.9	6.9	78.6	6.4	74.4	4.3

harvesting oversights some strips were left uncut resulting in the adjacent strips having a seed source for a longer period of time. These were classified as having 8+ years of natural seeding. There were a total of 72 strips used for these calculations: 84 first-cut strips less the 12 controls that received no site preparation.

The effects of the length of time of natural seeding (leave period), on stocking and density in the first-cut strips were still evident in the 1989 and 1992 regeneration assessments

(Table 16, Fig. 15). Stocking and density were higher in strips with longer seeding periods.

When combined with different strip widths there was a clear trend towards higher stocking and density as strip width decreased and leave period increased.

Table 16. Effects of strip width and leave period on the stocking (S) and density (D) of five species, all conifers, all hardwoods and all species, in the first-cut strips.

Species	Strip width									
	20-m			40-m			80-m			
	Years of seeding			Years of seeding			Years of seeding			
	2	4	8+	2	4	8+	2	4	8+	
Black spruce	S	67	82	81	64	66	75	51	65	72
	D	3.4	5.5	8.0	3.5	3.9	5.2	1.7	2.7	3.5
Jack pine	S	4.4	13	0	7.3	18	8	14	13	1.8
	D	0.1	0.3	0.0	0.2	0.4	0.2	0.4	0.2	0.0
Balsam Fir	S	17	26	24	15	30	8	20	7.4	25
	D	0.3	0.5	0.5	0.4	0.8	0.1	0.5	0.1	0.7
All conifers	S	73	90	87	71	85	79	62	69	78
	D	3.8	6.3	8.6	4.0	5.2	5.5	2.5	3.0	4.2
Trembling Aspen	S	15	10	16	20	15	11	13	9.8	13
	D	0.2	0.1	0.3	0.4	0.3	0.3	0.3	0.2	0.4
White Birch	S	27	57	56	28	37	46	12	26	44
	D	0.9	1.8	2.2	1.1	1.0	1.5	0.5	0.6	1.7
All hardwoods	S	39	64	62	44	47	51	23	32	52
	D	1.1	2.0	2.5	1.5	1.3	1.8	0.8	0.8	2.1
All species	S	83	95	96	82	90	86	70	75	87
	D	4.9	8.2	11.0	5.5	6.6	7.3	3.2	3.9	6.4
No. of strips		11	9	4	12	7	5	10	5	9

Table 17 presents mean stocking and mean density of black spruce by strip width and leave period. The highest levels of stocking for black spruce were in the 20-m strips with 4 and 8+ years of seeding (82 and 81% respectively) and the lowest was in the 80-m strips

Table 17. Mean stocking (S) and mean density (D) of black spruce in 72 first-cut strips for strip width and leave period.

Leave Period		Strip width							
		20-m		40-m		80-m		All	
		S	D	S	D	S	D	S	D
2 years	Mean	66.6	3.4	64.3	3.5	51.0	1.7	61.0	2.9
	n *	11		12		10		33	
	S.D.	18.4	2.8	18.0	1.6	12.8	1.0	17.6	2.1
4 years	Mean	81.8	5.5	65.7	3.9	64.6	2.7	72.3	4.3
	n	9		7		5		21	
	S.D.	14.6	3.3	11.0	2.7	14.3	1.2	15.3	2.8
8+ years	Mean	80.5	8.0	75.3	5.2	72.4	3.5	75.0	5.0
	n	4		5		9		18	
	S.D.	7.0	1.5	8.1	2.9	8.6	1.9	8.3	2.7
All	Mean	74.6	4.9	67.0	4.0	61.9	2.6	67.8	3.8
	n	24		24		24		72	
	S.D.	16.9	3.2	14.8	2.2	14.9	1.6	16.2	2.6

Note: * n = number of strips

with only 2 years of seeding (51%). Similarly, the highest mean density for black spruce of was observed in the 20-m strips with 8+ years of seeding (8.0 stems/2-m x 2-m quadrat) and the lowest was in the 80-m, 2-year leave strips (1.7 stems). Figure 11 clearly illustrates the

trend to increased stocking and density of black spruce in the narrower strips with longer leave periods. The densities of white birch, all conifers, all hardwoods and all species also increased as strip width decreased and leave period increased.

Table 18. Two-way analysis of variance for the effects of strip width and seeding period on stocking and mean density per strip.

Stocking					
Source	DF	Adj SS	F	P	
Seeding period	1	2989.1	15.04	0.000	***
Strip width	2	2193.0	5.52	0.006	**
Strip width / Seeding period	2	554.0	1.39	0.255	NS
Error	66	13120.5			
Total	71				
Density					
Source	DF	Adj SS	F	P	
Seeding period	1	56.72	10.94	0.002	**
Strip width	2	67.99	6.56	0.003	**
Strip width / Seeding period	2	10.67	1.03	0.363	NS
Error	78	373.374			
Total	83				

Note: * P < 0.05
 ** P < 0.01
 *** P < 0.001
 NS Not significant

A general linear model approach was used for an analysis of variance using the Minitab analysis package (Minitab Inc. 1989) to determine the level of effects of the two main factors, strip width (3 levels) and seeding period (2 levels), on % stocking and density (the number of stems per 2-m x 2-m quadrat) of black spruce in all of the first-cut strips.

Strips that had more than 4 years of natural seeding were considered as equivalent to 4-year seeded strips for the purposes of this analysis. The resulting levels of significance are presented in Table 18. Stocking (%) data was arcsine transformed, and an analysis of variance was performed. The resulting significance levels were unchanged.

Leave period (2 and 4 years) had a significant effect on stocking ($P < 0.001$). The effect of strip width (20-, 40- and 80-m) on density was also significant ($P < 0.05$) even after the intervening 16- to 18- years. The interaction of strip width and leave period was not significant on either stocking or density.

Effects of Leave Period and Site Type on Stocking and Density in the First-cut Strips

Table 19 summarizes the effects of leave period and site type on natural regeneration. All first-cut strips were assessed. For this, only first-cut strips were used. Area 1 was assessed in 1989, 15 years after harvest. Areas 2 and 3 were assessed in 1992, Area 2, 17 years after harvest and Area 3, 16 years after harvest.

For black spruce, stocking and density in the first-cut, 2-year leave strips, were less than in the 4-year leave strips. Both stocking and density, for black spruce, were greater in drainageways and lower slopes (sites 1 and 2) than in upper slopes and crests (sites 3 and 4) in both 2- and 4-year seeded strips. Stocking and density of black spruce in 4-year seeded strips were greater in both lower and higher site types than in the 2-year seeded strips.

For all species, stocking was greater in the 4-year leave strips (84.7%) compared to the 2-year leave strips (78.5%)(Table 19). For all species, density was also greater in the 4-

year leave strips (6.6) compared to the 2-year leave strips (4.4). Density for all species in the

Species		First-cut strips						
		2-years natural seeding			4-years natural seeding			
		Site type*						
		1,2	3,4	1,2,3,4	1,2	3,4	1,2,3,4	
Sb	S	62.2	55.0	58.7	72.7	68.8	70.3	
	D	3.3	2.2	2.8	4.9	4.2	4.4	
Pj	S	4.5	7.9	6.1	6.3	10.1	8.6	
	D	0.1	0.2	0.1	0.1	0.2	0.2	
Bf	S	16.0	18.9	17.4	17.4	21.7	20.0	
	D	0.4	0.4	0.4	0.4	0.5	0.5	
Pot	S	13.9	26.6	20.1	10.8	15.5	13.6	
	D	0.2	0.6	0.4	0.2	0.3	0.3	
Bw	S	15.4	26.7	20.9	32.3	40.3	37.1	
	D	0.5	1.0	0.7	1.0	1.4	1.2	
All Conifers	S	70.0	65.9	68.0	78.3	78.0	78.1	
	D	3.8	2.8	3.3	5.4	4.9	5.1	
All Hardwoods	S	27.4	45.1	36.0	37.7	51.5	46.0	
	D	0.8	1.5	1.1	1.2	1.7	1.5	
All Species	S	77.3	79.9	78.5	83.5	85.4	84.7	
	D	4.6	4.3	4.4	6.6	6.6	6.6	
Number of Quadrats		669	636	1305	443	672	1115	2420

Note: Area 1 - assessed 1989 - 15 years post-harvest
Area 2 - assessed 1992 - 17 years post-harvest
Area 3 - assessed 1992 - 16 years post-harvest

2-year leave strips was greater in the lower site types (4.6) than in the higher site types (4.3). Density for all species were the same (6.6) in the higher and lower site types in the 4-year leave strips.

All conifer species were present in 78% of the quadrats in the 4-year seeded strips compared to 68% in the 2-year seeded strips. Densities of all conifers were 5.1 and 3.3 per quadrat in the 4-year and 2-year seeded strips. All hardwood species were present in 46% of the quadrats in the 4-year seeded strips compared to 36% in the 2-year seeded strips. Density of all hardwoods was 1.5 and 1.1 respectively. All hardwoods had higher levels in the higher site types (3 and 4) in comparison to conifers, which had higher levels in the lower site types (1 and 2).

Effects of Site Preparation on Stocking and Density in the First-cut Strips

First-cut strips were scarified using a TTS disc-trencher in the 1+ year post-harvest. The control strips were all 40-m and were not scarified. Table 20 presents stocking and density in the 40-m strips only, to eliminate strip width effects, and differentiated between 2 and 4 years of natural seeding. Prescribed burning was performed in two 4-year leave strips (# 150, 152) in Area 3. Stocking for black spruce was greatest in the 4-year scarified strips (71.9%) and least in the burned strips (50.7%). Stocking for all conifers was also highest in the 4-year scarified strips (82.8%) and least in the burned strips (55.3%). Mean density for black spruce was highest in the 4-year scarified strips (4.9) and lowest (2.3) in the 2-year unscarified strips.

