Forest Research Branch

A STUDY OF BLACK SPRUCE FORESTS IN NORTHERN QUEBEC

by

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Sommaire en français

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ABSTRACT

The origin, age structure, species composition, volume and basal area distribution, growth rate, mortality and reproduction of even and uneven-aged stands of six site types in a forest of five square miles, and changes which occurred from 1950 to 1961, are described. A comparison with yield table data is presented, some implications of the findings are discussed, and a need for additional investigation is indicated.

A Study of Black Spruce Forests In Northern Quebec[1]

by

R. J. Hatcher[2]

INTRODUCTION

The bulk of Quebec's pulpwood supply is harvested from Forest Sections B.1a (Rowe 1959), where black spruce[3] and balsam fir predominate, and B.1b where extensive forests of pure or nearly pure black spruce are found. The economic value of black spruce in Canada is indicated by an extensive literature on the silvics, silviculture and management of this species. However, little study or experimentation in black spruce stands has been reported in Quebec apart from forest classifications by Linteau (1955) and Lafond (1960), and some investigations of regeneration (Bellefeuille 1935, LeBlanc 1954, Linteau 1941, 1957, MacArthur and Gagnon 1961).

For forest management to advance from the basic economic aim of efficient harvesting to the goals of successful regeneration after harvest and increased production in second-growth stands, a knowledge of yield potentials, growth rates, age structure, species composition, stand development and regeneration habits must be acquired.

In 1950 the Forestry Branch established sample plots over a five-square-mile area in Forest Section B.1b to study the growth, yield and regeneration of black spruce and black spruce-balsam fir stands, and remeasured these plots in 1961. The objectives of this report are: (1) to show the variability in origin and age structure in the forests of the area, (2) to indicate the variability in stand structure, increment, yield, and advance reproduction in relation to forest site types, and to show the changes which occurred from 1950 to 1961, and (3) to compare the yield and increment of black spruce in Section B.1b, as represented by this area, with black spruce in other regions of Canada.

FOREST DESCRIPTION

The Forest Sections

Forest Section B.1b as delineated by Rowe (1959) is an east-west band about 800 miles long by 100-170 miles wide between the spruce-fir forests of Section B.1a to the south and the subarctic woodland to the north. Eastward from Sept-Iles, Quebec, B.1b borders on the Gulf of St. Lawrence. The more rugged topography of the east, with southward drainage through moderately deep-cut valleys, gives way in the west to a rolling terrain with meandering rivers flowing westward.

Black spruce is the most abundant tree on most sites, from the flat low peaty areas to the well-drained rocky uplands. Fir is scarce relative to Section B.1a. Small groves of white birch are common, particularly in forests of recent fire origin where it also forms mixedwood stands with black spruce. Aspen, balsam poplar and tamarack are sparsely represented. Stands of jack pine are restricted to the west part of the Section.

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[1]Department of Forestry Canada, Forest Research Branch Contribution No. 532.
[2]Research Officer Forestry, Forest Research Branch, Dept. of Forestry, Quebec.
[3]Nomenclature as in "Native Trees of Canada", Bulletin 61. Dept. of Forestry. 6th ed. 1961.

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The Section has a long history of frequent and extensive forest fires and from the air it presents an interesting mosaic of fire stands of different ages. Regeneration after some of these fires has provided dense and high-volume black spruce stands comparable to any in the Province.

The Study Area

The three blocks of the study area border Lake St. Pierre (50°10′N, 68°25′W) 70 miles north of Baie-Comeau and the St. Lawrence River (Figure 1). The topography varies from relatively flat areas which border many of the principal streams (Block 2) to steep slopes which often begin almost at the lake shores (Block 3). The summits of the larger mountains frequently are flat. Elevation above sea level varies from about 1,050 to 1,900 feet.

Meteorological data are scarce and the closest inland station is at Labrieville (elevation 500 feet), 80 miles to the southwest. Four-year records[1] (1958–1961) indicated an average annual precipitation of 33.6 inches, 9.2 of which fell as snow. Mean July temperature was 63.5°F.

The forest in the study area is composed of three distinct age structures: (1) uneven-aged black spruce and black spruce-balsam fir stands of unknown origin in which trees as old as 280 years are found, (2) even-aged 64-year-old stands of black spruce and black spruce-white birch which occupy a small part of a large burned area (Figure 2) and (3) even-aged 120-year-old black spruce stands which include most of a small burned area (Figure 3).

The Forest Site Types

At the 1961 remeasurement the sample plots were classified by site types recognized and defined by Linteau (1955). The types found at Lake St. Pierre are described briefly below:

Hypnum Type (Hyp). This is a good, upland, black spruce type with an average site index of 37 at 50 years. Uneven-aged stands are 75-80 per cent spruce (basal area) with a codominant fir element. Even-aged fire-origin stands contain about the same proportion of spruce, but with the remainder divided equally between fir and birch. The forest floor is a continuous carpet of *Calliergon schreberi* and *Hypnum crista-castrensis* generally free of all herbs or ferns.

Calliergon-Vaccinium Type (Cal-Va). Described by Linteau (1955) as usually occupying dry flat terrain, this type was found on the dry steep upper slopes of the 1896 burn (Figure 2). Black spruce forms 70 per cent of the stand, white birch 25 per cent and fir 5 per cent. *Calliergon schreberi* is present in large patches and *Vaccinium pensylvanicum* is the main shrub but patchy in distribution.

Kalmia-Ledum Type (Ka-Le). This type is predominantly black spruce with a little fir and birch, and is found both on gentle lower slopes bordering lakes and gentle upper slopes where bedrock is overlain by a few inches of sand. A high water table results in defective drainage forming a peculiar vegetation pattern of alternating *Sphagnum* and *Hypnaceae* mosses. *Kalmia anqustifolia* and *Ledum groenlandicum* of equal abundance grow in regularly distributed tufts.

Kalmia-Ledum, cladonia sub-type (Ka-Le, clad.). As a result of the 1961 vegetation-study a sub-type of the Ka-Le type has been defined. Stands are dominantly black spruce but are more open, and spruce has a different height-diameter relationship, than in the typical Ka-Le. Found at both low and high elevations it always has a very thin sand layer overlying bedrock or boulders. Although the site looks dry the large patches of *Cladonia* lichens often provide

[1]Quebec, Department of Industry and Commerce, Bureau of Statistics, Meteorological Bulletins.

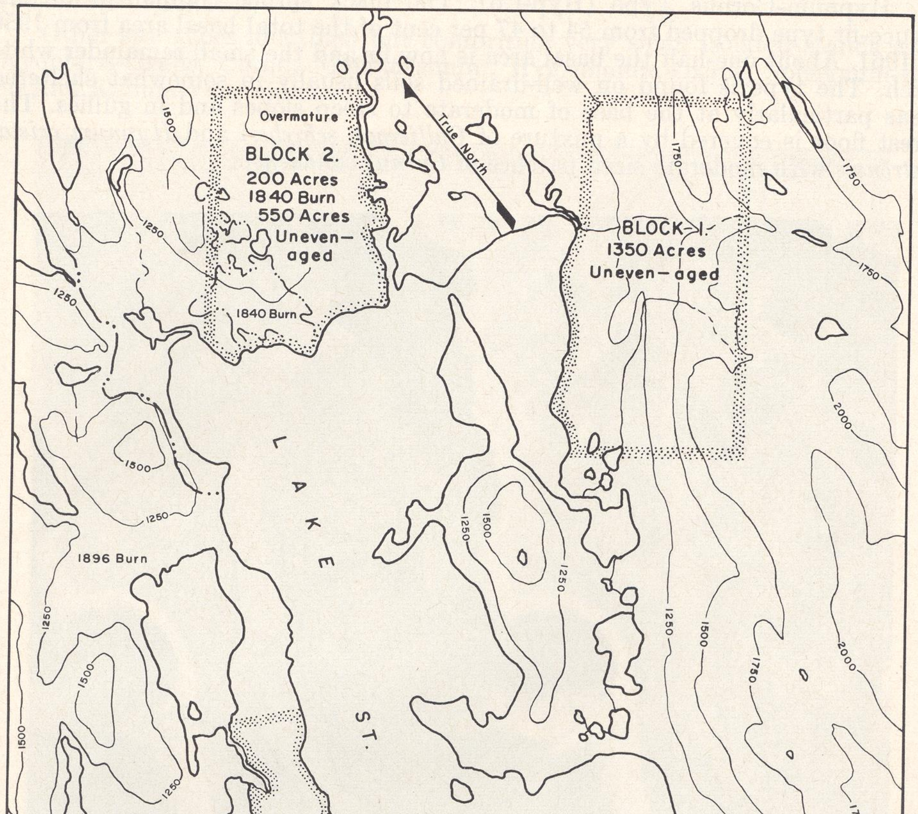

Figure 1. Topographic and age class map, Lake St. Pierre, P.Q.

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a slippery or greasy footing. The sub-type is easily distinguished from the typical Ka-Le by the openness of the stand, the presence of *Cladonia* spp. in large patches and the lesser abundance of *Sphaqnum* and *Hypnaceae* mosses.

Hypnum-Cornus Type (Hyp-Co). The black spruce component of this spruce-fir type dropped from 54 to 47 per cent of the total basal area from 1950 to 1961. About one-half the basal area is now fir and the small remainder white birch. The type is found on well-drained soils usually in somewhat sheltered areas particularly at the base of moderate to steep slopes and in gullies. The forest floor is covered by a mixture of *Calliergon schreberi* and *Hypnum crista-castrensis* with moderate sized patches of *Cornus canadensis*.

