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PARTIAL CUTTING BALSAM FIR STANDS ON THE EPAULE RIVER WATERSHED, QUEBEC

by
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Summary in French

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Partial Cutting Balsam Fir Stands on the Epaule River Watershed, Quebec

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R. J. Hatcher*

INTRODUCTION

Considerable interest was evinced by the pulp and paper industry in Quebec at the advent of partial cutting in mature and immature stands of balsam fir (*Abies balsamea* (L.) Mill.) by the Donnacona Paper Company in 1953 (Matte, 1952). After an analysis of test cuttings in 1951 and 1952 the Company began commercial partial or "selective" cutting operations in the 50-square-mile Epaule Block of the Jacques Cartier management unit. Modified by early experience, the cutting has continued up to 1960.

The Epaule Block is very accessible, lying on both sides of the Quebec-Chicoutimi highway about 35 miles from Quebec City and only 60 miles from the Company mill at Donnacona, Quebec.

The forest, 75 per cent fir by volume, had been cut over for pulpwood about 1925, and when the management plan for the Block was being revised in 1950 it was found that current yields of pulpwood were much higher than expected. Study of these second-growth stands showed that the average annual growth rate was 40 cubic feet per acre, and this, coupled with ease of access and proximity to mill, were sufficient justification for the adoption of more intensive management than had previously been contemplated for the area.

In 1954 a series of tenth-acre line plots was established by the Forestry Branch in stands which had been cut over in 1953 and 1954. The Company also clear cut an area to provide a comparison of regeneration with the partial cutting, and plots were established in this area in 1955.

In 1959 all plots were remeasured and this report presents the results after the first short critical period since logging. Post-cut development of mature stands has been disappointing owing to very high mortality. Results from immature stands and uneven-aged stands are more encouraging. Final analysis of yields from these stands should be delayed until the next remeasurement in 1964.

THE FOREST

The study area of about three square miles, in the Boreal Forest Region, Section B.1a (Rowe, 1959), is about 35 miles north of Quebec City at latitude 47°20′N. Drainage is westward to Big and Little Epaule Lakes and the Epaule River, a tributary of the Jacques Cartier River which flows southwestward to the St. Lawrence.

Considerable variation in topography is encountered, from flat, low swampy areas to high cliffs. However, most of the area comprises moderate slopes which rise from the Epaule River and its tributaries to the heights of land which form the cutting area boundaries. The elevation above sea level varies from 2,500 to 3,200 feet.

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The podsol soil over the pre-Cambrian granite on middle and lower slopes is generally a fairly deep, well drained, loamy till containing numerous stones and boulders. The ground surface is usually free of rock except on steep cliffs and ridges where rock may be exposed or only thinly covered with humus and mineral soil.

The climate is severe. According to Villeneuve (1946), the Laurentide Park, in which the area is located, has one of the shortest growth periods (60 to 90 days) of the inhabited areas of Quebec. Tremblay (1954) states that the Epaule River basin has an average growing season of 80 days. Annual precipitation is 32 to 56 inches and the Park is noted as an area of pronounced summer evaporation owing to high winds. The mean temperature of the four warmest months ranges from 54° to 58°F. and the monthly summer precipitation is 4.0 to 7.0 inches.

Only two site types were sufficiently represented by plots to permit analysis. These are the Dryopteris-Oxalis, Site Class I, and Hylocomium-Oxalis, Site Class II, which cover approximately 80 per cent of the area. These types, recognized and described in detail by Linteau (1955), are hereinafter referred to as Dry-O and H-O. Balsam fir dominates in both site types (Table 1) and the combined volume of spruce, *Picea glauca* (Moench) Voss and *P. mariana* (Mill.) BSP., and white birch, *Betula papyrifera* Marsh., seldom exceeds 25 per cent of the total.

Eighty per cent of the stands are even-aged; the remainder are many-aged and two-storeyed stands. Stands of 41 to 60 years have been classed as age class 50, those of 61 to 80 years classed as age class 70, and uneven-aged and two-storeyed stands compiled together as uneven-aged. Stand profiles before the recent partial cutting are shown in Figures 1 and 2. (Figures begin on page 16.)

The forest was cut over for pulpwood about 1925 under stump diameter limits of 10 inches for spruce and 7 inches for fir. Cutting intensity varied widely because of variability in the size of trees in different stands. Dominants and large scattered veterans when removed from immature and uneven-aged stands resulted in unevenly spaced openings of variable size and the application of the limits to mature and over-mature even-aged stands often resulted in clear cutting. Where the entire stand was thus removed, 30- to 35-year-old, well-stocked stands of nearly pure fir are now found. They represent about 20 per cent of the forest.

Before the last cut, the forest in general consisted of well-stocked stands with quite uniform crown canopies. Only a few small stands of overmature trees had begun to break up and they were restricted to the most exposed slopes at high elevations. The forest had survived a spruce budworm attack from 1949 to 1952 and while very little mortality occurred, occasional signs of past defoliation were noted in 1954. Some stem breakage in mature stands resulted from severe sleet storms during the winter of 1949-50. The quantity of white birch was greatly reduced by birch dieback, which caused heavy mortality between 1941 and 1946. In latter years this species has made at least a partial recovery.

The spruce-fir volume of 70-year stands of the Dry-O type was only slightly larger than that of the 50-year age class (Table 1), although the volume was distributed over fewer and larger trees (Table 2). Total basal areas were equal. However, in the H-O type, the spruce-fir volume of 70-year stands was considerably larger than that of 50-year stands, as was the total basal area. Volumes and basal areas of uneven-aged stands were relatively low. Dry-O spruce-fir volumes, total basal areas and average diameters were higher, and numbers of spruce-fir were lower, than those of corresponding age classes of the H-O type.