Stocking for trembling aspen was highest (28.6%) in the 2- year seeded, unscarified

strips, and lowest (11.4%) in the 4-year unscarified strips. Stocking for trembling aspen was also higher in the 2-year seeded, scarified strips (19.0%), than in the 4-year scarified strips (16.3). Stocking in the 2-year scarified strips (19.0%) was lower than in the 2-year unscarified strips (28.6%) whereas the opposite was true for the 4-year leave period in the scarified (16.3%) and unscarified strips (11.4%). Density for trembling aspen also showed the same

Table 20. Effects of site preparation in the first-cut, 40-m strips on stocking (S) and density (D) per 2-m x 2-m quadrat with 2 and 4 years of natural seeding.

		With Scarification		Without Scarification		
		Years of Natural Seeding		Years of Natural Seeding		
		2 years	4 years	2 years	4 years	4 years
						Prescribed Burn
Sb	S	64.3	71.9	53.7	66.7	50.7
	D	3.5	4.9	2.3	3.5	3.2
Pj	S	6.7	8.9	1.0	6.1	19.3
	D	0.2	0.2	0.0	0.1	0.4
Fb	S	14.7	21.2	19.8	12.3	1.3
	D	0.1	0.5	0.4	0.2	0.0
All conifers	S	71.0	82.8	62.8	70.2	55.3
	D	4.0	5.6	2.7	3.8	3.6
Pot	S	19.0	16.3	28.6	11.4	20.0
	D	0.4	0.4	0.7	0.4	0.4
Bw	S	29.0	37.4	18.1	7.0	2.0
	D	1.1	1.2	0.7	0.1	0.0
All Hardwoods	S	43.7	47.8	38.7	16.7	22.0
	D	1.5	1.5	1.4	0.3	0.5
All species	S	80.7	89.2	77.6	73.7	66.7
	D	5.4	7.1	4.1	4.0	4.1
# of quadrats		300	203	419	114	150

trends, 0.7 and 0.4 in the 2- and 4-year leave unscarified strips, respectively. White birch showed a reversed trend to trembling aspen in that both stocking and density were higher in the scarified strips. In the burned strips stocking for white birch was only 2.0% compared to 20.0% for trembling aspen.

Receptive Seedbed and Site Type in the First-cut Strips

Receptive seedbed, assessed 1+ years post-harvest (Jeglum 1984), was incorporated with the 1989 (Area 1) and 1992 (Areas 2 and 3) data ($n = 1726$) to determine if the present density of black spruce was affected by the amount of receptive seedbed created by site preparation after harvesting. The control strips were not included in this data-set. The resulting data file containing both receptive seedbed and site type consisted of data from 1,726 quadrats. The amount of receptive seedbed was calculated by summing individual categories of percentage receptive seedbed (Jeglum 1984). These values, classified into five levels of receptive seedbed and the four site types, mean densities, n (number of observations) and standard deviations are presented in Table 21.

Current mean density of black spruce ranged from 2.1 stems/2-m x 2-m quadrat in quadrats with 0% receptive seedbed (1+ years post-harvest) to 4.7 stems in quadrats with 20-100% receptive seedbed (Table 21). Only 62 or 3.6% of the total number of quadrats had 0% receptive seedbed while 1019 quadrats or 59% had 20.0 - 100% receptive seedbed. The highest mean density was found in the lower slope site type (4.2) and decreasing in upper slopes and crests (3.9, 3.1). Higher levels of density had been expected in drainageways, but the numbers may have been reduced owing to competition with grasses or speckled alder.

Table 21. Mean density of black spruce (1989- Area 1 and 1992- Areas 2 and 3) in five categories of amount of receptive seedbed (1+ years post-harvest) and four site types in the first-cut scarified strips.

Receptive Seedbed (%)		Receptive Seedbed (mean)	Site Type*				All
			1	2	3	4	
0	Mean	0	0.9	2.3	2.3	1.1	2.1
	n	62	7	46	87	24	164
	S.D.	0	1.6	4.7	4.8	1.7	4.4
0.1 - 4.9	Mean	2.5	1.7	2.5	2.3	2.9	2.4
	n	311	17	62	113	21	213
	S.D.	1.3	1.8	3.6	3.1	7.2	3.7
5.0 - 9.9	Mean	6.7	2.3	4.1	3.3	5.6	3.8
	n	60	9	40	60	19	128
	S.D.	1.2	2.0	5.4	5.7	13.2	7.1
10.0 - 19.9	Mean	12.5	3.4	3.5	3.2	1.7	3.1
	n	274	20	85	121	34	260
	S.D.	2.7	5.4	4.4	4.7	3.1	4.5
20.0 - 100	Mean	41.5	3.8	4.9	5.0	3.7	4.7
	n	1019	117	357	392	95	961
	S.D.	17.6	5.6	6.6	6.4	4.7	6.2
All	Mean	27.15	3.4	4.2	3.9	3.1	3.9
	n	1726	170	590	773	193	1726
	S.D.	22.2	5.1	5.9	5.6	6.0	5.7

* Site type: 1 = drainageway, 2 = lower slope, 3 = upper slope, and 4 = crest.

A one-way analysis of variance was performed on density for five levels of receptive seedbed (Table 22). The amount of receptive seedbed had a significant effect on density even after 16 - 18 years ($P = 0.001$). Another was performed for four site types (Table 22). Though

Table 22. One-way analysis of variance on density for receptive seedbed and site type.

Analysis of variance for receptive seedbed					
Source	DF	SS	F	P	
Receptive Seedbed	4	1817.0	14.28	0.000	
Error	1721	54761.8			
Total	1725	56578.8			

Analysis of variance for site type on density.					
Source	DF	SS	F	P	
Site type	3	220.2	2.24	0.082	NS
Error	1722	56385.6			
Total	1725	56578.8			

site type did not have a significant effect ($P = 0.082$) on density there were differences that indicate density of black spruce may be higher in lower site types. In a two-way analysis of variance, the interaction between receptive seedbed and site type was not significant ($P = 0.527$).

Predictor Equations for Stocking and Density

Regression models were developed to predict levels of stocking and density from percent receptive seedbed in various combinations of strip width and seeding period (leave time of second-cut strips). The data set utilized receptive seedbed, at one year after harvesting and site preparation, and for first-cut strips, in 1726 quadrats. Table 23 shows the regression equations, for stocking and density, and Figure 16 presents predictive models.

The Logistic Procedure (in SAS), a non-linear model, was used for stocking because the

percentage nature of stocking data allows interpretation as a probability (0-100%). The intercept did not make any significant contribution to predicting stocking. Only the independent variables, receptive seedbed, strip width and length of seeding period were important for this model. The chi-square analysis for percent receptive seedbed, strip width and seeding period produced highly significant results ($P < 0.0001$).

A general linear model procedure (in SAS) was used for the analysis for density. In this analysis for density, percent receptive seedbed is a continuous numerical variable, and strip width and seeding period are indicator variables, which means that when considering quadrats with $W = 1$, and $S = 1$, the other quadrats with W_2 , W_3 and $S_2 (=0)$ are ignored. The R^2 value for density of 0.098 is low due to the variation in density data. However the accompanying highly significant P values ($P < 0.0001$) for percent receptive seedbed, strip width and seeding period, indicate a good fit for the linear models.

Table 23. Equations and significance levels for stocking and density predictor models.

Stocking (Logistic Procedure, SAS)

$$\text{Stocking} = e^{(0.0806 + 0.180R - 0.3732W + 0.6296S)} / 1 + e^{(0.0806 + 0.180R - 0.3732W + 0.6296S)}$$

Variable		Parameter Estimate	Standard Error	Wald Chi-square	P Chi-square	Standardized Estimate
Intercept		0.0806	0.2186	0.1361	0.7122	
Receptive seedbed	R	0.180	0.00261	47.5510	0.0001	0.219971
Width	W	-0.3732	0.0657	32.3049	0.0001	-0.169239
Seeding period	S	0.6296	0.107	34.6024	0.0001	0.17328

Where:

- R = % receptive seedbed
W = 1, 2, 3 corresponding to the three strip widths (20-, 40-, 80 - m respectively)
S = 1, 2 corresponding to the two levels (2 and 4 years of natural seeding)

Density (General Linear Model Procedure, SAS)

$$\text{Density} = 1.966 + 0.049778R + \begin{bmatrix} 2.546851 \\ 1.736329 \\ 0 \end{bmatrix} \begin{bmatrix} W1 \\ W2 \\ W3 \end{bmatrix} + \begin{bmatrix} -1.91183 \\ 0 \end{bmatrix} \begin{bmatrix} S1 \\ S2 \end{bmatrix}$$

Type I Source	DF	Mean Square	F	P
R	1	2246.13811	75.75	0.0001
W	2	873.28139	29.45	0.0001
S	1	1554.02562	52.41	0.0001

R-Square 0.098035

	Estimate	T for H0 Parameter = 0	P	Standard Error of Estimate
Intercept	1.966174770	6.71	0.0001	0.29308456
R	0.049777700	8.40	0.0001	0.00592514
W	2.546851472	7.97	0.0001	0.31958770
	1.736328844	5.35	0.0001	0.32458449
	0.0	-	-	-
S	-1.911829471	-7.24	0.0001	0.26408965
	0.0	-	-	-

Where:

- R = % receptive seedbed
W = 1, 2, 3 corresponding to the three strip widths (20-, 40-, 80 - m respectively)
S = 1, 2 corresponding to the two levels (2 and 4 years of natural seeding)

DISCUSSION AND CONCLUSIONS

The assessment of black spruce regeneration in the 16 to 18 year-old, first-cut stripcuts confirms that alternate-strip clearcutting combined with scarification is a successful total harvesting/site preparation/seeding system, at least in shallow-soil upland black spruce. This method facilitates natural regeneration to acceptable (> 40%) and desirable (> 60%) levels of stocking. Present overall stocking of black spruce at 59.8% (Table 14) is comparable to the pre-harvest stocking level of 57% in Area 1 (Table 13). Density levels for black spruce of 4.2 stems per 2- x 2-m quadrat (pre-harvest) decreased to 2.9 stems per 2- x 2-m quadrat overall but density in the first-cut strips was 3.6 stems per 2- x 2-m quadrat, decreasing only slightly from pre-harvest levels. Various strategies of increasing levels of regeneration in second-cut strips should, and are, being investigated (Fleming and Groot 1984, Frisque 1990, Jeglum 1990b, Wood and Raper 1987).