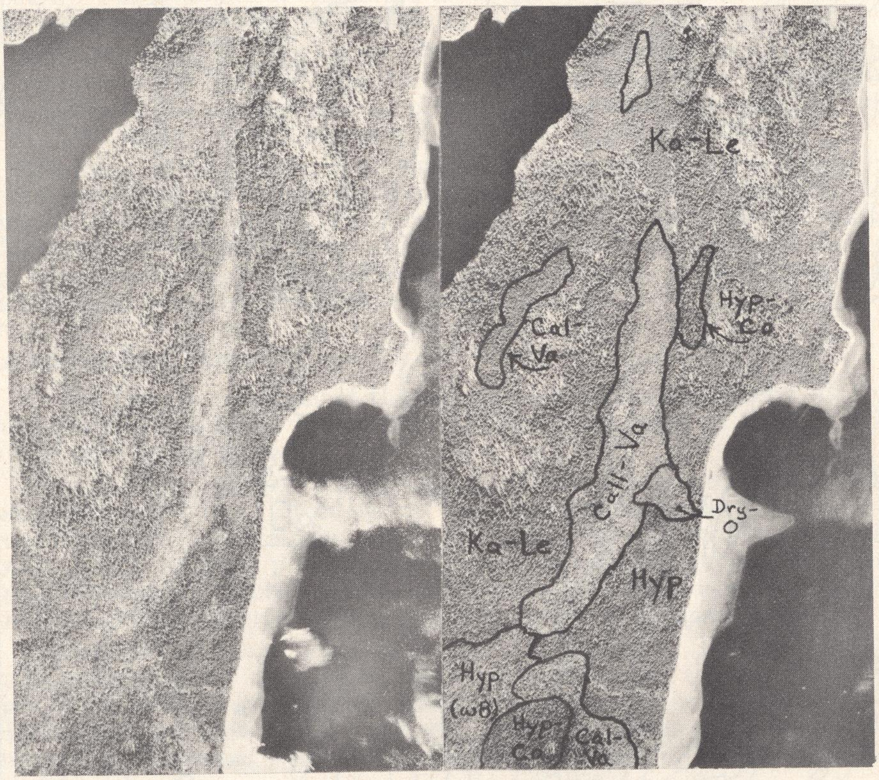

Figure 2. Stereogram of 1896 burn in Block 3. Open, light-coloured patches within Ka-Le represent the Cladonia sub-type

Hypnum-Hylocomium Type (H-H). Black spruce currently contributes 55 per cent, fir 41 per cent and birch 4 per cent of the total basal area. The occasional white spruce is seen. The site is characteristic of the gentle lower slopes and is reasonably moist. Large patches of *Hylocomium splendens* alternate with smaller ones of *Calliergon schreberi* and *Hypnum crista-castrensis*. Several herbs are present but form no definite layer; the most frequent are *Cornus canadensis*, *Coptis groenlandica*, *Clintonia borealis* and *Maianthemum canadense*.

Hylocomium-Cornus Type (H-Co). Linteau (1955) considers this type to be an infrequent local variant of the H-H type. It is the only type at Lake St. Pierre in which fir dominates to the extent of 80 per cent by basal area. Black spruce plus a few white spruce provide 15 per cent of the basal area and birch the small remainder. The type is most often found in the narrow valleys and gullies of streams in protected places with south or southwest aspects. More herbs were present than in any other type with *Cornus canadensis* and *Maianthemum canadense* the most abundant. The small patches of moss are mainly *Hylocomium splendens.*

Other site types identified but comprising very small isolated stands were Dryopteris-Oxalis, Cornus-Maianthemum, Hylocomium-Oxalis, Sphagnum-Rubus and Kalmia-Vaccinium.

Figure 3. Stereogram outlining 1840 burn in Block 2. Uneven-aged black spruce on right

METHOD OF STUDY

Field

In 1950 ten-chain grids of permanent tenth-acre square sample plots were established in each of the three blocks. Classification of the 259 plots was by cover type and general stand appearance and on each plot the following data were recorded: (1) d.b.h. in one-inch classes, by species, of all trees 0.6 inch d.b.h. and over, (2) d.b.h. of trees judged to have died between 1940 and 1950, (3) reproduction stocking on 10 milacre quadrats, by species, in two size classes, (4) three or four height-diameter measurements, (5) one or two age counts, and (6) a brief general plot description comprising notes on lesser vegetation, topography, drainage and stand origin. All living trees were bark-scribed with a short vertical stroke, and dead trees were scribed with an "x".

At the 1961 remeasurment the following information was recorded: (1) d.b.h. as in 1950, (2) d.b.h. of trees known from scribe marks to have died since 1950, (3) reproduction by species and origin, in two size classes on a single milacre quadrat, (4) three height-diameter-age determinations, (5) a detailed

TABLE 1. LINE PLOT CLASSIFICATION, 1961

Stand Origin	Number of Tenth-Acre Line Plots and Per Cent of Total								
	Spruce Forest				Spruce-Fir Forest			Others	Total
	Hypnum	Calliergon-Vaccinium	Kalmia-Ledum	Kalmia-Ledum, clad.	Hypnum-Hylocomium	Hypnum-Cornus	Hylocomium-Cornus		
Unknown	26	1	61	30	26	14	11	22	191
(Uneven-aged Stands)	*14%*	*<1%*	*32%*	*16%*	*14%*	*7%*	*6%*	*11%*	*100%*
Fire, 1840	8		2	8					18
	44%		*12%*	*44%*					*100%*
Fire, 1896	13	10	8	6		1		12	50
	26%	*20%*	*16%*	*12%*		*2%*		*24%*	*100%*
Total	47	11	71	44	26	15	11	34	259

vegetation relevé, and (6) a brief soil profile description. Living trees 3.6 inches d.b.h. and over were scribed with a short horizontal stroke at the point of measurement; living trees below 3.6 inches d.b.h. were not scribed. This procedure will permit a measure of ingrowth to be made at the next remeasurement. In order to obtain more data on the age structure of uneven-aged stands, ten 1/40-acre plots were located in representative stands. All trees 0.6 inch d.b.h. and over were cut at the root collar and discs were retained for accurate age counts. Height and d.b.h. also were measured on these trees.

Office

The 1961 vegetation relevé cards were checked against Linteau's (1955) classification as a first step in compilation. A vegetation table was made for the Ka-Le type to facilitate separation of the typical from the *Cladonia* sub-type. Site Index was used as an aid in classifying some doubtful plots. The remaining plots of doubtful site type, types sparsely represented and transition types were omitted from analysis. The distribution of plots by origin and site type is shown in Table 1. The per cent of the total number of plots represented by each type indicates its approximate proportion of the total area.

Height/diameter curves were drawn for black spruce and balsam fir for each site and age structure and compared with curves drawn for volume and yield table purposes by the Forest Research Branch in Quebec. As the curves were almost identical for a given species and type, volumes were calculated using the existing volume tables. Ages at the root collar from the ten 1/40-acre plots were determined in the laboratory by use of a binocular microscope.

RESULTS

Data are presented under five sub-headings: (1) Stand Origin and Age Structure; for both even and uneven-aged stands. (2) Numbers of Trees and Basal Area; data for 1950 and 1961 are presented by site and age structure. Numbers of trees are shown also by species in one-inch diameter classes. Basal area proportions by species are indicated. (3) Yield; both total and merchantable volumes are presented by site, age and species. Volumes are given also by species and diameter groups. (4) Growth; gross and net growth, 1950-1961, are presented by site, age and species, and net growth four inches d.b.h. and over is included. Mean annual increment to 1950 and to 1961 for fire-origin stands are presented by site, age and species. (5) Comparison with Yield Table Data; comparisons of numbers of trees, basal areas, total volumes and mean and current annual increments are made between Lake St. Pierre stands and values for Ontario, Saskatchewan and Alberta black spruce forests.

Stand Origin and Age Structure

In 1950 three age classes were tentatively established from a limited number of tree age counts. These classes were: (1) overmature even-aged stands, (2) 50-year fire-origin stands, and (3) 100-year fire-origin stands. In 1961 over 1,000 tree ages were counted to verify the origin and age structure of these three classes.

In the overmature stands the age frequency distributions by diameter classes for spruce and fir on each site type revealed a definite uneven-aged distribution for fir and also an element of uneven-aged structure for spruce. This was true both for the line plot and the 1/40-acre plot data.

Clearly the curves of tree distribution by diameter class do not conform to the typical bell-shape curves of even-aged stands (Figures 7 and 8), but the peak frequencies in the 6 inch and 7 inch spruce diameter classes suggest the presence of an even-aged spruce element. The possibility of a mosaic age structure with patches of both even and uneven-aged forest was eliminated by checking tree ages on individual plots. Usually a wide range in age occurred on a given plot, often up to 100 years or more.

To examine the somewhat complex age structure, the spruce frequency distribution by diameter and age classes was studied. The similarity in age distributions justified combining of data from different sites and plots. The distribution of these age samples through the diameter classes (Table 2) is proportional to the actual stand table for the combined sites for trees four inches d.b.h. and over. The small numbers of ages in the 1-3 inch classes are indicative of the difficulty in locating spruce saplings of seed origin. Most stems of this size were layers and attempts to discover where on the stem the age should be determined were unsuccessful.

The apparently even-aged spruce element was separated from the remainder of the stand by establishing even-aged stand limits of 25 per cent[1] of the approximate 200-year natural spruce rotation age. Using the 141-150 year age class with the largest age frequency as the mid-point, horizontal lines were drawn to include ages from 121 to 170 years (Table 2). Thus the total spruce age sample was divided into three parts: (a) an uneven-aged element, (b) an even-aged main stand, and (c) what was now considered as a veteran element from the previous stand. The proportions of (a), (b) and (c) by diameter class were plotted and adjusted curve values were obtained. The adjusted proportions for the age sample were then applied to the black spruce stand tables. The resultant diameter distribution curves for the sites involved, particularly the Hypnum and Kalmia-Ledum, were as expected (Figure 4). Also expected was the bell-curve peak of the richer Hypnum type plotting lower than, and to the right of, the peak for the Kalmia-Ledum.

Examination of the age data for the two age classes tentatively classified in 1950 as 50-and 100-year fire-origin forests revealed that these forests were even-aged. The presence of an occasional dead fire-charred trunk or stump, the abundance of carbon deposits on the surface of the mineral soil, the absence of a thick humus horizon, the relatively high proportion of white birch, and the low volumes of fir further testify to the fire origin of these stands.

No records exist from which these fires can be dated. No evidence of release on trees in adjacent unburned stands was discovered and no living trees with fire scars were noted. Thus the dates of the fires were established by comparing the range in tree age with age ranges of three other forests of known fire origin. An interesting recent study of two burned forests of known age in the Gaspé Peninsula (MacArthur and Gagnon, 1961) indicated a time lag in seedling establishment after fire, followed by a rise to a peak establishment year. These data, plus unpublished data from a 1960 study of a burn of known date at Lake Métis, Quebec, were plotted (Figure 5). For the young stands at Lake St. Pierre a short peak period of seedling establishment also was discovered, and this peak was plotted under the peaks for Lake Métis and York River, nine years since fire. The Lake St. Pierre curve for black spruce was remarkably similar to the white spruce curve at Lake Métis and started at one year since the origin year for the other burned areas. Thus nine years were added to tree age at the peak year, and four years added to adjust for the height of age borings above the ground (4-6 inches) to arrive at the reasonably accurate date of fire of 1896.

The 1840 fire date for the older burn was established in the same manner although with fewer age samples. The true date of this fire is believed to fall within a range of plus or minus two years from 1840.