TABLE 1.—SUMMARY OF STOCK TABLES, BEFORE TREATMENT

Site Type	Diameter Group (inches)	Volume in Total Cubic Feet Per Acre, by Age Class and Species: 50 Years			70 Years			Uneven-aged		
		Spruce	Fir	White Birch	Spruce	Fir	White Birch	Spruce	Fir	White Birch
Dryopteris-Oxalis	1–3	7	180	22	2	125	16	6	220	20
	4–9	94	2,417	104	108	2,444	271	93	1,728	179
	10+	39	466	340	160	513	437	109	596	469
	Total	140	3,063	466	270	3,082	724	208	2,544	668
	Per Cent of Total	*4*	*83*	*13*	*7*	*75*	*18*	*6*	*74*	*20*
Hylocomium-Oxalis	1–3	1	166	35	2	97	21	10	225	61
	4–9	202	2,018	95	230	2,407	296	216	1,641	267
	10+	47	309	82	137	201	177	63	510	83
	Total	250	2,493	212	369	2,705	494	289	2,376	411
	Per Cent of Total	*9*	*84*	*7*	*10*	*76*	*14*	*9*	*78*	*13*

TABLE 2.—NUMBER OF SPRUCE AND FIR TREES, AVERAGE DIAMETER, AND TOTAL BASAL AREA, BEFORE TREATMENT

Site Type	Age Class	Number of Spruce and Fir Per Acre	Average Diameter (inches)	Total Basal Area, Square Feet Per Acre
Dryopteris-Oxalis..........................	50	876	5.4	157
	70	590	6.2	157
	Uneven-aged	580	5.6	130
Hylocomium-Oxalis........................	50	882	5.1	137
	70	748	5.7	152
	Uneven-aged	914	4.8	132

TREATMENT

The objectives of the partial cutting listed by Matte (1952) are summarized as follows: 1) to remove mature stems and release suppressed trees to allow the stands to produce maximum yield at maturity, 2) to salvage an important volume by cutting what would otherwise be lost through natural mortality, 3) to prevent windfall, disease and insect attack by growing healthier trees, and 4) to accelerate the establishment of conifer reproduction and prevent the rich sites from becoming covered with dense shrub growth. These objectives were to be achieved by "partial cutting" in mature stands and "selective cutting" in immature stands under the following general marking rules: 1) remove mature, defective and wolf trees, and 2) remove trees not likely to benefit from release, i.e. trees with low live crown ratios.

The intention was to remove 35 per cent of the merchantable spruce-fir volume (4 inches d.b.h. and over) from mature stands and 40 per cent from immature stands, but in practice over 50 per cent was cut in all stands.

TABLE 3.—PER CENT OF VOLUME, NUMBER OF TREES AND BASAL AREA CUT

Site Type	Age Class	Per Cent of Spruce-Fir Trees Cut		Per Cent of Spruce-Fir Volume Cut		Per Cent of Total Basal Area Cut	
		1″ dbh+	4″ dbh+	1″ dbh+	4″ dbh+	1″ dbh+	4″ dbh+
Dryopteris-Oxalis	50	36	43	52	54	44	46
	70	45	49	54	55	44	45
	Uneven-aged	34	47	57	61	47	47
Hylocomium-Oxalis	50	42	46	53	55	50	51
	70	40	42	52	53	43	45
	Uneven-aged	30	41	55	59	44	49

In unmanaged stands over 40 years of age there are defective and dying trees in each diameter class and, as far as was determined, these were the trees which were cut, along with most of the dominants. It is noted (Figures 7, 8 and 11) that many 3- and 4-inch trees were removed although they contributed little to the total harvest. Almost all spruce and fir larger than 11 inches d.b.h. were cut.

The trees to be cut were marked by forest rangers using paint guns (Figure 3), usually under the supervision of a forest engineer. On the whole the sampled stands were skilfully marked, judging from the residual stand of healthy, well-formed trees regularly spaced and with ample room for crown development (Figure 4).

Cutting was carried out in summer and early fall by a contractor under the supervision of company inspectors and the forest engineer in charge. Marked trees were felled, cut into 4-foot bolts which were hand-bunched and piled along strip roads. These narrow roads were spaced about 60 to 80 feet apart. Stumps were cut very low, often at ground level, and very few large tops were left. Sound dead trees also were utilized.

Between 1,470 and 1,820 total cubic feet per acre (including stump, top and cull) were removed (Table 4), according to the line plot data. Reducing these values by 15 per cent to allow for stump, top and cull, and dividing by 85 for conversion to cords, the equivalent merchantable volume removed ranges from 14.7 to 18.2 cords per acre. This is considerably larger than the company estimate for all sites and age classes of 13.4 cords which was derived by dividing the scaled number of cords by the estimated cut-over area.

TABLE 4.—VOLUME OF SPRUCE AND FIR REMOVED, PER ACRE

Site Type	Total Cubic Feet Removed, by Age Class		
	50 Years	70 Years	Uneven-aged
Dryopteris-Oxalis	1,676	1,824	1,572
Hylocomium-Oxalis	1,466	1,590	1,467

The area clear cut to provide a comparison of reproduction is, as planned, a perfect example of commercial clear cutting (Figure 16). Utilization was almost complete and the few uncut stands contain no merchantable trees.

METHOD OF STUDY

In 1954 a 10-chain grid of 108 tenth-acre line plots was established in the partial-cut area and in 1955 a similar grid of 32 plots was laid out in the clear-cut area. On each plot, the following data were recorded: 1) d.b.h. of all trees 0.6 inch and over, 2) diameter of stumps, 3) d.b.h. of all trees that had died since the cut, 4) stocking on 20 milacre quadrats, in two size classes, 5) 4 or 5 height-diameter measurements for the construction of local volume tables, 6) ages from increment borings and stump annual ring counts, and 7) a general plot description, comprising notes on herb and shrub vegetation, topography drainage, plot origin and disturbances.

All plots were remeasured in 1959 and their site classification checked. Dead spruce and fir were classified by cause of death as 1) wind, and 2) physiological decadence. In the first class are included those trees which were broken or uprooted by other wind-blown trees. The second class includes dead trees with evidence of severe sunscald, and standing dead trees with no visible signs of logging damage or fungus and insect attack.