The effects of strip width and period of natural seeding were still significant even after the intervening 12 to 18 years. Generally, it can be stated that as strip width decreased and seeding period increased, both stocking and density increased. This is seeding period with an adjacent forested strip. Seeding period was slightly more significant than strip width. This may suggest that leave strips should be left as long as possible. However, blowdown will also continue over time, and seedbeds mature and get less receptive with age. This will make it necessary to remove the second strips as soon as acceptable or desirable levels are achieved, within 3 to five years.

Though site type was found not to have a significant effect on density, there were still differences that can be explained by site conditions. The highest densities occurred in the lower slopes and decreased through upper slopes and crests. The major contributing factor to this trend is probably the decreasing amount of available soil moisture as topographic location approaches the crest. This could be due to rapid runoff in coarse soils, and the extremely shallow of the soil and predominance of rocky outcrops. Lower levels of density in the lowest site type (1 - drainageways) could be due to increased competition by graminoids and shrubs,

and flooding by runoff from nearby slopes or watering-up in the lower more level areas.

Scarification was more successful than prescribed burning in producing receptive seedbed in regards to successful regeneration ($P < 0.000$). A mean density of 4.9 stems/quadrat was achieved in the scarified strips with 4 years of seeding while there were 3.5 stems/quadrat in the scarified strips with 2 years of seeding. Overall, this was comparable to pre-harvest advance growth densities. Prescribed burning in upland stripcuts is contraindicated as these strips showed the lowest stocking and density levels at 50.7% and 3.2 stems/quadrat respectively. The regeneration in the burned strips was clustered owing to the alternating swale and crest type of topography, where good seedbed remained in the wet sphagnum-filled drainageways but was destroyed by the burn in the higher and dryer site types.

Previous research on alternate strip clearcutting has shown that regeneration levels of black spruce are greater in strip clearcuts than in larger clearcuts (Fraser et al. 1976). However, in strip clearcuts, Jeglum, 1983 has found an increase in the proportion of hardwoods, especially by trembling aspen and white birch, 5 years after harvesting. At this time, 12 to 18 years after harvest, there is a suggestion that the stand is returning to pre-harvest levels. The pre-harvest ratio of conifer to hardwood was 82:12. This changed to 40:60 after 5 years, but after 12 to 18 years in the first-cut strips, reversed back to higher conifer to hardwood with 75:25 (74:26 overall).

Prediction of stocking and density can be achieved by relating % receptive seedbed, strip width and seeding period by using the graphs in Figure 13. The amount of receptive seedbed can be assessed by the methods outlined in "Strip clearcutting in black spruce: a guide for the practicing forester" (Jeglum and Kennington 1993). In this way strip cut design and scarification levels can be prescribed for optimum levels of stocking and density, a useful tool for the black spruce silviculturist.

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Appendix A:

LIST OF SCIENTIFIC AND COMMON NAMES OF SPECIES MENTIONED

<i>Abies balsamea</i> (L.) Mill.	balsam fir
<i>Alnus crispa</i> (Ait.) Pursh.	green alder
<i>Alnus rugosa</i> (Du Roi) Spreng.	speckled alder
<i>Betula papyrifera</i> Marsh.	white birch
<i>Fraxinus nigra</i> Marsh.	black ash
<i>Larix laricina</i> (Du Roi) K. Koch	tamarack
<i>Picea glauca</i> [Moench] Voss	white spruce
<i>Picea mariana</i> [Mill] B.S.P.	black spruce
<i>Pinus banksiana</i> Lamb.	jack pine
<i>Populus balsamifera</i> L.	balsam poplar
<i>Populus tremuloides</i> Michx.	trembling aspen
<i>Thuja occidentalis</i> L.	white cedar

Regeneration data collection, as described earlier (Contractor's Report, Collection of Regeneration, Vegetation, and Seedbed Data, Areas 1,2 and 3, Section 3.2.1) , targeted black spruce. Identical data were also collected for white spruce , jack pine, balsam fir, cedar, tamarack, trembling aspen, white birch, balsam poplar and black ash. These species were given codes used in data collection as follows:

0	-	No trees	
1	-	Black Spruce	Sb
2	-	White Spruce	Sw
3	-	Jack pine	Pj
4	-	Balsam Fir	Fb
5	-	Cedar	Ce
6	-	Tamarack	Ta
7	-	Trembling Aspen	Pot
8	-	White Birch	Bw
9	-	Balsam Poplar	Pob
10	-	Black Ash	Ab.

Only species 1, 3, 4, 7, 8 were analyzed for the purposes of this report due to their predominance and the scarcity of the other species.

Appendix B:

STOCKING AND DENSITY FOR EACH OF FIVE SPECIES WITHIN EACH STRIP

APPENDIX 8.2. Stocking(%) and density (# of stems / 2mX2m quadrat , N) for each of five :
each strip(for stems > 0 cm height and < 10cm dbh).

Strip No.	Black Spruce		Jack Pine		Balsam Fir		Trembling Aspen		White Birch		All Conifers		All Hardwoods		All Species		N
	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	
1	60	1.4	16	0.2	48	1.2	28	0.3	60	1.8	84	2.8	68	2.1	92	4.9	25
2	96	3.5	24	0.3	20	0.2	20	0.2	44	0.7	96	4.1	56	1	100	5	25
3	84	4.2	8	0.2	24	0.4	16	0.3	48	1.3	88	4.8	60	1.6	96	6.4	25
4	76	3	20	0.2	24	0.4	8	0.1	68	1.9	92	3.6	72	2	100	5.6	25
5	28	0.9	20	0.2	60	2.1	44	0.6	56	1.4	88	3.2	76	2	96	5.2	25
6	68	2	28	0.4	36	0.7	4	0	56	0.8	84	3.1	60	0.8	84	3.9	25
7	24	1	0	0	68	3.2	52	1.1	40	0.9	76	4.2	76	2	92	6.1	25
8	52	1.5	0	0	64	1.4	36	0.5	32	0.5	84	2.9	56	1	96	3.9	25
9	68	2.7	8	0.2	56	1.2	32	0.5	60	1.5	80	4	76	2	100	6	25
10	72	1.7	0	0	56	0.9	20	0.2	40	1	88	2.6	60	1.2	92	3.8	25
11	56	1.5	0	0	64	2	28	0.4	28	0.7	84	3.5	48	1.1	88	4.6	25
12	40	0.8	4	0	24	0.4	28	0.5	16	0.3	56	1.2	36	0.8	76	2	25
13	64	1.5	4	0	48	1.8	32	0.5	20	0.8	84	3.3	36	1.3	88	4.6	25
14	52	1.4	4	0	24	0.4	16	0.2	32	0.5	68	1.8	44	0.7	80	2.5	25
15	60	1.8	16	0.2	16	0.2	4	0	40	0.9	64	2.2	44	0.9	76	3.2	25
16	48	0.8	36	0.9	4	0.1	0	0	24	0.3	64	1.8	24	0.3	68	2.1	25
17	32	0.5	0	0	68	2.8	40	0.7	64	3	84	3.2	76	3.8	100	7	25
18	16	0.3	0	0	48	0.9	16	0.2	44	1.1	52	1.2	60	1.3	80	2.5	25
19	32	0.6	4	0	72	2.2	36	1.1	40	1.4	84	2.9	64	2.6	88	5.4	25
20	76	4.1	20	0.3	40	1	48	1.1	48	1.7	88	5.4	76	2.8	92	8.3	25
21	36	2.4	16	0.4	40	0.9	8	0.2	36	0.7	72	3.7	40	0.9	84	4.6	25
22	60	2.6	16	0.6	16	0.3	20	0.3	32	0.8	68	3.5	52	1.1	84	4.6	25
23	48	1.5	16	0.3	48	0.7	8	0.1	40	1.1	68	2.6	44	1.2	84	3.8	25
24	64	3.2	12	0.3	28	0.4	20	0.5	20	0.2	84	3.8	36	0.7	84	4.5	25
25	90	2.8	15	0.2	55	1.4	15	0.3	45	1.2	95	4.3	60	1.5	100	5.8	20
26	70	2.7	40	0.9	20	0.2	0	0	50	1.7	80	3.8	50	1.7	90	5.5	10
27	60	1.6	0	0	20	0.2	0	0	20	0.8	80	1.8	20	0.8	80	2.6	5
28	66.7	1.7	0	0	0	0	0	0	66.7	1.3	66.7	1.7	66.7	1.3	66.7	3	3
29	48	1.2	0	0	80	4	0	0	12	0.4	100	5.2	12	0.4	100	5.6	25
30	44	1.2	28	0.6	64	1.9	32	0.6	40	1.2	92	3.7	60	1.7	96	5.4	25
31	55	1.5	0	0	60	1.4	10	0.2	20	0.9	85	3	30	1.1	85	4.1	20
32	72	2.2	28	0.5	28	0.6	12	0.1	68	1.2	84	3.4	76	1.3	96	4.7	25
33	56	1	16	0.4	52	1.2	32	0.7	28	0.9	92	2.6	52	1.6	92	4.2	25
34	52	1.2	4	0	28	0.6	32	0.6	8	0.1	76	1.8	40	0.7	84	2.5	25
35	68	1.7	4	0	40	0.9	24	0.4	20	0.6	84	2.7	44	1	84	3.7	25
36	52.6	0.7	21.1	0.5	31.6	0.4	36.8	0.6	26.3	0.6	84.2	1.6	52.6	1.4	89.5	3	19
37	60	1.7	0	0	48	1	28	0.8	4	0.2	76	2.7	28	0.9	80	3.6	25
38	88	3.4	0	0	28	0.3	16	0.2	12	0.2	88	3.8	28	0.4	100	4.1	25
39	80	1.6	10	0.1	20	0.3	10	0.1	10	0.1	80	2	20	0.2	90	2.2	10
40	60	1.1	0	0	16	0.3	12	0.2	0	0	64	1.4	12	0.2	64	1.6	25
41	52	1.6	4	0	24	0.7	12	0.1	0	0	64	2.3	12	0.1	64	2.4	25
42	40	0.5	16	0.4	12	0.1	8	0.2	4	0	52	1	12	0.2	60	1.2	25
43	52	1.8	12	0.4	16	0.3	16	0.5	12	0.2	68	2.5	24	0.8	68	3.2	25
44	64	1.4	4	0	8	0.2	20	0.4	12	0.2	68	1.6	26	0.6	72	2.2	25
45	40	1.7	0	0	12	0.2	0	0	8	0.2	48	1.9	8	0.2	56	2.2	25
46	68	2.8	8	0.2	0	0	4	0	4	0	68	3	8	0.1	72	3.1	25
47	56	2.2	0	0	20	0.4	0	0	12	0.2	60	2.6	12	0.2	64	2.8	25
48	68	2.2	32	0.5	4	0	24	0.6	20	0.2	76	2.7	40	0.8	92	3.6	25
49	36	0.6	16	0.4	52	0.9	36	0.8	16	0.3	76	1.9	48	1.1	84	3	25
50	32	0.7	12	0.1	16	0.3	24	0.4	4	0	52	1.2	26	0.4	76	1.6	25
51	44	1.5	24	0.4	20	0.4	40	0.6	0	0	64	2.4	40	0.8	80	2.9	25
52	52	0.9	64	2.3	0	0	24	0.7	0	0	76	3.2	24	0.7	84	3.9	25
53	66	2.4	16	0.2	44	1	20	0.5	24	0.6	80	3.6	36	1.1	88	4.8	25
54	78.3	2.1	17.4	0.2	8.7	0.1	8.7	0.1	21.7	0.3	78.3	2.4	26.1	0.4	82.6	2.6	23
55	81	3.6	9.5	0.1	14.3	0.3	9.5	0.2	14.3	0.1	81	4.2	23.8	0.3	85.7	4.6	21
56	40.9	1.3	0	0	4.5	0.1	4.5	0	4.5	0	40.9	1.4	9.1	0.1	40.9	1.5	22
58	84	10.2	0	0	32	0.3	8	0.2	56	2.1	96	10.6	60	2.3	100	12.9	25
60	84	6.6	0	0	20	0.6	44	0.6	68	2.8	88	7.4	84	3.4	96	10.8	25
62	70	7.6	0	0	30	1	0	0	70	3.3	80	8.6	70	3.3	95	11.9	20
64	84	7.4	0	0	12	0.2	12	0.3	28	0.6	84	7.6	32	0.9	92	8.5	25
66	96	6.4	0	0	20	0.4	16	0.2	16	0.8	96	6.8	32	1	96	7.8	25
68	88	8	0	0	16	0.2	20	0.4	8	0.1	88	8.3	28	0.4	96	8.7	25
70	80	8	0	0	20	0.5	8	0.1	12	0.1	84	8.6	20	0.2	88	8.8	25
72	72	2.8	0	0	0	0	32	0.4	24	0.6	72	2.8	44	1	84	3.8	25
74	80	9.2	0	0	4	0	20	0.6	8	0.5	80	9.2	24	1.1	84	10.4	25
76	76	7.2	0	0	8	0.2	16	0.3	52	3.2	80	7.4	60	3.6	88	11	25
78	88	8.7	0	0	4	0	16	0.8	20	0.5	88	8.8	36	1.3	92	10.1	25
80	76	5.2	0	0	8	0.1	24	0.4	40	0.8	80	5.4	44	1.2	92	6.6	25
82	72	4.1	0	0	4	0.1	20	0.3	56	4.8	72	4.2	72	5.1	96	9.4	25