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[1]Maximum per cent age range, even-aged stand, as defined in Forest Terminology, Society of American Foresters, 1950.

TABLE 2. BLACK SPRUCE AGE FREQUENCY BY DIAMETER AND AGE CLASSES, UNEVEN-AGED FOREST, KA-LE; KA-LE, CLAD.; HYP, HYP-CO AND H-H TYPES COMBINED

Stand Element	Age Class Years	Frequency of Age Samples — Diameter Class-Inches: 1	2	3	4	5	6	7	8	9	10	11	Total
(a) Uneven-aged	31–40	2	—	—	—	—	—	—	—	—	—	—	2
	41–50	—	—	—	—	—	—	—	—	—	—	—	—
	51–60	—	—	—	2	—	—	—	—	—	—	—	2
	61–70	—	1	3	3	1	—	—	—	—	—	—	8
	71–80	1	—	1	2	2	—	1	—	—	—	—	7
	81–90	1	—	—	6	4	1	—	1	—	—	—	13
	91–100	2	—	—	6	2	4	1	—	—	—	—	15
	101–110	2	—	2	8	4	2	3	1	1	—	—	23
	111–120	—	—	3	5	9	5	3	1	1	—	—	27
(b) Even-aged Main Stand	121–130	—	—	1	16	9	7	7	2	4	2	2	50
	131–140	—	1	2	11	14	12	8	9	7	2	—	66
	141–150	—	1	—	9	16	13	13	17	7	2	1	79
	151–160	—	—	2	7	10	7	16	10	4	1	2	59
	161–170	—	—	1	6	9	10	8	7	7	2	—	50
(c) Veterans	171–180	—	—	—	3	4	5	7	3	2	4	1	29
	181–190	—	—	—	4	2	4	6	5	2	1	1	25
	191–200	—	—	1	3	—	3	—	1	2	1	1	12
	201 +	—	—	—	1	3	5	2	1	1	3	—	16
	Value	a, b and c as Per Cent of Total for Diameter Class											
a	Actual	—	—	57	35	25	15	11	5	5	0	—	
	Curve	*100*	*98*	*77*	*36*	*24*	*16*	*11*	*5*	*2*	*0*	*0*	
b	Actual	—	—	37	53	65	63	69	78	76	50	—	
	Curve	*0*	*2*	*17*	*52*	*61*	*68*	*73*	*75*	*73*	*56*	*21*	
c	Actual	—	—	6	12	10	22	20	17	19	50	—	
	Curve	*0*	*0*	*6*	*12*	*15*	*16*	*16*	*20*	*25*	*44*	*79*	

Number of Trees and Basal Area

A large ingrowth of conifer saplings occurred in uneven-aged stands since 1950 (Figures 6, 7, and 8) indicating a period of rapid and significant change. The result was a substantial increase in numbers of trees per acre (Table 3). In contrast, numbers of trees hardly changed in the 1840 stands and the slight downward and rightward shifts of the diameter distribution curves since 1950 suggest a normal, stable, stand development (Figure 9).

A large and unexpected increase in the numbers of trees occurred in the 1896 stands, and the typical bell-shaped curve of even-aged stands has not evolved (Figure 10). Seedlings are evidently still entering the sapling category and are filling openings that resulted from either low initial stocking or from the dying out of white birch. In 1961, up to 3,000 spruce and fir per acre below 0.6 inch d.b.h. were still present (Table 4). This ingrowth did not occur where initial conifer stocking was dense (Figure 11).

As expected, spruce regeneration of layer origin outnumbered those of seedling origin on all sites except the relatively rich Hylocomium-Cornus (Table 4, Figure 12). Most fir regeneration was of seedling origin although layering was not uncommon.

Basal areas show corresponding changes since 1950 (Table 3). Notably the largest basal areas of 189 and 161 square feet per acre were found in fire-origin stands. In uneven-aged stands, much of the sapling increase was fir and resulted in increased proportions of fir basal area, particularly in spruce-fir stands (Figure 13). In fire-origin stands spruce increased its proportion of the total basal area at the expense of white birch.

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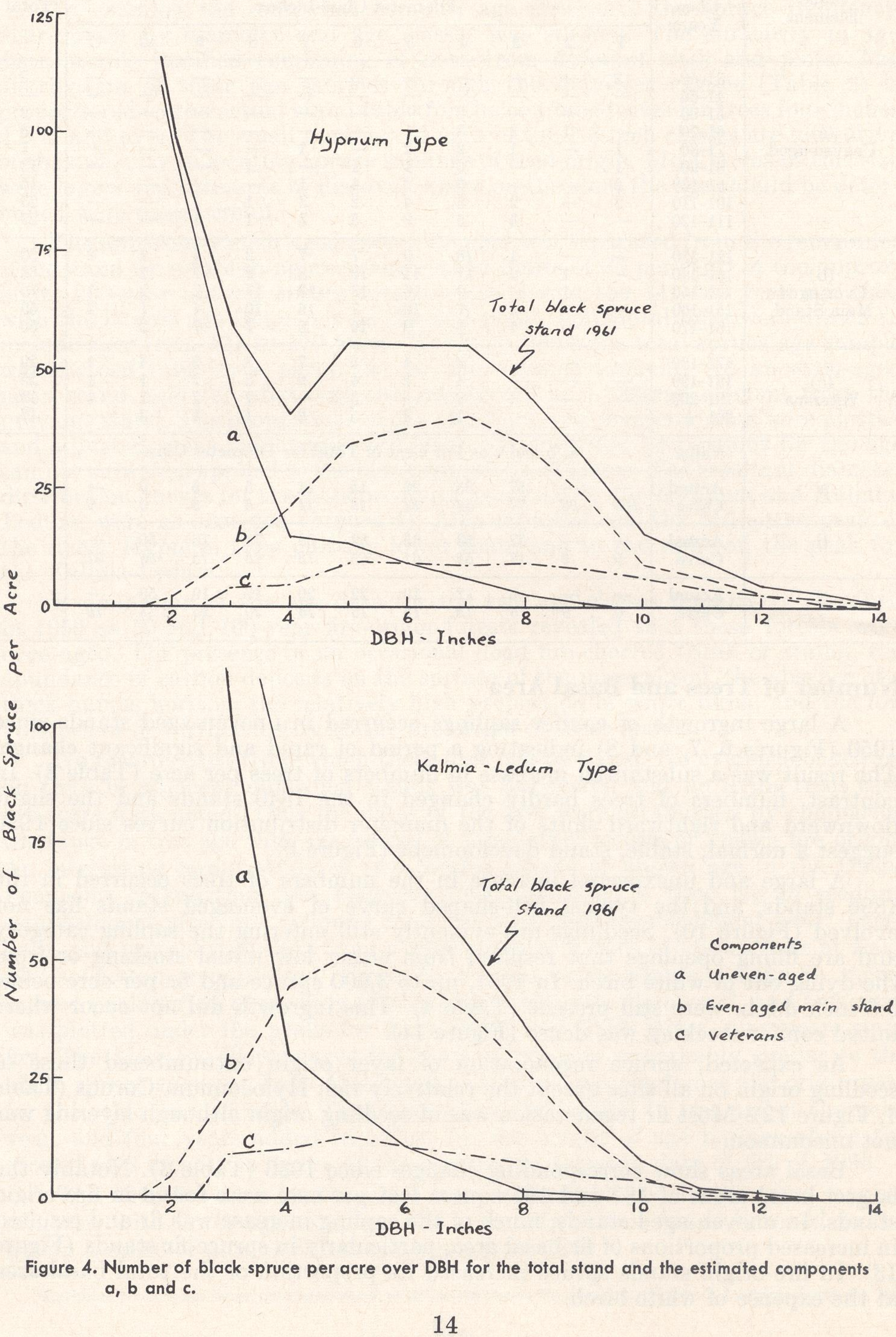

Figure 4. Number of black spruce per acre over DBH for the total stand and the estimated components a, b and c.

Although in these, as in all the data, variations due to different site productivity are evident, nevertheless very few spruce trees over 12 inches d.b.h. are present on any site.

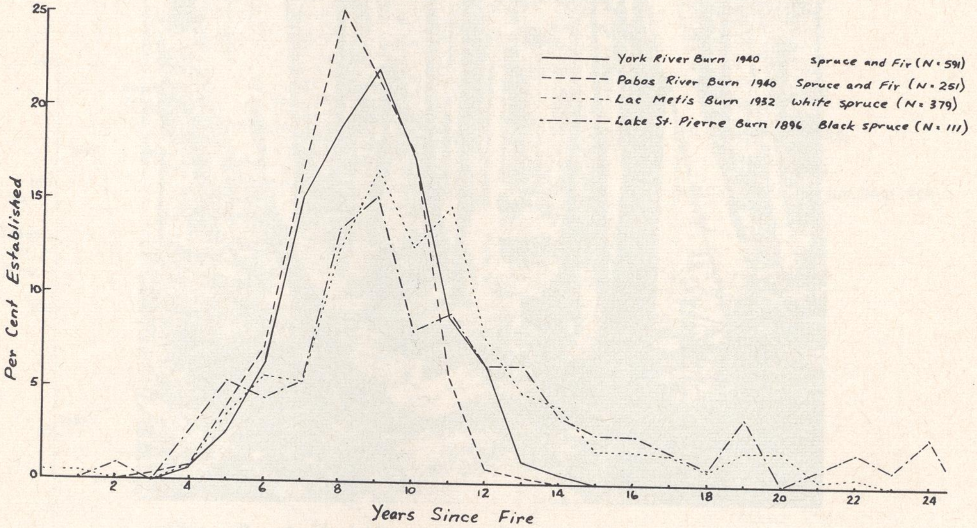

Figure 5. Rate of seedling establishment by years since fire

Yield

Changes in uneven-aged stand volumes since 1950 correspond to changes in numbers of trees and, since much of the sapling ingrowth was fir, an increased fir proportion is again evident (Tables 5 and 6). Spruce volume actually decreased on two sites and merchantable volume decreased on three sites. Mortality, which ranged from 151 to 501 cubic feet per acre (Table 7), was more than balanced by growth and sapling ingrowth which resulted in small total volume increases ranging from 61 to 230 cubic feet per acre. However, maximum volume increase for trees four inches d.b.h. and over was only 111 cubic feet with two sites registering a decrease.

In the 1896 stands a remarkably large increase in volume occurred and the largest total volumes in 1961 of 3,326 and 3,291 cubic feet were found for the Hypnum type in the 1840 and 1896 stands respectively. Some of the finest stands of black spruce occur in the 1840 forest (Figure 14).

Changes in volume distribution through the diameter classes were as expected, with the noted exception of the large increase in the 1-3 inch diameter group in the 1896 forest (Figures 15 and 16).