Measurements of annual radial growth for 4 years before and after cutting were taken from borings at breast height for trees 4 inches and over. Borings were made also in uncut stands outside the study area. Additional age-height measurements were taken on each partially cut plot to establish a site index, and each plot was classified by site type according to Linteau's (1955) classification. The plot distribution is shown in Table 5.

TABLE 5.—PARTIAL CUT PLOT CLASSIFICATION, 1959

Site Type	Number of Plots, by Age Class			Total
	50 Years	70 Years	Uneven-aged	
Dryopteris-Oxalis	16	37	9	62
Hylocomium-Oxalis	5	13	7	25
Total	21	50	16	87

The remaining 21 plots of 108 established in the area partially cut were omitted from subsequent analysis, either because they represented types insufficiently sampled, or because the site type could not be definitely identified.

RESULTS

Age Class 70

There is little doubt that the partial cutting in mature stands has failed to achieve its objectives because of very heavy mortality of fir (Table 6). For both site types and all species, volumes are less in 1959 than in 1954. These facts were recognized by the Company as early as 2 years after logging began and latterly such stands have been clear cut except for those considered as exceptionally good risks.

The amount of mortality varied from stand to stand, from total loss (Figure 5) to almost no loss (Figure 6). The latter stands are beautiful in appearance, the

TABLE 6.—VOLUME, MORTALITY AND INCREMENT, 70-YEAR AGE CLASS, 4 INCHES DBH AND OVER

Site Type	Year—Period	Total Cubic Feet per Acre, by Species		
		Spruce	Fir	White Birch
Dryopteris-Oxalis	1954	120	1,258	652
	1959	114	853	536
	Net Increment 1954–59	−6	−405	−116
	Mortality 1954–59	23	614	150
	Gross Increment, 1954–59	17	209	34
Hylocomium-Oxalis	1954	137	1,260	436
	1959	122	842	428
	Net Increment 1954–59	−15	−418	−8
	Mortality 1954–59	22	573	48
	Gross Increment, 1954–59	7	155	40

trees growing rapidly in diameter, but unfortunately they are quite rare. The average loss in merchantable pulpwood was about 5 cords per acre, some of which has been salvaged.

Notably the biggest differences between the 1954 and 1959 stock profiles (Figure 7) occur in the diameters from 3 to 7 inches and not in the larger trees as might have been expected.

Age Class 50

The results in immature stands are more encouraging although a final appraisal of yields should await the 1964 measurement. Mortality per acre, ranging from about 2 to 4 cords for the H-O and Dry-O types respectively, was less than in mature stands but still high enough to produce negative net increments for fir (Table 7) in the Dry-O type. The lower mortality is clearly reflected in the stock profiles (Figure 8) which show increasing volumes in diameters 8 inches and over.

TABLE 7.—VOLUME, MORTALITY, AND INCREMENT, 50-YEAR AGE CLASS, 4 INCHES DBH AND OVER

Site Type	Year—Period	Total Cubic Feet per Acre, by Species		
		Spruce	Fir	White Birch
Dryopteris-Oxalis	1954	97	1,253	427
	1959	106	1,053	322
	Net Increment, 1954–59	9	−200	−105
	Mortality, 1954–59	30	449	120
	Gross Increment, 1954–59	39	249	15
Hylocomium-Oxalis	1954	184	954	129
	1959	265	988	149
	Net Increment, 1954–59	81	34	20
	Mortality, 1954–59	0	228	6
	Gross Increment, 1954–59	81	262	26

Similar to the 70-year age class, mortality varied greatly between stands, from complete loss (Figure 9) to almost no loss (Figure 10), with the difference that healthy, well-stocked stands were not as rare as similar stands of 70 years.

The distribution of fir mortality through the diameter classes reveals (Table 8), as might be expected from the stock profiles, that except for the 11-inch class, the highest percentage losses occurred in the 4- to 7-inch classes.

TABLE 8.—FIR MORTALITY 1954 TO 1959[1] BY DIAMETER CLASS AND CAUSE, DRYOPTERIS-OXALIS SITE TYPE, 50-YEAR AGE CLASS

Diameter Class (inches)	Volume of Fir Mortality, Cu. Ft. per Acre, by Cause			Per Cent of Residual Volume Lost
	Wind	Physiological Decadence	Total	
1				
2				
3	0.6	3.6	4.2	11
4	10.6	11.9	22.5	25
5	55.9	7.9	63.8	38
6	82.7	16.5	99.2	32
7	92.4	14.0	106.4	34
8	67.7	3.8	71.5	30
9	5.4	5.4	10.8	9
10	21.4		21.4	34
11	11.3		11.3	50
Total	348.0	63.1	411.1	

[1] Does not include 38 cu. ft. of unclassified mortality which occurred between logging and the 1954 measurement.

Uneven-aged Stands

Uneven-aged Dry-O stands produced a positive net fir increment, 1954-59 (Table 9). This increase in growing stock is evident in the stock profile (Figure 11). Conversely, some uneven-aged H-O stands suffered high mortality resulting in a negative average net increment. It should be remembered that the uneven-aged stand profiles (Figures 1 and 2) represent composite stands of many different age distributions. Actually only two of seven H-O plots suffered very high mortality, and a like number out of nine Dry-O plots.

TABLE 9.—VOLUME, MORTALITY AND INCREMENT, UNEVEN-AGED STANDS, 4 INCHES DBH AND OVER

Site Type	Year-Period	Total Cubic Feet per Acre, by Species		
		Spruce	Fir	White Birch
Dryopteris-Oxalis	1954	96	880	562
	1959	96	1,086	601
	Net Increment, 1954–59	0	206	39
	Mortality, 1954–59	17	119	43
	Gross Increment, 1954–59	17	325	82
Hylocomium-Oxalis	1954	161	820	339
	1959	190	786	350
	Net Increment, 1954–59	29	−34	11
	Mortality, 1954–59	14	302	48
	Gross Increment, 1954–59	43	268	59

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Mortality

Breakage and uprooting by wind accounted for 53 to 85 per cent of all mortality. Mortality from this source showed no definite relationship to either site or age class (Table 10).