84	60	3.1	0	0	16	0.5	12	0.2	64	3	68	3.6	72	3.2	88	6.8	25
86	84	5.8	0	0	20	0.6	16	0.2	28	0.5	84	6.4	44	0.7	96	7	25
88	80	5	0	0	4	0	36	0.6	36	1.3	80	5.1	60	1.8	96	6.9	25
90	42.7	1.7	0	0	29.3	0.6	60	1.8	40	1.8	61.3	2.3	74.7	3.6	92	5.9	75
92	53.3	2.3	0	0	22.7	0.5	22.7	0.4	45.3	2.1	60	2.8	56	2.4	80	5.3	75
94	84	4.1	0	0	26.7	0.5	9.3	0.1	0	0	86.7	4.6	9.3	0.1	88	4.7	75
96	42.7	1.7	0	0	9.3	0.1	25.3	0.7	1.3	0	48	1.8	26.7	0.7	64	2.5	75
98	50	2.6	0	0	58.3	2	4.2	0	8.3	0.2	83.3	4.6	12.5	0.3	83.3	4.9	24
100	36	0.9	0	0	56	1.2	24	0.4	32	1.2	68	2.2	44	1.6	76	3.8	25
102	64	1.5	0	0	8	0.1	8	0.1	8	0.1	68	1.6	16	0.2	72	1.8	25
104	68	2.5	0	0	40	1.3	32	1.1	40	0.8	84	3.8	60	1.9	100	5.7	25
106	72	1.8	0	0	24	0.4	20	0.4	28	0.7	76	2.2	48	1.1	92	3.3	25
108	72	2.1	0	0	12	0.2	4	0	52	1.6	72	2.3	52	1.6	80	3.9	25
110	68	3.6	0	0	16	0.2	12	0.4	32	0.8	72	3.8	36	1.2	72	5	25
112	68	4.2	0	0	20	0.5	28	1.4	76	3.4	72	4.6	84	4.7	96	9.4	25
113	36	0.9	4	0	8	0.2	4	0	4	0.2	40	1.2	8	0.2	48	1.4	25
114	44	1	4	0	8	0.1	8	0.1	12	0.2	52	1.1	20	0.3	60	1.4	25
115	60	2	4	0	12	0.1	20	0.4	40	2.1	68	2.2	52	2.4	84	4.6	25
116	68	2.7	0	0	8	0.1	4	0	52	1.2	68	2.8	52	1.3	84	4.1	25
117	40	0.8	0	0	20	0.2	8	0.2	36	0.8	52	1.1	40	1	68	2	25
118	72	3.8	0	0	12	0.1	12	0.1	64	5.1	72	4	68	5.2	84	9.2	25
119	60	2.1	0	0	8	0.1	12	0.3	44	4	64	2.2	44	4.3	72	6.5	25
120	80	6.6	0	0	20	0.4	4	0	64	4.6	84	6.9	68	4.6	88	11.6	25
121	52	1.3	0	0	16	0.3	12	0.4	24	0.6	60	1.6	32	1	72	2.7	25
122	88	8	0	0	8	0.1	4	0.1	76	2.6	88	6.1	80	2.7	92	8.8	25
123	24	1.2	16	0.3	16	0.2	0	0	4	0.1	52	1.7	4	0.1	52	1.8	25
124	92	7.3	24	0.5	4	0.2	4	0	56	2.2	92	8	56	2.2	100	10.2	25
125	60	1.6	8	0.2	16	0.4	0	0	16	0.7	72	2.1	16	0.7	72	2.8	25
126	96	11.6	8	0.6	32	0.7	0	0	76	1.7	96	13	76	1.7	100	14.7	25
127	56	2.4	8	0.1	24	0.4	0	0	12	0.2	68	2.8	12	0.2	68	3	25
128	88	7.6	12	0.6	28	0.4	12	0.2	44	1.4	96	8.6	52	1.6	96	10.1	25
129	24	2.2	0	0	24	0.6	12	0.2	16	0.3	40	2.8	28	0.4	56	3.2	25
130	76	5.7	12	0.1	20	0.6	12	0.2	48	1.8	84	6.5	56	2	92	8.5	25
131	36	1.5	12	0.2	60	1.8	16	0.3	16	0.3	72	3.4	28	0.6	84	4	25
132	60	3.1	28	1.6	20	0.4	0	0	28	0.8	84	5.1	28	0.6	88	5.7	25
133	36	1.1	0	0	64	2.4	0	0	24	0.5	72	3.6	24	0.5	72	4	25
134	60	2.9	16	0.3	44	1.6	12	0.2	44	1.6	84	4.8	48	1.8	88	6.6	25
135	56	2.9	4	0.1	20	0.6	8	0.2	16	0.4	68	3.5	24	0.5	76	4	25
136	48	1.6	8	0.1	4	0	8	0.4	0	0	48	1.8	8	0.4	48	2.2	25
137	40	1.2	0	0	0	0	0	0	4	0	40	1.2	4	0	40	1.2	25
138	72	3	0	0	12	0.2	12	0.2	20	0.5	72	3.2	28	0.7	72	3.9	25
139	48	2.5	0	0	4	0	12	0.2	12	0.4	48	2.6	24	0.5	64	3.1	25
140	46.7	2.3	0	0	6.7	0.2	21.3	0.6	1.3	0	50.7	2.5	22.7	0.6	60	3.1	75
141	28	1.2	0	0	0	0	0	0	8	0.2	28	1.2	28	1	52	2.1	25
142	68	4.7	0	0	8	0.2	16	0.2	0	0	68	4.9	16	0.2	68	5.1	25
143	68	4.4	0	0	8	0.1	24	1	0	0	72	4.6	24	1	80	5.5	25
144	68	4.9	0	0	4	0	24	0.5	0	0	68	5	24	0.5	80	5.4	25
145	36	0.7	48	1.4	0	0	20	0.4	0	0	64	2.1	20	0.4	72	2.5	25
146	68	2.2	44	1.2	0	0	8	0.2	4	0	88	3.4	12	0.2	88	3.7	25
147	48	0.9	20	0.7	0	0	12	0.2	0	0	56	1.6	12	0.2	64	1.8	25
148	62.7	4.2	9.3	0.1	9.3	0.1	13.3	0.2	9.3	0.1	68	4.4	20	0.3	72	4.7	75
149	56	2.5	0	0	4	0.1	12	0.4	4	0	56	2.6	16	0.4	56	3	25
150	45.3	2.6	16	0.3	2.7	0.1	17.3	0.4	2.7	0	50.7	3	20	0.5	60	3.4	75
151	56	2.2	12	0.1	0	0	8	0.2	0	0	60	2.4	8	0.2	64	2.6	25
152	56	3.8	22.7	0.5	0	0	22.7	0.4	1.3	0	60	4.3	24	0.5	73.3	4.7	75
153	52	1.6	4	0	52	1.3	0	0	20	0.3	88	3.2	20	0.3	92	3.5	25
154	72	3.9	4	0	16	0.4	0	0	32	0.8	76	4.4	32	0.8	80	5.2	25
155	72	4.2	8	0.1	8	0.3	4	0	40	1.4	76	4.6	40	1.4	84	6	25
156	64	4	12	0.2	4	0	12	0.2	52	1.8	72	4.3	52	2	80	6.3	25
157	28	0.8	16	0.2	12	0.2	0	0	16	0.6	44	1.2	16	0.6	52	1.8	25
158	80	6.5	0	0	40	0.8	0	0	72	3.5	92	7.3	72	3.5	100	10.6	25
160	92	6.4	4	0	68	2.9	0	0	84	4.6	100	9.4	84	4.6	100	14	25
161	56	1.5	8	0.1	4	0	24	0.4	4	0.1	60	1.6	28	0.6	72	2.2	25
162	68	3.2	16	0.8	0	0	8	0.1	0	0	76	4	8	0.1	80	4.1	25
163	52	2.4	20	0.2	0	0	12	0.1	4	0	60	2.6	16	0.2	64	2.7	25
164	52	1.4	28	0.5	0	0	8	0.1	0	0	68	2	8	0.1	68	2	25
165	56	1.6	8	0.1	8	0.1	4	0.1	0	0	64	1.8	4	0.1	64	1.9	25
166	68	2.1	8	0.2	28	0.4	8	0.2	4	0.1	76	2.6	12	0.3	84	2.9	25
167	52	2.5	0	0	4	0.4	0	0	16	0.6	52	2.9	16	0.6	56	3.5	25
168	48	3.1	8	0.5	40	1.3	28	0.6	72	3.9	68	4.9	84	4.5	92	9.4	25