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Figure 6. Uneven-aged Hypnum-Hylocomium stand showing fir saplings in the understorey

TABLE 3. NUMBER OF TREES AND BASAL AREA PER ACRE, BY YEAR ONE INCH D.B.H. PLUS

Site Type	Number of Trees 1950	1961	Basal Area, Square Feet 1950	1961
	Uneven-Aged Spruce-Fir Stands			
Hyp-Co	908	1,921	117	131
H-H	995	1,778	127	139
H-Co	1,201	2,609	122	139
	Uneven-Aged Spruce Stands			
Hyp	925	1,463	125	130
Ka-Le	853	1,276	93	100
Ka-Le, clad	926	1,345	69	74
	1840 Fire-Origin Stands			
Hyp	1,737	1,681	148	161
Ka-Le, clad	1,972	2,032	122	139
	1896 Fire-Origin Stands			
Hyp	3,358	4,694	121	189
Cal-Va	2,016	2,578	106	148
Ka-Le	1,685	2,481	67	110
Ka-Le, clad	939	1,452	41	64

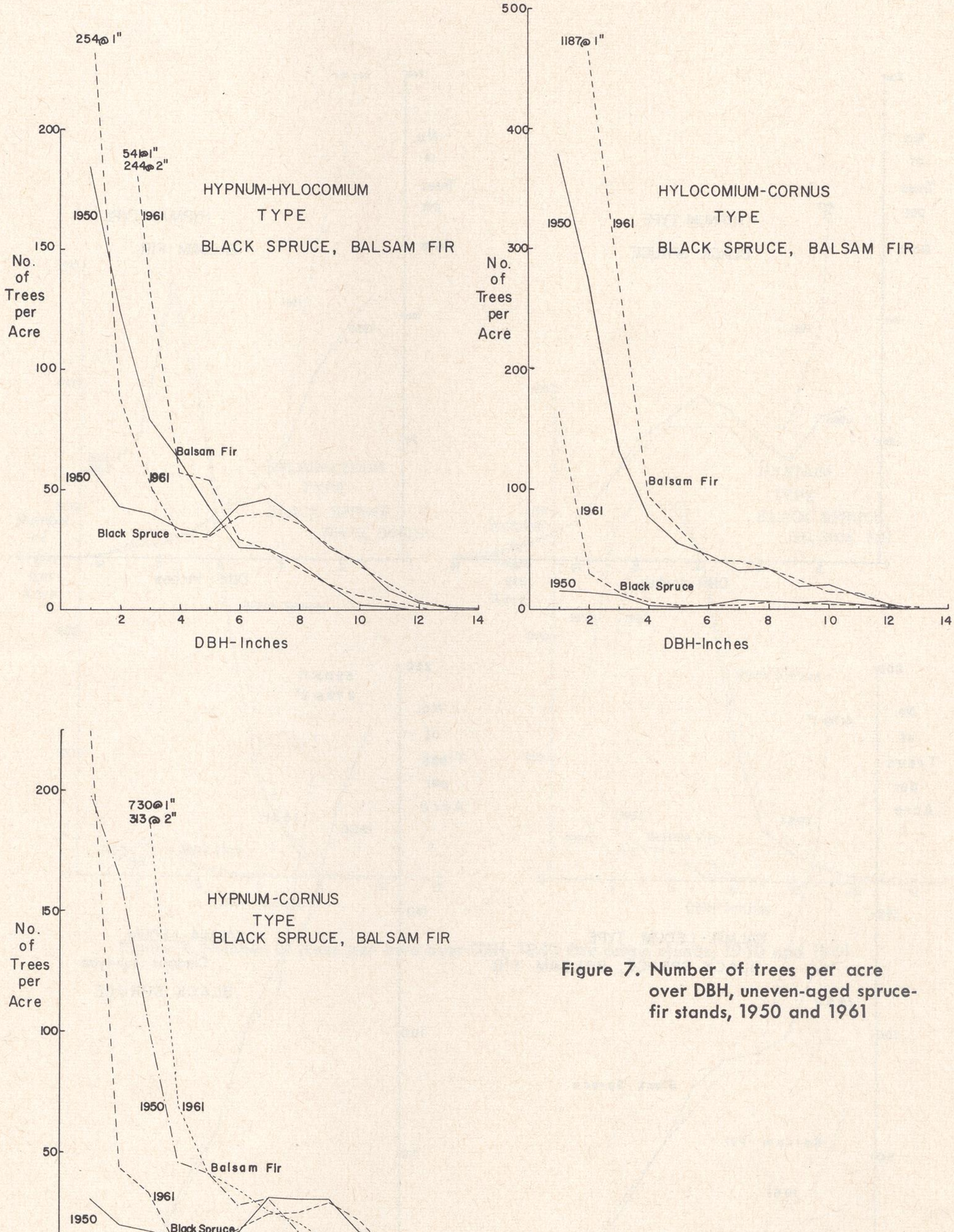

Figure 7. Number of trees per acre over DBH, uneven-aged spruce-fir stands, 1950 and 1961

Figure 7

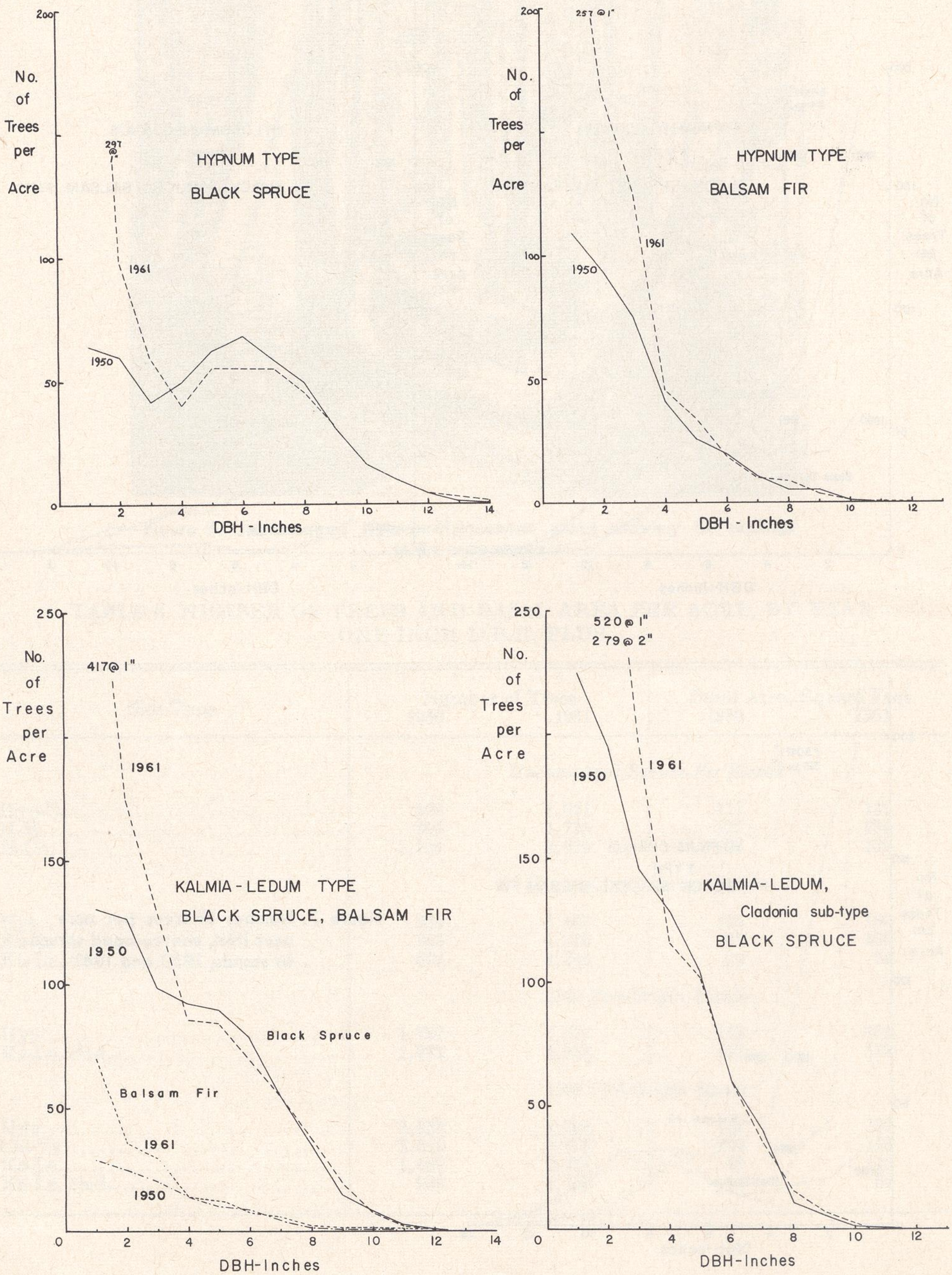

Figure 8. Number of trees per acre over DBH, uneven-aged spruce stands, 1950 and 1961

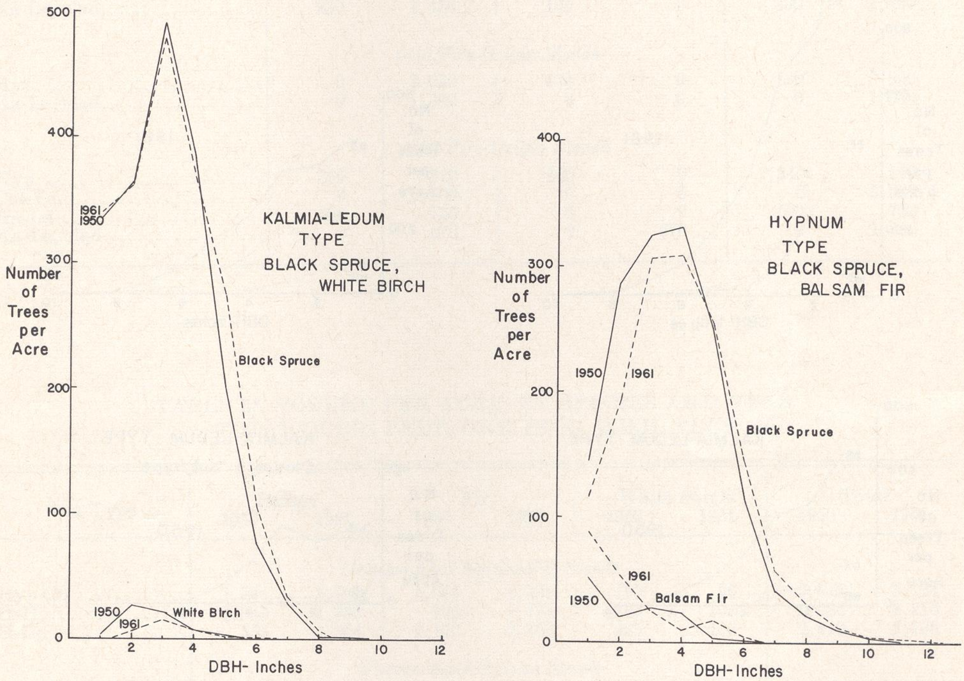

Figure 9. Number of trees per acre over DBH, 1840 fire origin stands, 1950 and 1961