TABLE 10.—CAUSES OF FIR MORTALITY

Site Type	Age Class	Per Cent of Total Cubic Foot Fir Mortality, by Cause	
		Wind	Physiological Decadence
Dryopteris-Oxalis	50	85	15
	70	77	23
	Uneven-aged	53	47
Hylocomium-Oxalis	50	61	39
	70	80	20
	Uneven-aged	85	15

Many factors may influence the amount of post-cut conifer mortality. Attempts using scattergrams were made to discover any relationship that might exist between this mortality and the independent variables of pre- and post-cut stand density, cut intensity, aspect, slope and elevation. The per cent of the residual spruce-fir basal area lost since logging was used as the measure of mortality, and total basal area was used to measure stand density and cut intensity. Three facts emerged from this analysis: 1) no evidence of relationship was found for any of the variables in 70-year stands, 2) in 50-year and uneven-aged stands only one variable, cut intensity, indicated a possible relationship to mortality, and 3) this relationship was very similar for both Dry-O and H-O sites, and for 50-year and uneven-aged stands.

The 37 Dry-O and H-O plots of age classes 50 and uneven-aged were combined and individual plot values for per cent mortality of residual spruce-fir basal area were plotted over per cent of total basal area cut. Two plots with exceptionally high cut intensity, three plots that were within 5 chains of the highway and unprotected by uncut stands, and two plots whose deviations were greater than two standard deviations were eliminated from analysis. Using the remaining 30 plots, cut intensity group means were calculated and the freehand curve drawn (Figure 12). The index of correlation was calculated at +0.71, providing an index of determination of 0.50, indicating that for these samples, 50 per cent of the variation in post-cut mortality was related to variation in cut intensity. Almost certainly cut intensity was by far the largest single factor influencing the amount of post-cut conifer mortality. The shape of the curve suggests that losses begin to mount rapidly after more than 40 per cent of the total basal area has been removed.

Although conifer mortality was not classified by year of death, it was observed that most trees had died at least two years before the 1959 remeasurement, or within three years of cutting.

Diameter Growth

Unfortunately the growth figures compiled from increment borings are confused by the recovery from a spruce budworm attack which took place at the same time as increased growth would have been expected as a result of partial cutting.

The annual diameter increments of fir for four years before and after cutting are shown in Figures 13, 14, and 15. The downward trend of the growth rate for the years before logging likely was caused by the budworm attack. The upward trend after 1953 in uncut stands is due to recovery from this attack but in partially cut stands, part of the increase in growth rate is probably the result of the less intense competition brought about by the cut. All comparisons of the growth rate between uncut and partially cut stands for the third and fourth years after logging reveal that growth in cut-over stands is greater than that in uncut stands. As was to be expected, diameter growth in the Dry-O type was greater in 50-year than in 70-year stands for corresponding diameters.

Reproduction

The amount of reproduction increased substantially between 1954 and 1959, particularly in uneven-aged stands (Table 11). Total stocking in 1959, including quadrats occupied by residual trees, varies from 82 to 97 per cent. Spruce and fir stocking, with a low of 57 per cent in the Dry-O 50-year stands, is considered adequate for the formation of well-stocked pulpwood stands, particularly since new seedlings are obviously originating from the seed of the residual trees.

TABLE 11.—REPRODUCTION BY SITE TYPE, AGE CLASS, SPECIES AND SIZE

Site Type	Age Class	Year of Measurement	Per Cent Stocked Quadrats by Species and Size						Total Plus Trees
			Spruce and Fir		White Birch		Total		
			0.6-3.5 inches d.b.h.	Under 0.6 inch d.b.h.	0.6-3.5 inches d.b.h.	Under 0.6 inch d.b.h.	0.6-3.5 inches d b.h.	Under 0.6 inch d.b.h.	All Sizes
Dryopteris-Oxalis	50	1954 1959	4 9	38 48	1 2	18 55	4 10	45 69	n/a 82
	70	1954 1959	2 17	68 67	0 1	17 45	2 17	71 75	n/a 94
	Uneven -aged	1954 1959	3 13	27 54	1 4	7 35	4 16	28 65	n/a 84
Hylocomium-Oxalis	50	1954 1959	4 10	53 62	0 3	35 57	4 12	67 74	n/a 87
	70	1954 1959	2 5	70 88	0 1	21 60	2 6	72 91	n/a 97
	Uneven -aged	1954 1959	1 16	48 69	1 1	18 76	1 17	51 78	n/a 95

The establishment of new seedlings has occurred despite the cover of raspberry which has appeared under all but the lightest cutting intensities (Figures 5, 6, 9 and 10). Growth of seedlings is satisfactory as witnessed by increased stocking of the larger size-class.

Stocking percentages are lower on areas with dense herb and shrub growth (Table 12), and are lower in the Dry-O than in the H-O type. As expected, the 70-year age class has the highest stocking.

TABLE 12.—SPRUCE-FIR REPRODUCTION RELATIVE TO HERB AND SHRUB GROWTH ON MILACRE QUADRATS 1959

Site Type	Age Class	Herb and Shrub Growth					
		Heavy		Medium		Light	
		No. of Quadrats	Per Cent Stocked	No. of Quadrats	Per Cent Stocked	No. of Quadrats	Per Cent Stocked
Dryopteris-Oxalis.......	50	83	33	105	63	132	67
	70	156	66	352	84	232	97
	Uneven-aged	26	35	86	70	68	79
Hylocomium-Oxalis.....	50	37	43	34	82	29	97
	70	32	75	69	94	159	97
	Uneven-aged	29	48	23	91	88	93

The comparison of reproduction after clear and partial cutting shows higher stocking in partial-cut stands (Table 13). However, it is too early to estimate whether the new stands after clear cutting will be understocked.