Note: The following strips were not included in the above table as there were no quadrats within the strip that were cut:
57, 59, 61, 63, 65, 77, 79, 105, 107, 109, 111, 159.

Appendix C:

DATA MANIPULATION

The edited files, using only the cut quadrats, were saved as:

Area 1	Area 2	Area 3	All Areas
A1Ev89u.WB1	A2Evenu.WB1	A3Evenu.Wb1	Even.WB1
A1Oddu.WB1	A2Oddu.WB1	A3Oddu.Wb1	Odd.WB1

A program, 'Redat', was written to change the format of the original data files into one resembling the data files from earlier studies. That is, the data for each species were concatenated so that all the data per quadrat were saved as one record⁴. The resulting file allowed for a maximum of five species per quadrat. The source code for the program, is saved as Redat.pas and the executable code is saved as Redat.exe. This program allows for 25 quadrats per strip. To allow for the 75 quadrats in the control strips, a second version was written titled Cdat.pas. The R[strip number].dat files were transformed by the program 'Redat' and [strip number].new files were created. See Example 2 for the format of the resulting data file after manipulation by the program 'Redat'.

Program Redat was run on all files and the resulting files were saved as [strip number].new. Copies of these files were also created for safe keeping. At this point each file

⁴Tenhagen, M. D. 1992. Strip-cutting in shallow-soil upland black spruce near Nipigon, Ontario. V. Collection of regeneration, vegetation and seedbed data in 16 to 18 year-old strip-cuts. 53 Contractor's Rep., Sault Ste. Marie, Ont. Rep. 4Y050-2-0459/01-XE.

contained only the data from each strip. The *.new files were appended so that the resulting three data files called Regarea1.new, Regarea2.new, and Regarea3.new; each contained the entire data set for each area. These files were backed up for safe keeping. Each of the three files were subdivided into two files, one containing only the even numbered or first-cut strips

Example 2. Sample Portion of File Created by the Program Redat and/or Cdat.

```

      *
150 24 R192 10 0 2 2 000000 0 03 00 0 0 0 00000 0 00 00 0 0 0 00000 ...
150 25 R192 10 0 0 4 220000 0 02 70 0 0 3 30000 0 00 81 1 1 0 00000 ...
151  1 R192 00 0 0 0 000000 0 00 00 0 0 0 00000 0 00 00 0 0 0 00000 ...
151  2 R192 30 0 0 0 101000 0 00 00 0 0 0 00000 0 00 00 0 0 0 00000 ...
151  3 R192 41 3 4 1 000000 0 03 00 0 0 0 00000 0 00 00 0 0 0 00000 ...

```

The column designated with an * indicates the first species recorded within the quadrat. With eleven species codes (ten species plus "0" for no species), different species are represented in this column with the following "string" containing the data pertaining to that species.

and the other containing only the odd numbered, second-cut strips. These were saved as

A1odd.new, A2even.new, A2odd.new,
A3even.new, A3odd.new.

In 1992, Area 1 data was collected in the second-cut, or odd numbered, strips only. To obtain complete information pertinent to Area 1 (ie. first-cut strips) data collected by S. Taylor during the 1989 field season were used. The format of the data file Reg189.dat was different from the newer files. This file was manipulated to conform to the "*.new" format; the 'string' following the species code was composed of slightly different data bits and

condition codes were not collected in 1989. The resulting "string" of data following the species code contained 16 characters as opposed to 18 characters in the *.new files.

It was decided that an efficient method of analysis would be to use IBM compatible, PC based, spreadsheet software. Borland's Quattro Pro for Windows (Ver. 1.0) was chosen due to its ease of use and the built-in graphics capabilities.

A program, 'QPredat' was written to rearrange the *.new data files so that the first column in each set of species specific columns, would contain only a certain species, and would also place all species into dedicated columns and the resulting files were given the ".qpr" extension. This indicated that these were the files to import into the "Quattro Pro" spreadsheet package. In these *.qpr data files each species were grouped together for easier manipulation in Quattro Pro. The files were expanded in a way that allowed for all ten species. See Example 3 for format of the *.new files.

The source code for the program, Qpredat, is saved as Qpredat.pas and the executable code is saved as Qpredat.exe. A second version of Qpredat, titled QP, was written to conform the 1989 file to the *.new files. The resulting file was saved as A1even.new. The source code for the program, QP, is saved as QP.pas and the executable code is saved as QP.exe.

Example 3. Format of data *.qpr files.

	*	**
138 10R192	10 0 0 8 00000 0 03	20000000000000000000 3 1 0 0 1 0 00 ...
138 11R192	10 0 0 8 00000 0 03	20000000000000000000 300000000000 ...

138 12R192 10 0 0 8 00000 0 03 20000000000000000000 300000000000 ...

Note: All species are grouped together

* - Indicates species 1, Sb

** - Indicates species 3, Pj

The format of the *.qpr files is as follows:

1-3	...	Strip Number
4-6	...	Quadrat no.
7-8	...	Data type
9-10	...	Year
11-12	...	Species
13	...	Presence/Absence
14-15	...	Height Class 1
16-17	...	Height Class 2
18-19	...	Height Class 3
20-21	...	Height Class 4
22	...	Diameter Class 1
23	...	Diameter Class 2
24	...	Diameter Class 3
25	...	Diameter Class 4
26-27	...	DBH1
28	...	DBH2
29-30	...	Condition

The files imported into Quattro Pro required a format line to be "parsed" into individual cell addresses. The format line required for the 1992 data is as follows

V>>V>>L>V>[V>VV>V>V>VVVV>V>V]V>VV>V>V>VVVV>V>V...

Note: the portion enclosed in brackets is to be repeated 10 times

The format line required for the 1989 data is as follows:

V>>V>>L>[V>VVVV>V>VVVV>V>] V>VVVV>V>VVVV>V>...

Note: the portion enclosed in brackets is to be repeated 10 times

The resulting Quattro Pro worksheets were saved with the .WB1 file extension.

The following worksheets were created:

Area 1

A1Odd.WB1 - all odd-numbered strips
A189even.WB1 - all even-numbered strips(1989 data)
A189Odd.WB1 - all odd-numbered strips(1989 data)

Area 2

Area2Con.WB1 - control strips only
Area2All.WB1 - all strips
Ar2Even.WB1 - all even-numbered strips
Area2Odd.WB1 - all odd-numbered strips

Area 3

Area3Con.Wb1 - control strips only
Area3All.WB1 - all strips
Ar3Even.WB1 - all even-numbered strips
Area3Odd.WB1 - all odd-numbered strips

Copies of the above files were created for safe-keeping.

Calculations of the number of stems per strip was accomplished, using Quattro Pro for Windows worksheets, with the files in Section 6.5, using the following instruction:

@IF(X>0,1,@IF(X>0,1,@IF(X>0,1,@IF(X>0,1,@IF(X>0,1,@IF(X>0,1))))))

Note: X = cell address

The @IF function checks for the value in X and assigns a value of 1 (in this case). In this way if there was a value greater than 0 in the range of cell addresses a value of 1 was assigned. This reflected the presence of a species within a quadrat for a range of height and

diameter classes. Addition of the relevant columns yielded the absolute numbers.

The two versions of the program CheckForFrequency (saved as 5SpPres.pas and 5SpPresA.pas and included in Part 2, Appendix 1 Contractors Report 1992) were written to ascertain the frequency (%) of the presence of all species within each strip. Frequency for a species in this sense is the percentage of quadrats within a strip that had at least one stem of that species. The two versions of the program Pres (saved as Pres.pas and PresA.pas are included in Part 2, Appendix) were written to find overall frequency in all areas using the total number of quadrats, rather than by strip.