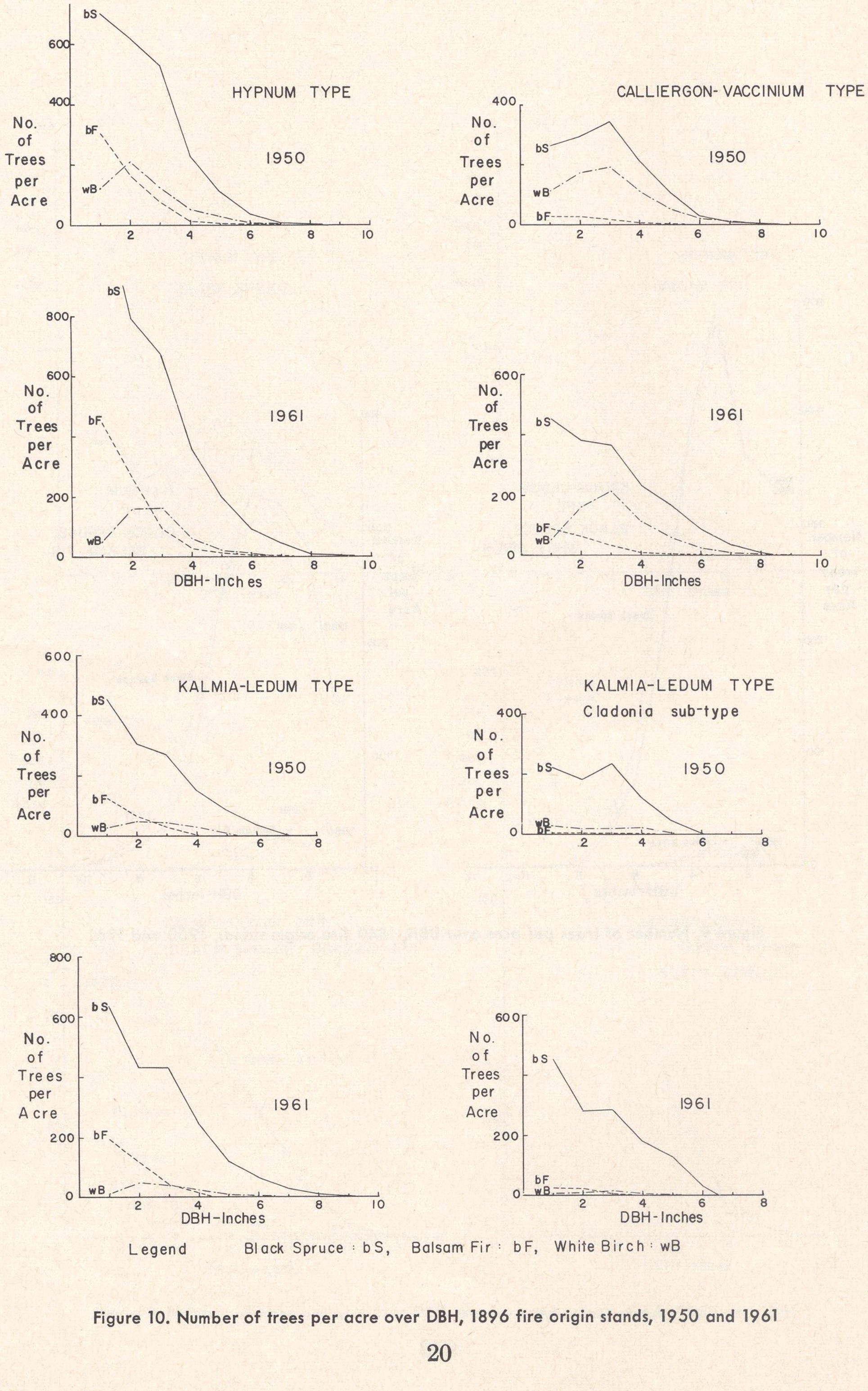

Figure 10. Number of trees per acre over DBH, 1896 fire origin stands, 1950 and 1961

TABLE 4. NUMBERS AND ORIGIN OF SPRUCE AND FIR STEMS BELOW 0.6 INCH D.B.H., PER ACRE, 1961

Site Type	Spruce		Fir		Total	
	Seedlings	Layers	Seedlings	Layers	Seedlings	Layers
	Uneven-Aged Spruce-Fir Stands					
Hyp-Co	0	3,000	8,780	570	8,780	3,570
H-H	190	2,730	5,450	40	5,640	2,770
H-Co	1,730	820	10,640	450	12,370	1,270
	Uneven-Aged Spruce Stands					
Hyp	190	3,690	4,840	500	5,030	4,190
Ka-Le	0	2,740	800	440	800	3,180
Ka-Le, clad	230	1,460	100	0	330	1,460
	1840 Fire-Origin Stands					
Hyp	0	3,250	120	0	120	3,250
Ka-Le, clad	0	1,380	0	0	0	1,380
	1896 Fire-Origin Stands					
Hyp	390	310	850	0	1,240	310
Cal-Va	0	3,000	0	0	0	3,000
Ka-Le	500	750	0	0	500	750
Ka-Le, clad	0	670	0	670	0	1,340

TABLE 5*. VOLUME PER ACRE, BY SPECIES AND YEAR TOTAL CUBIC FEET, ONE INCH D.B.H. PLUS

Site Type	Spruce		Fir		White Birch		Total	
	1950	1961	1950	1961	1950	1961	1950	1961
	Uneven-Aged Spruce-Fir Stands							
Hyp-Co	1,744	1,707	1,061	1,321	107	96	2,912	3,124
H-H	1,883	1,933	995	1,178	108	105	2,986	3,216
H-Co	555	594	2,130	2,356	231	156	2,916	3,106
	Uneven-Aged Spruce Stands							
Hyp	2,407	2,357	487	738	66	64	2,960	3,159
Ka-Le	1,729	1,806	161	204	19	19	1,909	2,029
Ka-Le, clad	1,195	1,258	13	12	1	<1	1,209	1,270
	1840 Fire-Origin Stands							
Hyp	2,710	3,076	85	119	169	131	2,964	3,326
Ka-Le, clad	1,899	2,226	11	20	43	36	1,953	2,282
	1896 Fire-Origin Stands							
Hyp	1,388	2,552	153	254	442	473	1,988	3,291
Cal-Va	918	1,681	40	99	825	872	1,783	2,652
Ka-Le	767	1,445	37	81	175	148	979	1,679
Ka-Le, clad	452	924	6	20	122	50	585	1,004

*Small amounts of aspen and tamarack not shown.

Figure 11. Dense even-aged black spruce stand of the Hypnum type of 1896 fire origin. Note complete lack of seedlings or layers

Figure 12. Uneven-aged Kalmia-Ledum stand showing spruce layering (right) and fir seedlings (centre)