TABLE 13.—COMPARISON OF REPRODUCTION, PARTIAL CUT AND CLEAR CUT, 1959

Age Class	Species	Per Cent Stocked Quadrats 1959		
		Partial Cut		Clear cut, Sites I and II Combined
		Dryopteris-Oxalis	Hylocomium-Oxalis	
50....................	Spruce and Fir....................	57	72	56
	White Birch........................	57	60	40
	Total..........................	79	86	71
70....................	Spruce and Fir....................	84	93	74
	White Birch........................	46	61	39
	Total..........................	92	97	83
Uneven-aged..........	Spruce and Fir....................	67	85	52
	White Birch........................	39	77	37
	Total..........................	81	95	63

It is possible that present stocking percentages for the clear-cut area are slightly low because of the extreme difficulty of locating all seedlings in the dense slash and shrub growth which covers most of the ground (Figure 16).

DISCUSSION

The general failure of 70-year-old fir stands to survive partial cutting where over 50 per cent of the stand volume was removed is not surprising. The process of stand deterioration and regeneration begins in these fir forests at about 60 years of age, as it does in similar stands in Gaspé (Webb, 1957), and lasts 20 to 25 years. Healthy stands of fir aged 85 years or over are very rare in this area. It might be stated that partial cutting in such stands hastens rather than delays this natural process of destruction and regeneration. This age class is now being clear cut except for a few of the younger stands, on lower, leeward slopes, which are considered as very good risks.

Partial cutting in immature 50-year and uneven-aged stands has resulted in varying degrees of success from stand to stand. Fortunately it is this variation, reflected in individual plot values, which illustrates the difference between success and failure. The results strongly suggest that the intensity of the cut is the most important factor influencing the amount of post-cut conifer mortality. It also appears that when cutting exceeds 40 per cent of the total basal area, the chances of mortality being very high are much greater than when cutting is less than 40 per cent.

Although the 40 per cent basal area figure appears to be the limit up to which cutting could proceed without undue concern about post-cut losses, two qualifications should be mentioned. First, it should be emphasized that this limit must be applied to each acre or each stand and must not be thought to represent a permissable average cut calculated for cutting areas of 100 or more acres. Referring again to the original intention to remove up to 40 per cent of the merchantable volume of immature stands (Matte, 1952) it is evident that this percentage was well chosen. Had it been uniformly applied the cutting would probably have been much more successful and, in immature stands, would have provided a yield of approximately 11 to 12 cords per acre, about 3 cords less than the actual cut. This limit is higher than that proposed by McLintock (1954) for the northeastern United States where he suggests it would be unwise to cut more than 25 per cent of the basal area 4 inches d.b.h. and over in spruce-fir stands.

The second qualification is that acceptance of the 40 per cent limit would be based on a mortality rate for only the first 5 years following logging and that additional future losses might force a downward revision of the limit. The 1964 remeasurement will determine if such a revision is advisable. However, it would be reasonable to expect that stands which survived the first 5 years following logging would subsequently suffer only minor losses during the 5 to 10 years up to the time of final harvest, and that stands highly susceptible to wind damage would be destroyed shortly after partial cutting. This contention is supported by the observation that most of the losses in the study area occurred within 3 years following logging.

Although confused by the occurrence of a spruce budworm attack, the increment borings indicate that partial cutting has stimulated diameter growth and more so for the 50-year age class than for the 70-year. Perhaps the best comparison of uncut and cut-over stands would be for the third growing season after logging (Figures 13, 14, and 15). For all diameters, sites and age classes, the growth rate in uncut stands dropped in this year whereas not a single growth rate in cut-over stands was less than the previous year and some were actually greater.

The increase in stocking of regeneration which occurred between 1954 and 1959 is evidence that the almost continuous cover of raspberry does not materially inhibit the germination and growth of fir, except perhaps on ground where the carpet is very dense (Table 12). This observation substantiates the finding on a neighbouring watershed (Hatcher, 1959) where, after clear cutting, dense growth of raspberry had no important effect on the development of fir reproduction. Per cent stocking in the partially cut forest, already higher than in the clear-cut area, will likely increase further. It is too early to make a final appraisal. Possibly the high stocking in the partial cut will give rise to overstocked stands while the lower stocking in the clear-cut area may result in a more desirable stocking in young stands.

The continuation of partial cutting by the company is an indication of the serious intent to increase pulpwood yields through improved silviculture. If in the near future the economics of woods operations permits a slight reduction in cords per acre removed, the goal of higher total yield will be closer to realization with losses kept to a reasonable level.