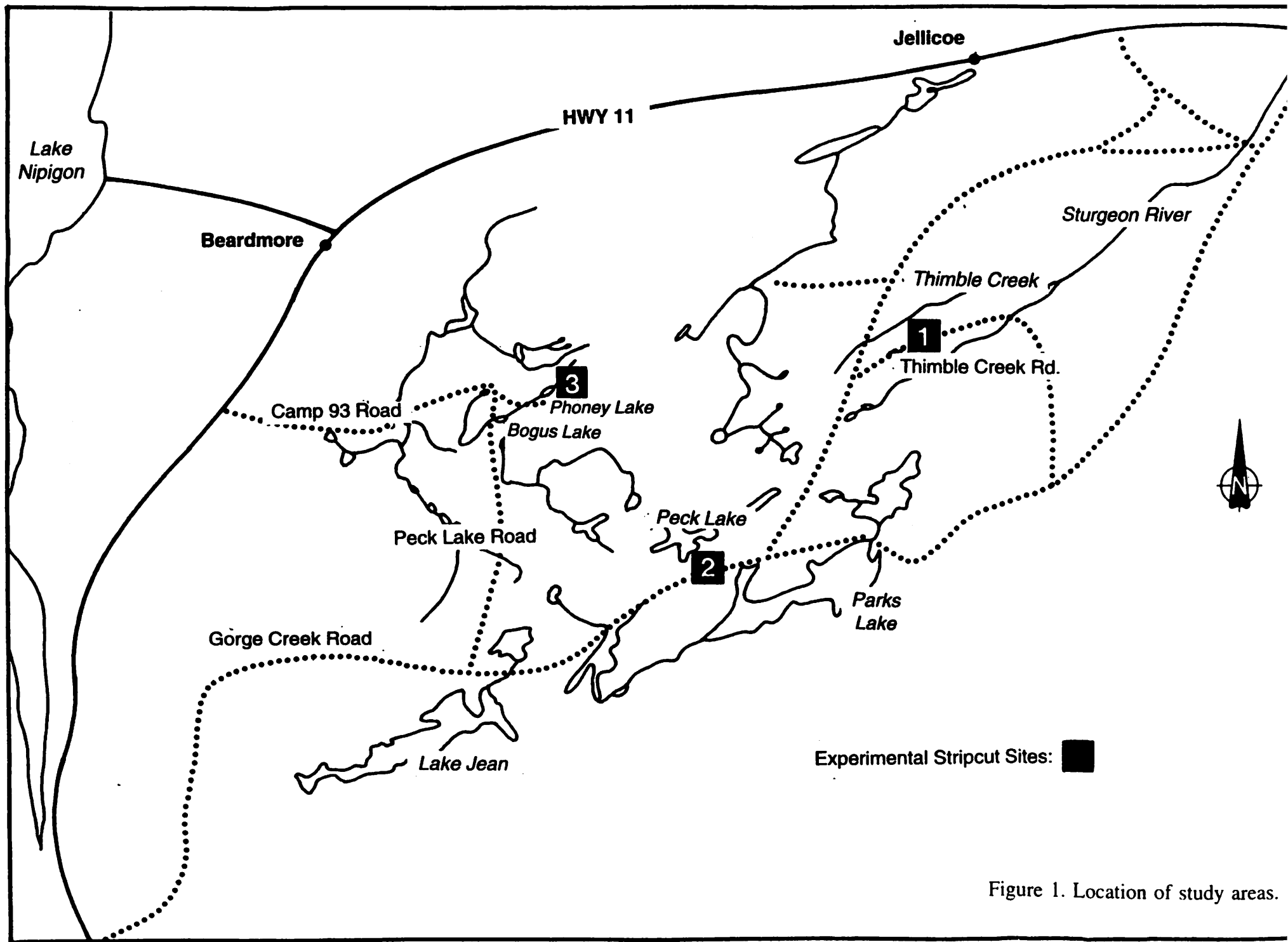


Figure 1. Location of study areas.

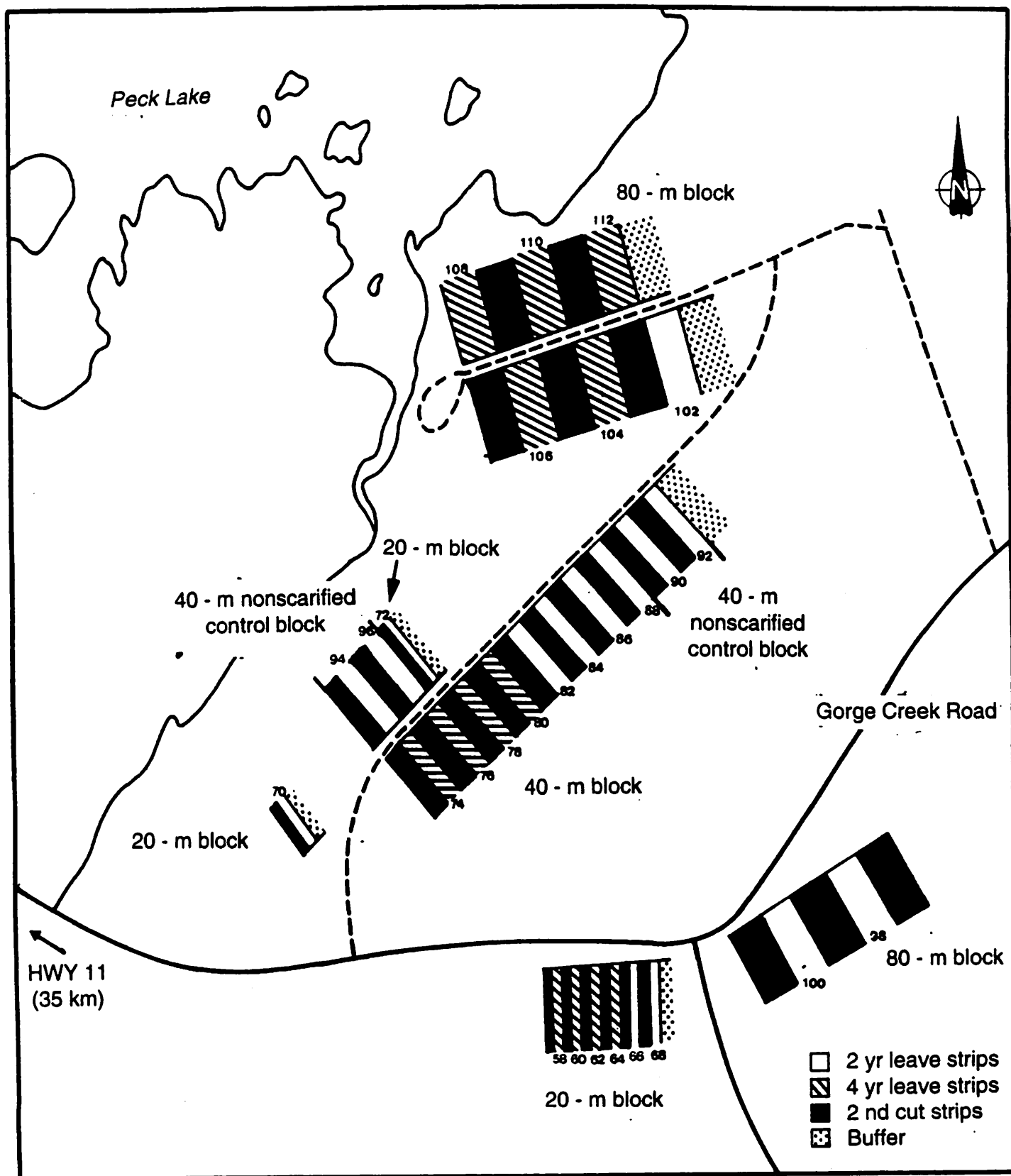


Figure 3. Layout of Area 2.