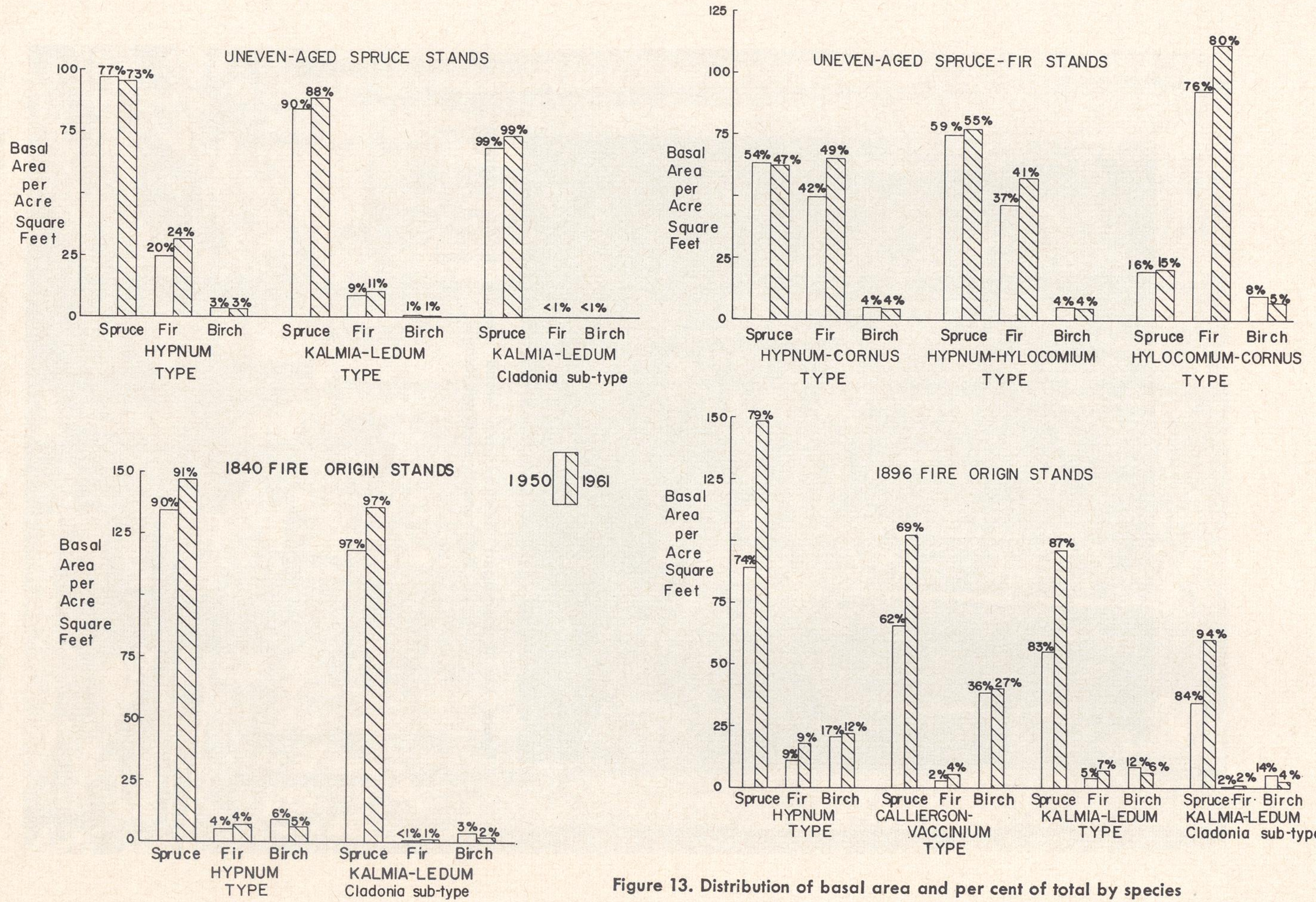

Figure 13. Distribution of basal area and per cent of total by species

TABLE 6*. MERCHANTABLE VOLUME PER ACRE, BY SPECIES AND YEAR
TOTAL CUBIC FEET, FOUR INCHES D.B.H. PLUS

Site Type	Spruce 1950	Spruce 1961	Fir 1950	Fir 1961	White Birch 1950	White Birch 1961	Total 1950	Total 1961
Uneven-Aged Spruce-Fir Stands								
Hyp-Co	1,723	1,659	935	1,068	104	93	2,762	2,820
H-H	1,842	1,864	897	989	106	103	2,845	2,956
H-Co	542	569	1,942	1,953	230	146	2,714	2,668
Uneven-Aged Spruce Stands								
Hyp	2,360	2,278	403	590	61	60	2,824	2,928
Ka-Le	1,620	1,642	139	169	18	19	1,777	1,830
Ka-Le, clad	1,027	1,018	11	10	1	0	1,039	1,028
1840 Fire-Origin Stands								
Hyp	2,403	2,806	57	83	149	124	2,609	3,013
Ka-Le, clad	1,437	1,774	6	13	18	22	1,461	1,809
1896 Fire-Origin Stands								
Hyp	828	1,778	38	89	202	228	1,072	2,106
Cal-Va	635	1,294	14	38	534	570	1,183	1,902
Ka-Le	525	1,057	2	21	102	83	629	1,165
Ka-Le, clad	259	623	2	8	89	29	355	671

*Small amounts of aspen and tamarack not shown.

TABLE 7. MORTALITY, FOUR INCHES D.B.H. PLUS, 1950–1961

Site Type	Mortality, Total Cubic Feet Per Acre			Total
	Spruce	Fir	White Birch	
Uneven-Aged Spruce-Fir Stands				
Hyp-Co	327	117	18	462
H-H	206	176	8	390
H-Co	60	342	99	501
Uneven-Aged Spruce Stands				
Hyp	378	66	7	451
Ka-Le	204	12	4	220
Ka-Le, clad	146	3	2	151
1840 Fire-Origin Stands				
Hyp	100	5	39	144
Ka-Le, clad	96	0	10	106
1896 Fire-Origin Stands				
Hyp	3	0	10	13
Cal-Va	6	0	53	59
Ka-Le	2	0	26	28
Ka-Le, clad	0	0	63	63

Growth

The increasing importance of fir in the uneven-aged forest, particularly in spruce-fir stands, is indicated by annual increment values, 1950-1961 (Table 8). Net fir increments for spruce-fir stands, and the black spruce Hypnum site, were much larger than corresponding values for spruce which in two sites were actually decrements. Gross annual increments reflect the site differences in productivity ranging from 63.7 cubic feet per acre in the Hylocomium-Cornus to 21.0 cubic feet in the Kalmia-Ledum, cladonia.

The largest net and gross annual increments of 118.4 and 129.7 cubic feet respectively occurred in the 1896 stands of the Hypnum site. In contrast to the uneven-aged forest most of the growth in fire-origin stands is spruce, and fir increments are almost negligible.

Figure 14. Stereogram showing a Hypnum black spruce stand of 1840 fire origin. Note lack of seedlings and layers

Very small increments or decrements for merchantable volumes were recorded in uneven-aged stands (Table 9). As yet, the upsurge of fir has had little effect on volumes four inches d.b.h. and over. The 1896 stands grew rapidly, the Hypnum type increasing at a rate approximately equal to one cord per acre per year. Evidence that growth rates for these fire-origin stands increased since 1950 are the substantially larger mean annual increments in 1961 (Table 10). Small increases in M.A.I. were noted for 1840 stands.