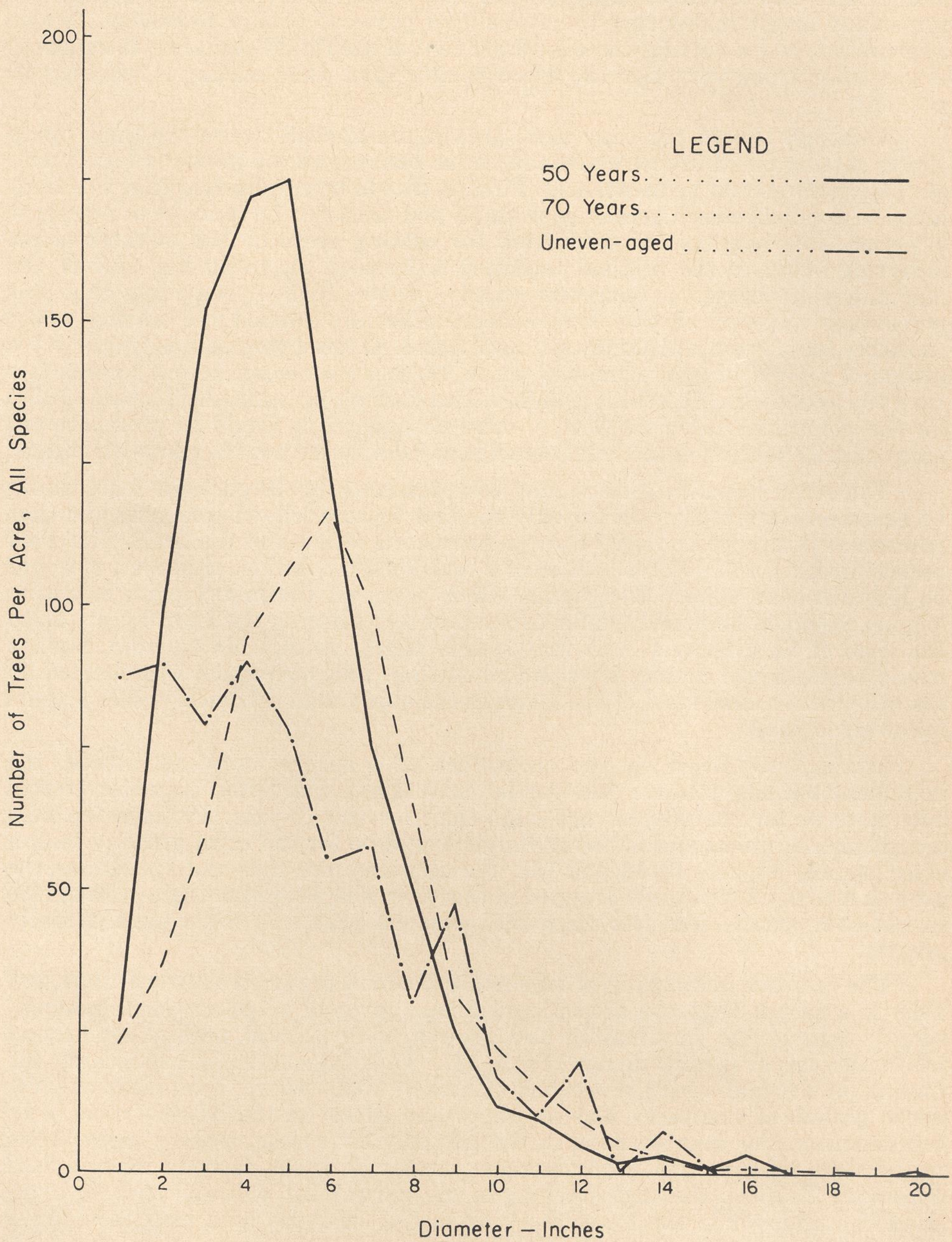

Figure 1. Original stand profiles, Dry-O type, all species.

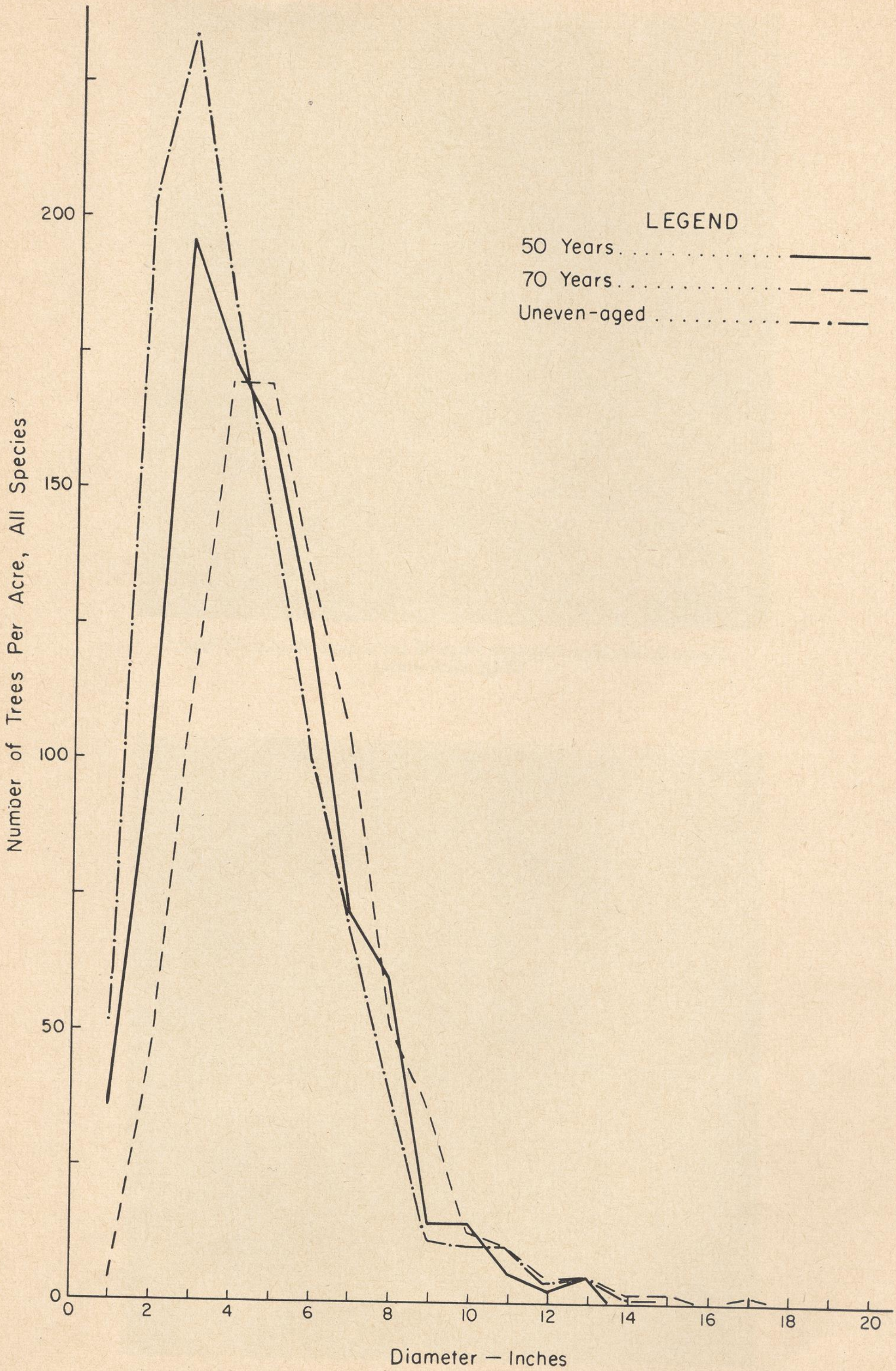

Figure 2. Original stand profiles, H-O type, all species.