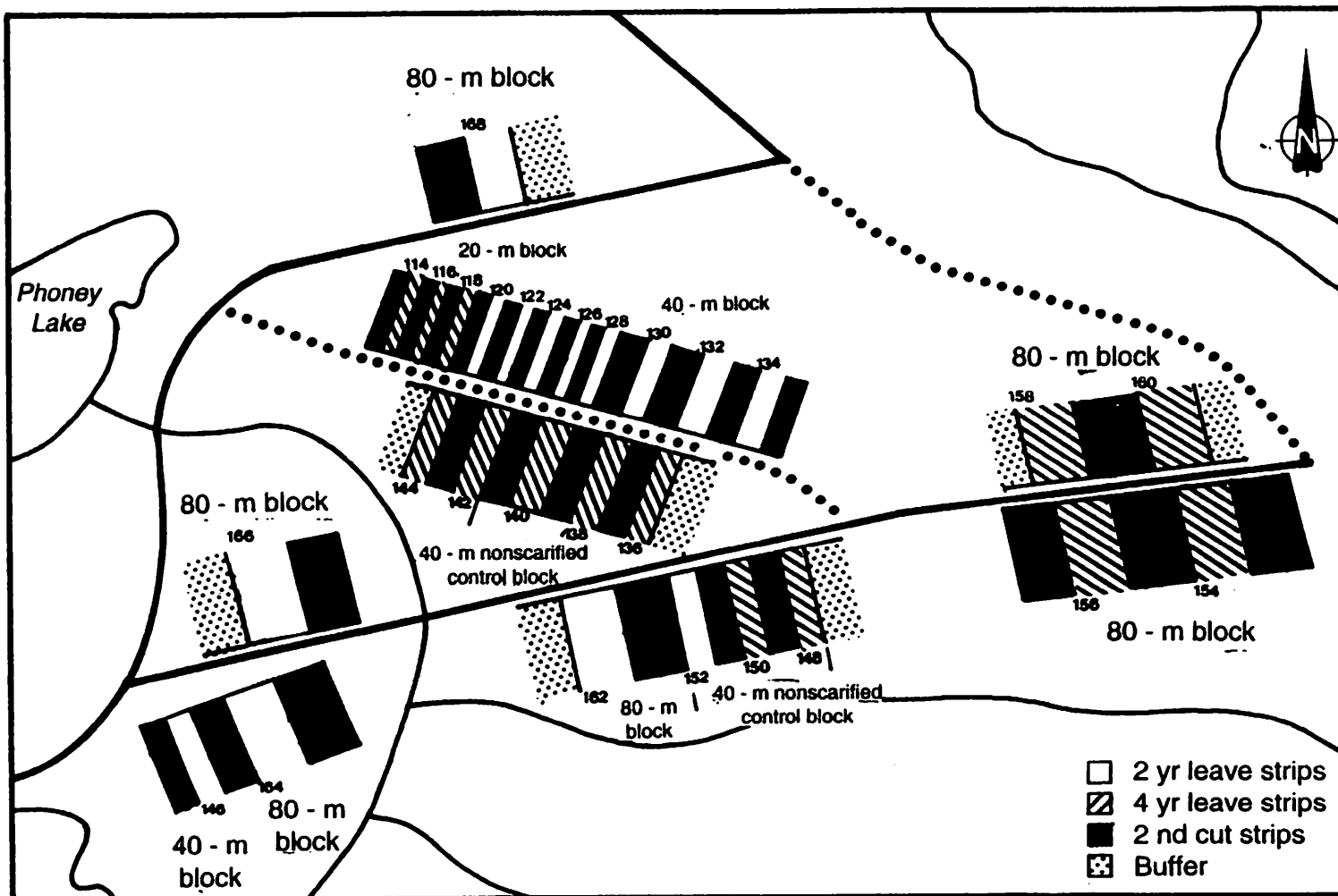


Figure 4. Layout of Area 3.

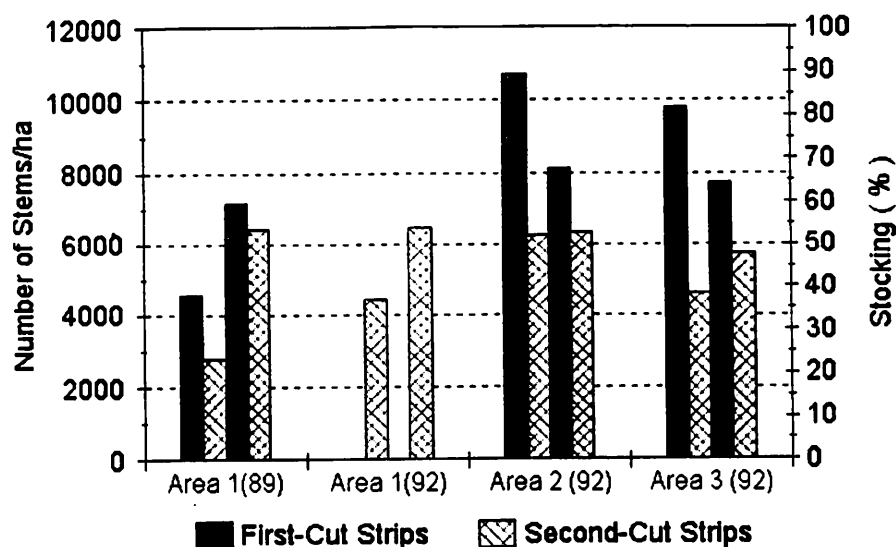


Figure 5. The number of stems of black spruce per hectare and stocking (%) in all areas (Note: No regeneration data were collected in 1992 for the first-cut strips in Area 1). For each category, first- and second-cut strips, the left bar refers to the number of stems/ha; the right to % stocking.

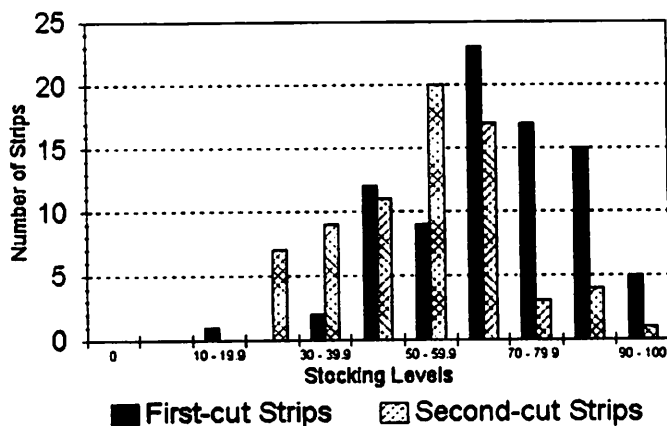


Figure 6. The number of strips and their levels of stocking of black spruce for stems up to 10 cm dbh; based on 25 quadrats per strip (75 in the control strips). Regeneration in the first-cut strips in Area 1 was assessed in 1989; the rest in 1992.

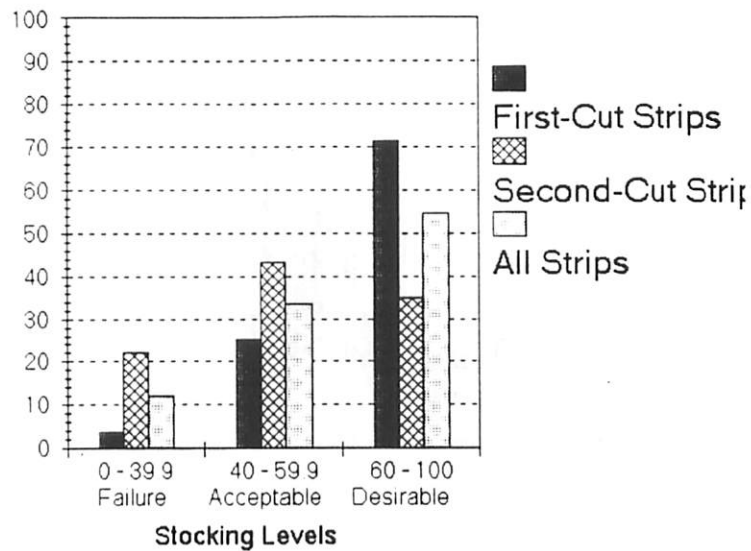


Figure 7. Overall frequency of strips achieving three levels of stocking (failure, acceptable and desirable) for stems up to 10 cm dbh for black spruce; based on 25 quadrats per strip (75 in the control strips).

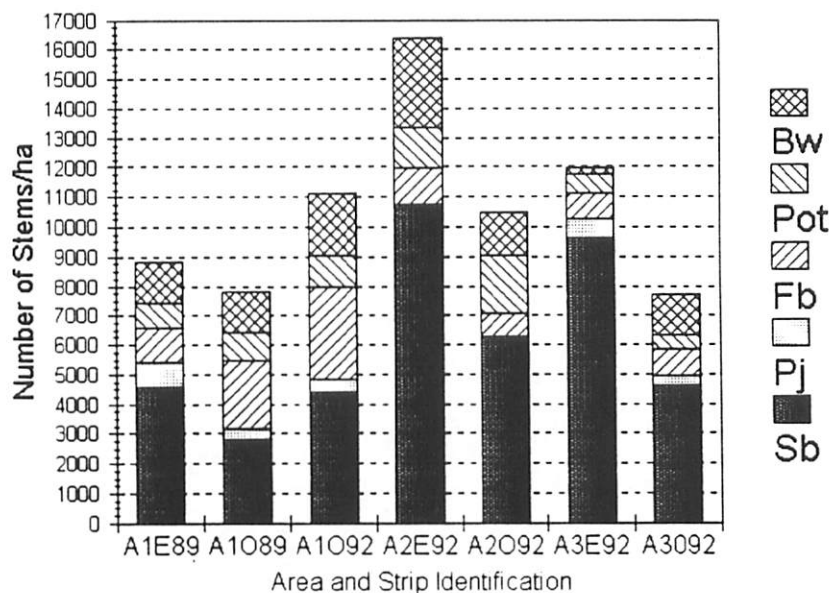


Figure 8. Summary of number of stems up to 10 cm dbh for all species in all areas. A1, A2 and A3 are Areas 1, 2 and 3. E = even-numbered first-cut strips; O = odd-numbered second-cut strips. Regeneration in the first-cut strips in Area 1 was assessed in 1989; the rest in 1992.

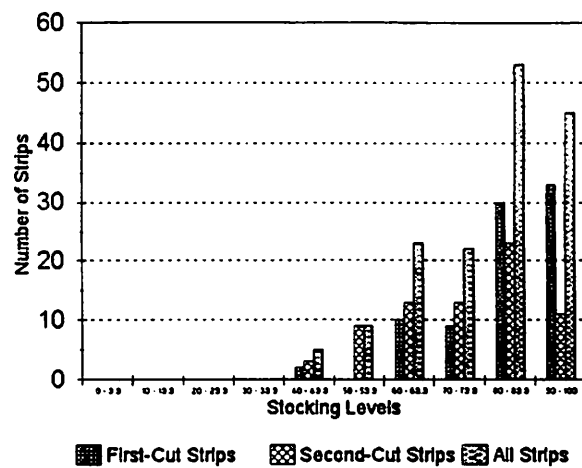


Figure 9. Number of strips achieving various levels of stocking for five major species combined for stems up to 10 cm dbh (cf. Fig. 2). Regeneration in the first-cut strips in Area 1 was assessed in 1989; the rest in 1992.

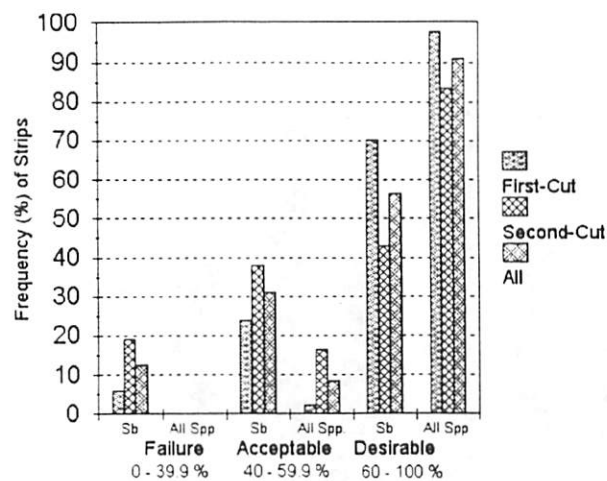


Figure 10. Overall frequency of strips achieving three levels of stocking (failure, acceptable and desirable) for stems up to 10 cm dbh for black spruce compared with the five major species combined. Regeneration in the first-cut strips in Area 1 was assessed in 1989; the rest in 1992.