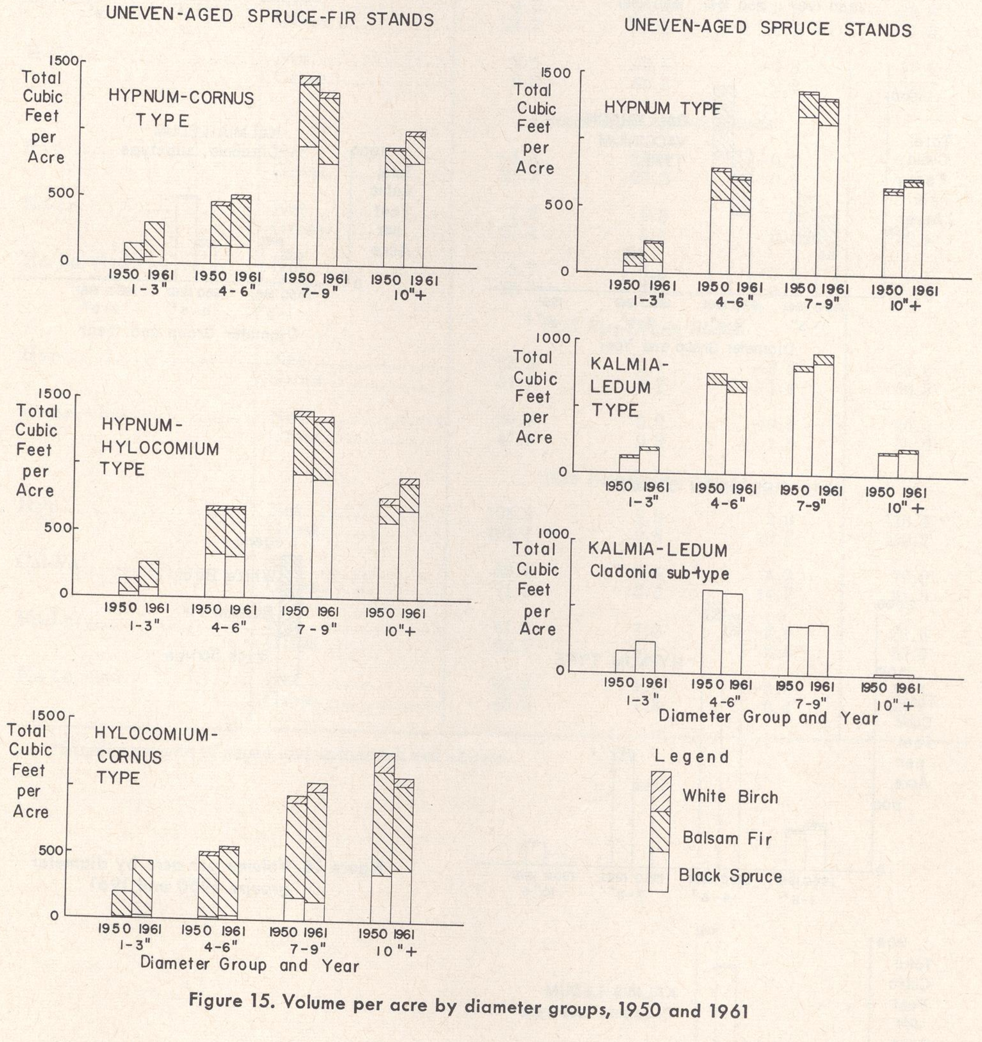

Figure 15. Volume per acre by diameter groups, 1950 and 1961

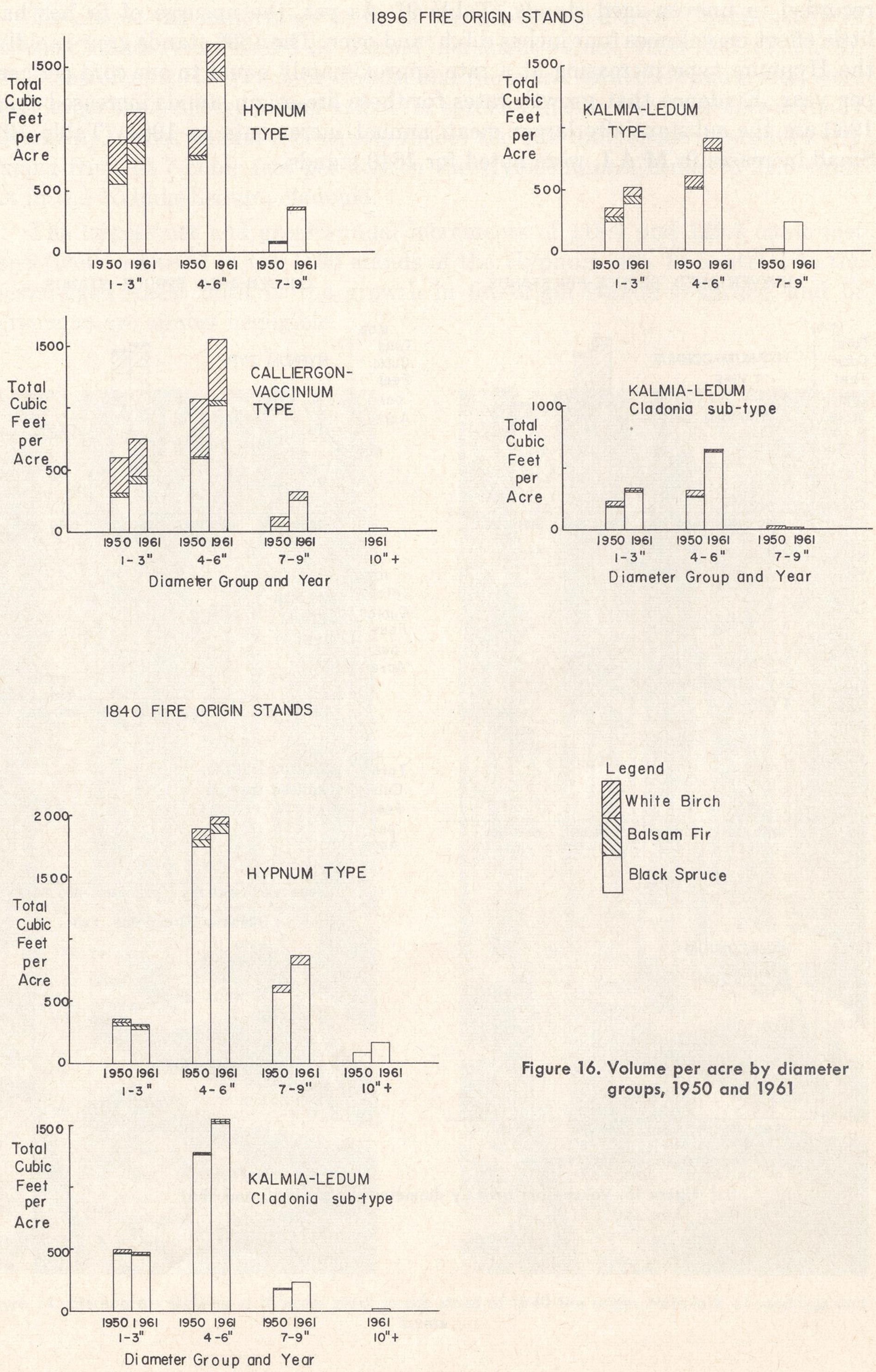

Figure 16. Volume per acre by diameter groups, 1950 and 1961

TABLE 8*. ANNUAL VOLUME INCREMENT, 1950–1961
ONE INCH D.B.H. PLUS

Site Type	Annual Increment	Volume Increment, Total Cubic Feet Per Acre			Total
		Spruce	Fir	White Birch	
		Uneven-Aged Spruce-Fir Stands			
Hyp-Co	Net	−3.3	23.6	−1.0	19.3
	Gross	26.6	34.9	0.7	62.2
H-H	Net	4.5	16.6	−0.3	20.8
	Gross	24.2	33.2	0.5	57.9
H-Co	Net	3.5	20.4	−6.8	17.1
	Gross	9.0	52.5	2.2	63.7
		Uneven-Aged Spruce Stands			
Hyp	Net	−4.5	22.8	−0.2	18.1
	Gross	31.2	29.2	0.6	61.0
Ka-Le	Net	7.0	3.9	0	10.9
	Gross	27.3	5.1	0.5	32.9
Ka-Le, clad	Net	5.7	−0.1	−0.1	5.5
	Gross	20.7	0.2	0.1	21.0
		1840 Fire-Origin Stands			
Hyp	Net	33.3	3.1	−3.4	33.0
	Gross	51.7	3.7	1.4	56.8
Ka-Le, clad	Net	29.8	0.8	−0.6	30.0
	Gross	47.6	0.8	1.8	50.2
		1896 Fire-Origin Stands			
Hyp	Net	105.8	9.2	2.9	118.4
	Gross	108.7	9.8	10.5	129.7
Cal-Va	Net	69.4	5.4	4.2	79.0
	Gross	71.2	5.5	14.7	91.5
Ka-Le	Net	61.6	4.0	−2.4	63.6
	Gross	62.7	4.1	2.4	69.6
Ka-Le, clad	Net	42.9	1.3	−6.6	38.1
	Gross	43.0	1.3	0.4	45.1

*Small amounts of aspen and tamarack not shown.

TABLE 9*. NET ANNUAL VOLUME INCREMENT, 1950–1961
FOUR INCHES D.B.H. PLUS

Site Type	Net Annual Increment, Total Cubic Feet Per Acre			Total
	Spruce	Fir	White Birch	
	Uneven-Aged Spruce-Fir Stands			
Hyp-Co	−5.8	12.1	−1.0	5.3
H-H	2.0	8.4	−0.2	10.2
H-Co	2.4	1.0	−7.6	−4.2
	Uneven-Aged Spruce Stands			
Hyp	−7.4	17.0	−0.1	9.5
Ka-Le	2.0	2.7	0	4.7
Ka-Le, clad	−0.8	−0.1	−0.1	−1.0
	1840 Fire-Origin Stands			
Hyp	36.6	2.4	−2.3	36.7
Ka-Le, clad	30.6	0.6	0.5	31.7
	1896 Fire-Origin Stands			
Hyp	86.4	4.7	2.4	94.0
Cal-Va	59.8	2.2	3.3	65.4
Ka-Le	48.4	1.7	−1.7	48.7
Ka-Le, clad	33.1	0.6	−5.4	28.7

*Small amounts of aspen and tamarack not shown.

TABLE 10*. MEAN ANNUAL INCREMENT (M.A.I.) TO 1950 AND 1961,
ONE INCH D.B.H. PLUS

Site Type	Year	M.A.I., Total Cubic Feet Per Acre			Total
		Spruce	Fir	White Birch	
		1840 Fire-Origin Stands			
Hyp	1950	24.6	0.8	1.5	26.9
	1961	25.4	1.0	1.1	27.5
Ka-Le, clad	1950	17.3	0.1	0.4	17.8
	1961	18.4	0.2	0.3	18.9
		1896 Fire-Origin Stands			
Hyp	1950	25.7	2.8	8.2	36.8
	1961	39.3	3.9	7.3	50.6
Cal-Va	1950	17.0	0.7	15.3	33.0
	1961	25.9	1.5	13.4	40.8
Ka-Le	1950	14.2	0.7	3.2	18.1
	1961	22.2	1.2	2.3	25.8
Ka-Le, clad	1950	8.4	0.1	2.3	10.8
	1961	14.2	0.3	0.8	15.4

*Small amounts of aspen and tamarack not shown.

Comparison with Yield Table Data

Data for even-aged forests at Lake St. Pierre compare very favourably with those from black spruce forests elsewhere in Canada (Bedell *et al.* 1955, Horton and Lees 1961, Kabzems 1953, Plonski 1960; Table 11).

Notable features of the comparison are: (1) the mean annual increments of 50.6 and 40.8 cubic feet for 64-year-old stands of the Hypnum and Calliergon-Vaccinium sites (approx. 46 per cent of the 1896 burn area) exceed all but one M.A.I. presented in the yield tables, (2) current annual increments (period 1950-1961) for these sites also are much larger than those in the yield tables, (3) for 120-year-old stands, the yield tables indicate C.A.I.'s smaller than M.A.I.'s whereas the reverse is true for Lake St. Pierre stands, and (4) numbers of trees decrease going from richer to poorer sites at Lake St. Pierre whereas the opposite is true for the other regions shown.

DISCUSSION

Overmature black spruce stands at Lake St. Pierre that appeared to be even-aged were in fact uneven-aged stands of composite age structure with both even and uneven-aged components. The separation of the components as applied herein was not intended to delimit them precisely, but rather to illustrate a method of division which may be helpful in revealing age structure, in indicating the relative importance of even and uneven-aged elements, and as an indicator of the mode of stand origin.

How or why the uneven-aged stand structure developed is not known although the process began over 100 years ago. Traces of carbon were found on the surface of the mineral soil throughout the forest, but lack of fire evidence on the oldest spruce trees and the high proportion of fir in the spruce-fir stands both suggest that the forest may not have burned for over 200 years. However, a large part of the volume is provided by an even-aged component approximately 150 years old. It is difficult to explain the origin of this component without at least a light fire 160 to 170 years ago. The literature abounds in statements to the effect that dense black spruce stands of seedling origin often follow fire but none has reported dense mature stands resulting from layering or rooting. Nevertheless the possibility that the even-aged element developed from layers or from seedlings which followed severe and extensive blowdown cannot be eliminated.

Evidently a post-fire pattern of stand origin, characterized by an initial time lag followed by peak years of seedling establishment noted recently in three other burns, has been repeated in even-aged stands at Lake St. Pierre. Inasmuch as this pattern has now been found in four quite different burns in Quebec, it seems imperative that studies be initiated immediately after fire to determine precisely what happens. The chances of success in artificial seeding of burned areas might be greatly improved if the reasons for such a time lag could be definitely established. The tentative explanation of the origin pattern given for the York and Pabos burns (MacArthur and Gagnon 1961) was that seed moved into the burned area from a distant source. At Lake St. Pierre it seems improbable if not impossible that the 1896 burn could have seeded in this manner. Here it would appear that either a good many seed-bearing trees survived for several years after the fire or that spruce seed remains viable in cones of fire-killed trees for longer than has been reported. Only two references were found stating that a very small quantity of viable spruce seed was present in cones as long as 10 years after fire (Chai and Hansen 1952, Nickerson 1958). The duration of black spruce seed viability in cones on fire-killed trees is a subject which needs more study.

TABLE 11. COMPARISON OF EVEN-AGED BLACK SPRUCE STANDS AT LAKE ST. PIERRE WITH YIELD TABLE DATA

Site	Quebec Lake St. Pierre Forest Section B.1b				Ontario (Plonski, 1960)			Ontario (Bedell *et al*, 1955)* Forest Sections B.4, B.9				Saskatchewan (Kabzems, 1953) Forest Section B.18			Alberta (Horton & Lees, 1961) For. Sections B.19a B.19c		
	Hyp	Cal-Va	Ka-Le	Ka-Le, clad	1	2	3	B	D	G	K	Good	Medium	Poor	1	2	3
Site Index, 100 years	53′	57′	44′	—	56′	45′	35′	64′	56′	50′	42′	52′	42′	32′	55′	45′	35′
Per Acre Values at 60 Years (64 years Lake St. Pierre)																	
Number of Trees	4,694	2,578	2,481	1,452	1,265	1,727	2,190	1,500	1,800	2,100	2,270	2,340	3,335	4,010	—	—	—
Basal Area, Sq. Ft.	189	148	110	64	143	118	87	154	143	115	63	114	108	84	178	135	93
Total Volume, Cu. Ft.	3,291	2,652	1,679	1,004	2,729	1,969	1,027	1,946	1,598	858	221	2,125	1,710	1,115	2,360	1,375	615
Mean Annual Increment	50.6	40.8	25.8	15.4	45.5	32.8	17.1	32.4	26.6	14.3	3.7	35.4	28.5	18.5	39.3	22.9	10.2
Current Annual Increment	118.4	79.0	63.6	38.1	53.2	45.6	36.4	58.6	64.6	48.4	11.0	68.0	63.3	41.5	52.0	38.0	28.0
Per Acre Values at 120 years																	
Number of Trees	1,681	—	—	2,032	672	993	1,315	700	885	1,010	1,910	775	1,415	1,845	—	—	—
Basal Area, Sq. Feet	161	—	—	139	176	164	148	140	160	142	121	159	151	126	196	172	150
Total Volume, Cu. Ft.	3,326	—	—	2,282	4,658	3,774	2,664	3,111	3,154	2,380	1,266	3,350	2,915	2,140	4,225	3,090	2,050
Mean Annual Increment	27.5	—	—	18.9	38.8	31.4	22.2	25.9	26.3	19.8	10.6	27.9	24.2	17.8	35.2	25.6	17.1
Current Annual Increment	33.0	—	—	30.0	15.4	15.2	14.0	−2.5	8.6	10.2	19.5	−9.5	−7.5	−2.5	15.0	13.0	12.0

*Empirical Yield Tables—Volumes 4″ DBH Plus.