Figure 3. Marking a mature stand of the Dryopteris-Oxalis type using paint guns.

Figure 4. Mature stand of the Hylocomium-Oxalis type after partial cutting in 1954.

Figure 5. Complete loss of conifers after partial cutting mature stand, Dry-O type (1959).

Figure 6. One of the rare mature stands where partial cutting was successful, Dry-O type (1959).

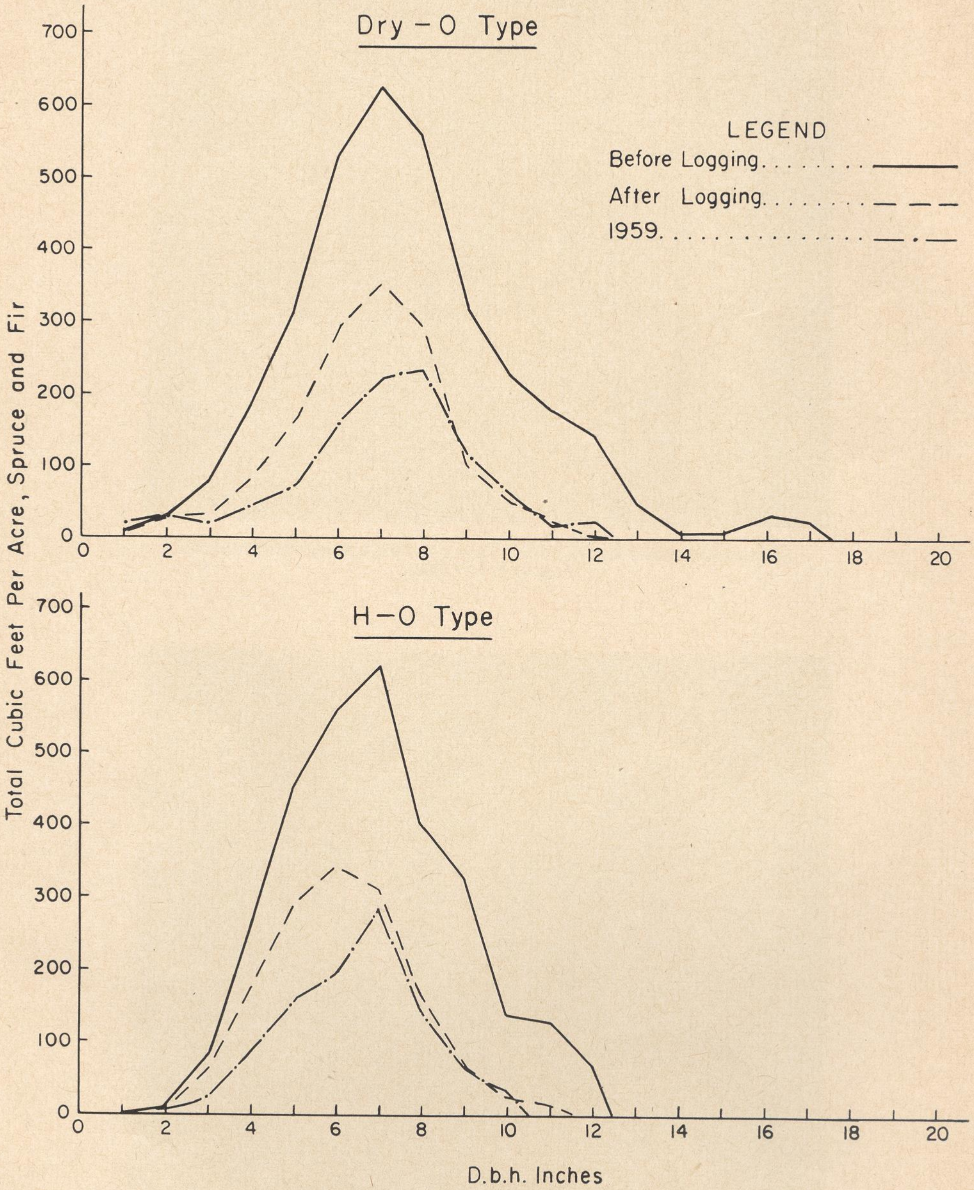

Figure 7. Spruce-fir stock profiles, age class 70.