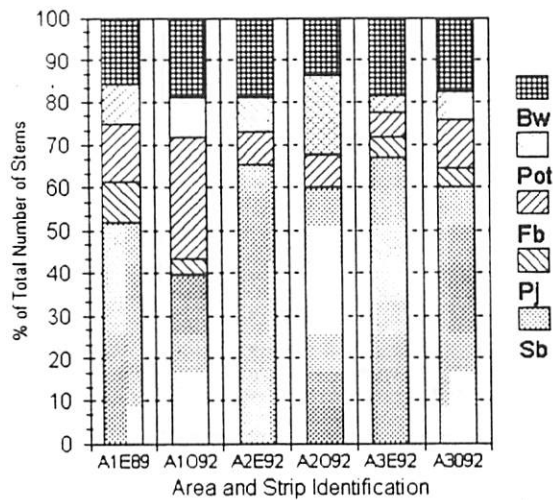


Figure 11. Stand composition - all species' numbers of stems/hectare as a percentage of the total number of stems per ha. A1, A2 and A3 are Areas 1, 2 and 3. E = even-numbered first-cut strips; O = odd-numbered second-cut strips. Regeneration in the first-cut strips in Area 1 was assessed in 1989; the rest in 1992.

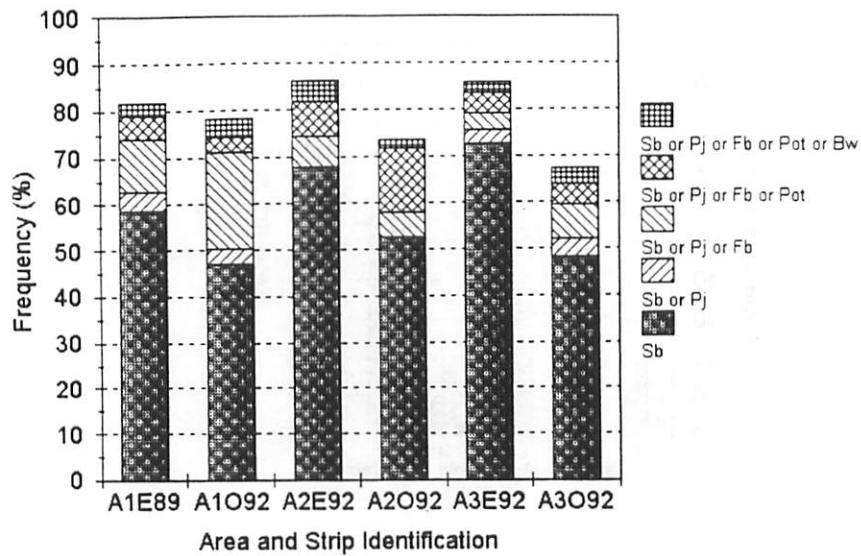


Figure 12. Five species cumulative frequency. The criteria for stocking is that one of the species included in the legend category must be present for the quadrat to be stocked. A1, A2 and A3 are Areas 1, 2 and 3. E = even-numbered first-cut strips; O = odd-numbered second-cut strips.

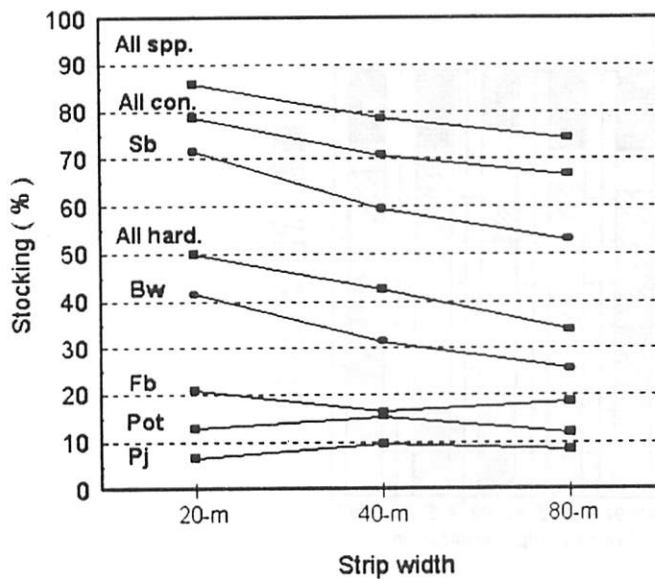


Figure 13. Levels of stocking of five species, all conifers, all hardwoods and all species in three widths of first-cut strips (24 strips of each width). Areas 2 and 3 were assessed in 1992 and Area 1 was assessed in 1989.

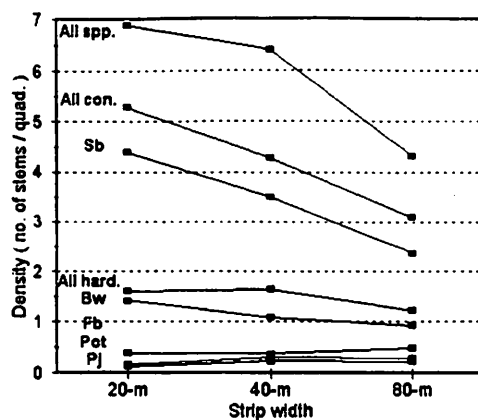


Figure 14. Density of five species, all conifers, all hardwoods and all species in three widths of first-cut strips (24 strips of each width). Areas 2 and 3 were assessed in 1992 and Area 1 was assessed in 1989.

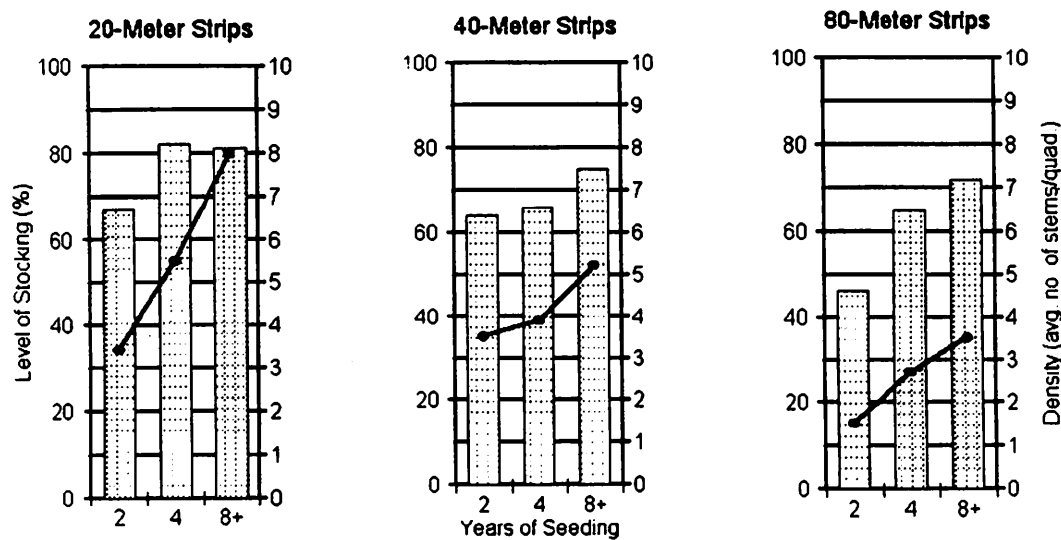


Figure 15. Levels of stocking and density of black spruce, for cut quadrats only, in the first-cut, 20-, 40- and 80-m strips with 2, 4, and 8+ years of natural seeding (stocking - bar, density - line).

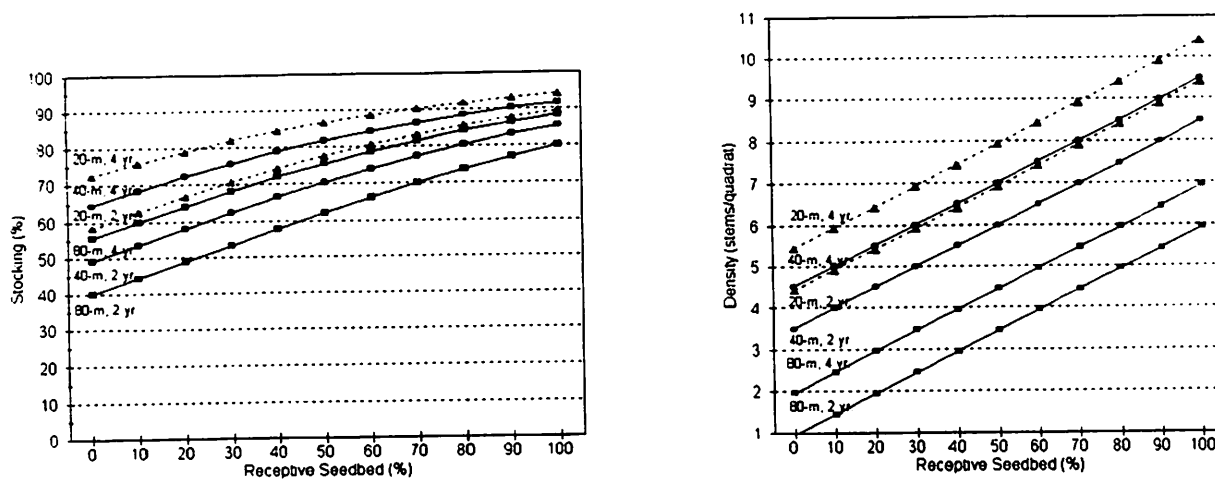


Figure 16. Predicted levels of density and stocking for a gradient of receptive seedbed (%). Points are predicted values calculated by best fit linear regression. Equations with mean square error, standard deviation and significance levels are presented in Table 23. Based on 1726, 2- x 2-m quadrats.