Significant changes occurred in uneven-aged stands from 1950 to 1961: (1) numbers of trees increased greatly owing to ingrowth of saplings, particularly fir, (2) volume likewise increased; mortality of older and larger trees was more than compensated for by growth and by ingrowth of saplings, and (3) fir proportion increased in all but the poorest Kalmia-Ledum, clad. site.

Since 1950 the uneven-aged forest experienced a marked increase in the numbers of both spruce and fir saplings, many of which were of layer origin. The volume increases in the sapling group (1-3 inches) compensated for much of the mortality losses which were as high as 5½ cords per acre. This increase suggests an accelerated mortality rate of the older trees, a significant stage in the deterioration of these stands. Volume increases since 1950 are believed to indicate one of perhaps several volume fluctuations which have or may occur during this stage. It seems likely that volumes were larger earlier in the life of the stand because some of the 1896 and 1840 stands currently support larger volumes than corresponding sites in uneven-aged stands. The fact of near-constant or decreasing spruce volumes also supports this belief.

If present volumes are lower than in the past the stands may be said to have deteriorated. Indisputably such a reduction in volume represents a definite loss of wood, but such deterioration can hardly be considered critical when much of the forest in 1961 contained over 3,000 cubic feet of spruce and fir per acre. Since there appears to be a size limit on the lifespan of black spruce (i.e. very few trees over 12 inches d.b.h.), eventually the mortality rate will reach a peak as the even-aged stand element approaches the critical size. Judging from present diameter growth rates this peak may not occur for 40-50 years.

The phenomenon of increasing fir proportions in black spruce stands has been noted elsewhere (Holt 1949, Lebarron 1948, Losee 1961, MacLean 1960, Millar 1936). The main explanation given is that in the absence of fire the moss and litter cover build up to a thickness which inhibits spruce seedling survival. The same reasoning no doubt applies at Lake St. Pierre. The increase in fir proportion is proceeding at a moderate rate which probably will not change for some years barring a sudden catastrophe such as hurricane-force winds. The largest fir increase from 1950 to 1961 was from 42 to 49 per cent of the basal area in the Hypnum-Cornus type. For woods managers, such changes may be cause for concern for two reasons: (1) spruce is a more highly regarded pulpwood species than fir, and (2) as fir proportion increases so does susceptibility to severe spruce budworm attack.

Notable features of the even-aged fire-origin forests are the high volumes and rapid growth, plus the continued ingrowth into the sapling category. Perhaps the high volumes, compared with uneven-aged stands, indicate a rejuvenating effect of fire in old-growth black spruce. Possibly the relatively high proportion of white birch had a beneficial effect.

The continued filling of stand openings with seedlings and layers did not occur uniformly throughout the forest but it nevertheless introduced an uneven-aged element into many stands. Future changes should be studied closely as this may explain the development of the uneven-aged stands in the area. The degree to which even-aged stands become uneven-aged in this way is probably a function of the original post-fire stocking. Dense fire origin stands with little white birch had very little advance regeneration or ingrowth. At the next remeasurement, stems of layer origin should be tallied separately in order to follow their development and to provide a comparison with seed-origin stems. Development of layers and layer origin stands is a facet of spruce and fir silvics which has been neglected.

Annual growth rates, both mean and current, for the best 64-year-old stands exceeded the best sites shown in yield tables for other regions of Canada. The magnitude of current increments suggests that M.A.I.'s will continue to increase. It will be interesting to discover whether M.A.I.'s continue to increase beyond 80 years when most M.A.I.'s in the yield tables begin to decrease. In this regard it is notable that M.A.I.'s for 120-year-old stands at Lake St. Pierre increased slightly from 1950 to 1961.

Current annual increments of up to 94 cubic feet of spruce and fir per acre four inches d.b.h. and over enhance the possibility of economic thinning or partial cutting to increase final yields. Experimentation in thinning and harvesting black spruce stands in this region, both to increase final yields and to encourage spruce regeneration, would probably yield very worthwhile results.

The fact that richer sites had more trees per acre than poorer sites, contrary to the yield table data, is probably explained by one or both of the following: (1) yield tables are constructed from data on fully-stocked stands which would provide no openings for ingrowth, and (2) white birch at Lake St. Pierre probably developed faster and began to die sooner on the richer sites thus providing more openings for conifer ingrowth than on poorer sites.

In brief, the study has shown that the age structure of overmature and seemingly even-aged black spruce stands may be very complex with both even and uneven-aged components. The origin pattern of black spruce after fire, characterized by an initial time lag in seedling establishment, corroborates findings elsewhere in Quebec. The reason for such delay in regeneration should be determined since it may prove to be the key to successful restocking of burned forests.

The increasing proportion of fir in black spruce stands parallels findings elsewhere in Canada. Apparently on well-drained sites, in the absence of forest fire, the climax species is fir rather than black spruce. Spruce will continue to be represented but increasingly so by stems of layer origin. The future value of such stems is unknown. In general, the black spruce forests at Lake St. Pierre are comparable in yield and growth rate to stands in many parts of Canada; the best even-aged stands are better than those represented by published yield tables.

SUMMARY

A study of stand development was begun in 1950 in black spruce and black spruce-balsam fir stands in Forest Section B.1b, Quebec. The five-square-mile study area 70 miles north of Baie-Comeau contains uneven-aged stands of unknown origin and even-aged stands of fire origin. The tenth-acre line plots of the one percent systematically located sample were remeasured in 1961 when additional age studies also were made to determine the origin and age structure of the forest.

Overmature stands that appeared even-aged were discovered to be uneven-aged with both even and uneven-aged components. A method of separating these components was applied which proved helpful in determining age structure, in revealing the importance of the stand components and in suggesting possible stand origin. Uneven-aged stand origin could not be precisely determined. Evidence suggests there was at least a light fire about 160 to 170 years ago. However, the possibility that the even-aged element developed from layers or from seedlings after a severe blowdown could not be eliminated. Volumes per acre were probably lower in 1961 than some time in the past, but increases in volume since 1950 suggest the possibility of fluctuation. Although the forest may be considered to have deteriorated to some degree, many stands still contain over 3,000 cubic feet per acre of spruce and fir. Volume of mortality was almost balanced by growth and by sapling ingrowth whose numbers increased greatly since 1950. However, more fir than spruce appeared in these small diameters resulting in an increase in the fir proportion. Most of the new spruce are of layer origin; most fir are seedlings.

A pattern of spruce establishment following fire characterized by an initial time lag followed by peak years of establishment was found for the 1896 fire-origin stands. This is the fourth burned area in Quebec to exhibit the same pattern. These stands have been growing remarkably fast and values for volume, M.A.I. and C.A.I. compare favourably with yield table data for other parts of Canada. An uneven-aged element recently entered this forest in the form of layers and seedlings filling openings that resulted from either low initial stocking or the death of birch.

The results suggest that studies should be undertaken to determine: (1) the development of layers and their value in forming stands, (2) the duration of black spruce seed viability in cones on fire-killed trees and (3) the pattern of seedling establishment following fire. Experimental thinning for higher yields and possibly better regeneration of spruce also would appear justified.

SOMMAIRE

Le développement des peuplements d'épinette noire à l'état pur ou associée au sapin baumier dans la Section forestière B-1b, dans le Québec, a fait l'objet d'une étude préliminaire en 1950. A cette fin, le choix porta sur une superficie de cinq milles carrés située à 70 milles au nord de Baie-Comeau, et contenant des peuplements inéquiennes d'origine inconnue et des peuplements équiennes venus après feu. En 1961, on remesura les places expérimentales de 1/10 d'acre établies 11 ans auparavant le long de lignes d'inventaire équidistantes et formant un échantillonnage de 1 pour cent. Des études d'âge supplémentaires ont également servi à déterminer l'origine et la structure d'âge de la forêt.

Les peuplements surannés qui avaient paru équiennes au premier abord, se sont montrés hétérogènes à l'analyse et comportent à la fois des éléments équiennes et des éléments inéquiennes. Ce procédé d'analyse suivant lequel les peuplements ont été décomposés en leurs divers éléments d'importance variable a permis d'en établir la structure d'âge et, dans une certaine mesure, l'origine. Il n'a pas été possible de préciser l'origine des peuplements inéquiennes, mais il y a lieu de croire qu'il y eut un léger feu il y a quelque 160 ans. Les éléments équiennes pourraient être dus à un développement de marcottes ou de semis établis à la suite de chablis de forte étendue.

Les volumes à l'acre, en 1961, étaient probablement inférieurs à ce qu'ils étaient il y a quelques décennies, mais au cours de la période étudiée, ils se sont accrus, ce qui suggère l'alternance de relèvements et de dépressions. Il y a, dans l'ensemble, des signes certains d'une détérioration, mais de nombreux peuplements possèdent encore des volumes en épinette et en sapin de plus de 3,000 pieds cubes à l'acre. La croissance est presque en équilibre avec la mortalité grâce aux recrues nombreuses qui ont joint les rangs depuis 1950. A cet égard, le sapin a fourni un cortège plus impressionnant que l'épinette. Le premier a originé de la semence tandis que celle-ci était surtout formée de marcottes.

Les peuplements d'épinette noire qui se sont établis à la suite du feu de 1896 présentent un cas intéressant quant à la façon dont l'ensemencement s'est produit. Il y a indication d'un retard initial suivi de fortes années semencières. C'est le quatrième exemple dans Québec où une telle modalité d'ensemencement s'est produite après incendie. Les peuplements d'origine de feu dans cette aire expérimentale ont crû fort rapidement et leur volume, leur croissance annuelle courante se comparent favorablement avec les valeurs de tables de production en provenance d'autres parties du Canada. Un élément inéquienne s'est introduit récemment dans cette forêt sous la forme de marcottes et de semis comblant les clairières constituées par un repeuplement initial insuffisant ou par la disparition du bouleau.

A la lumière des résultats obtenus au cours de cette étude, il serait opportun, croyons-nous, de poursuivre les recherches suivantes: 1. suivre le développement des marcottes et en déterminer la valeur d'avenir; 2. établir la viabilité des semences retenues dans les cônes sur les arbres tués par le feu; 3. déterminer la modalité du repeuplement par semis à la suite de l'incendie. On serait également justifié de procéder à des éclaircies expérimentales dans le but d'augmenter la production ligneuse et possiblement, grâce à ces éclaircies, de susciter au moment approprié un rajeunissement abondant en épinette noire.

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