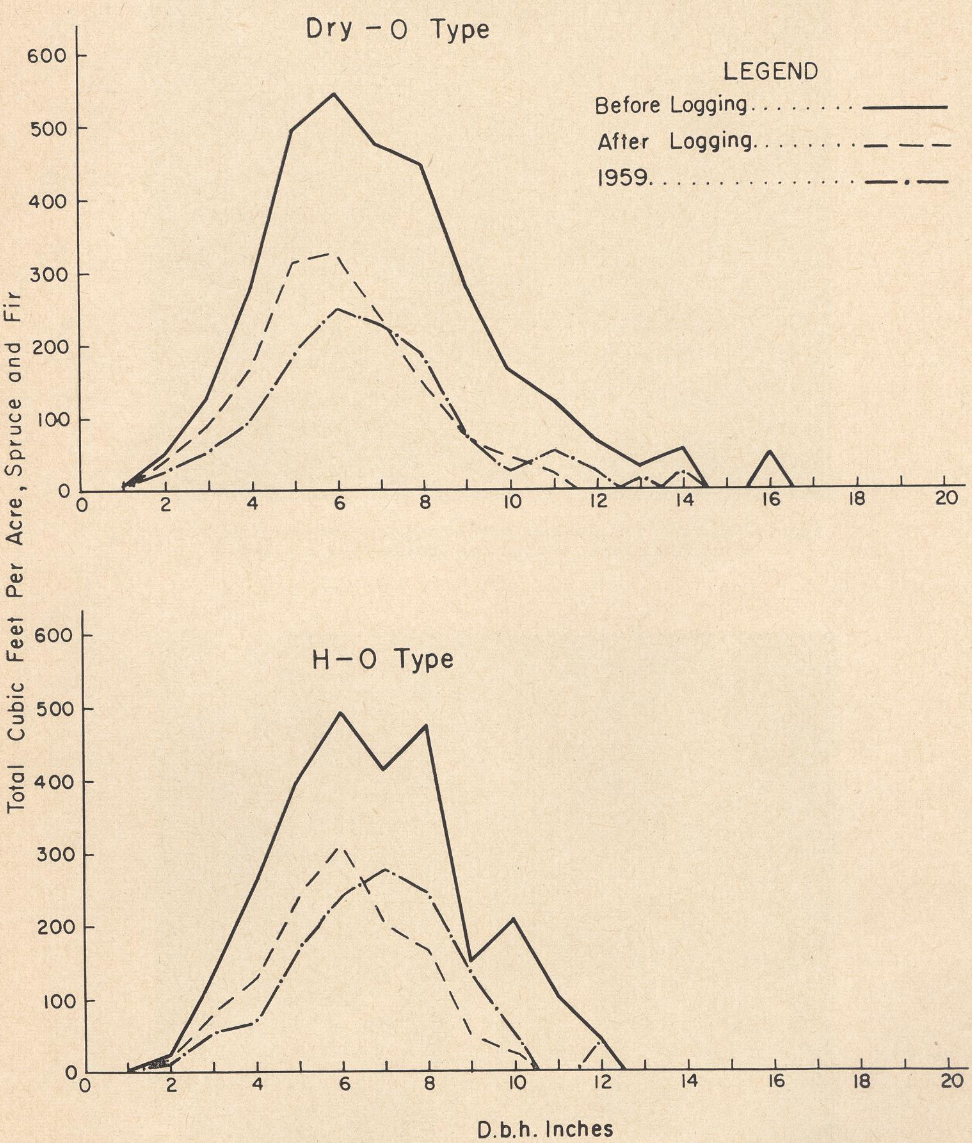

Figure 8. Spruce-fir stock profiles, age class 50.

Figure 9. Partially cut immature stand completely devastated by wind, with a dense cover of raspberry (*Rubus idaeus* L.), 1959.

Figure 10. Healthy, well-stocked 50-year-old stand, five years after partial cutting.

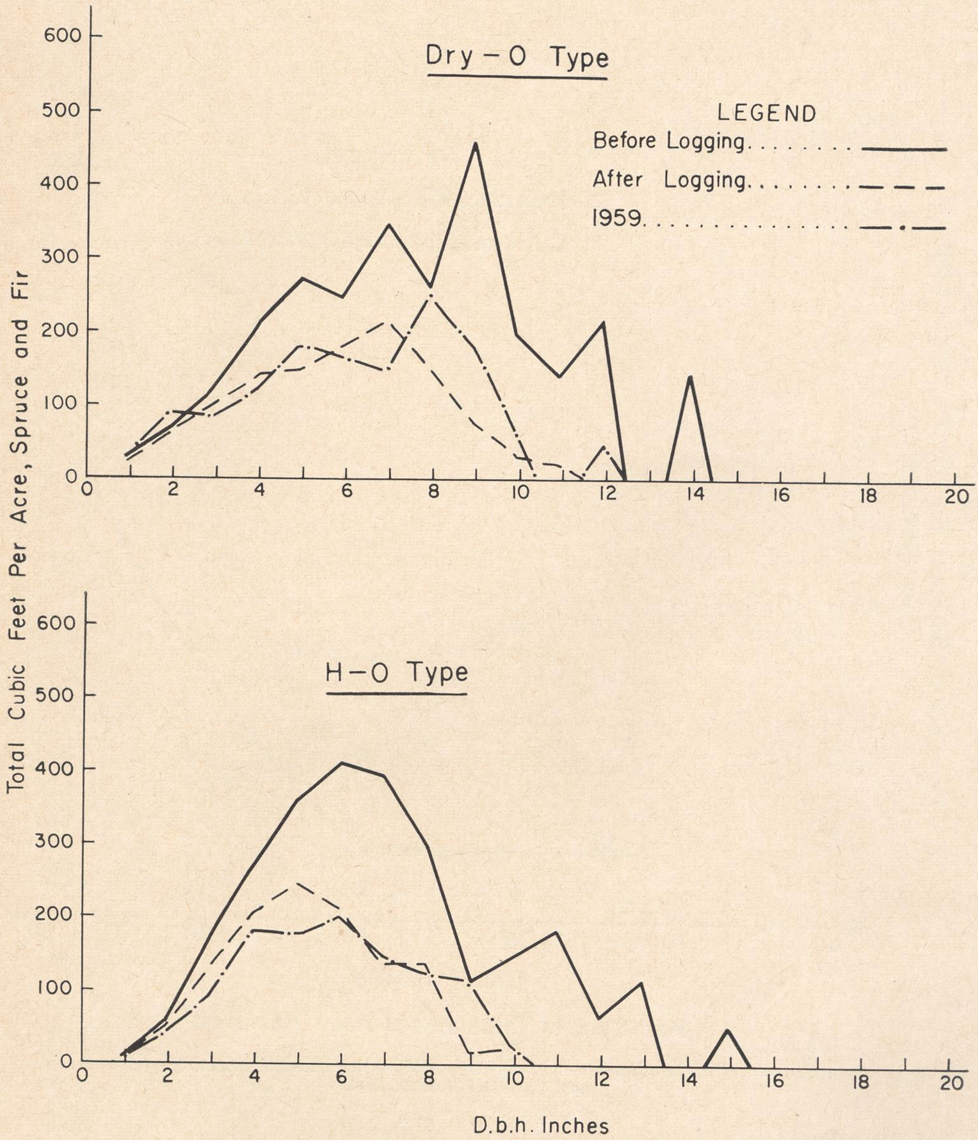

Figure 11. Spruce-fir stock profiles, uneven-aged stands.

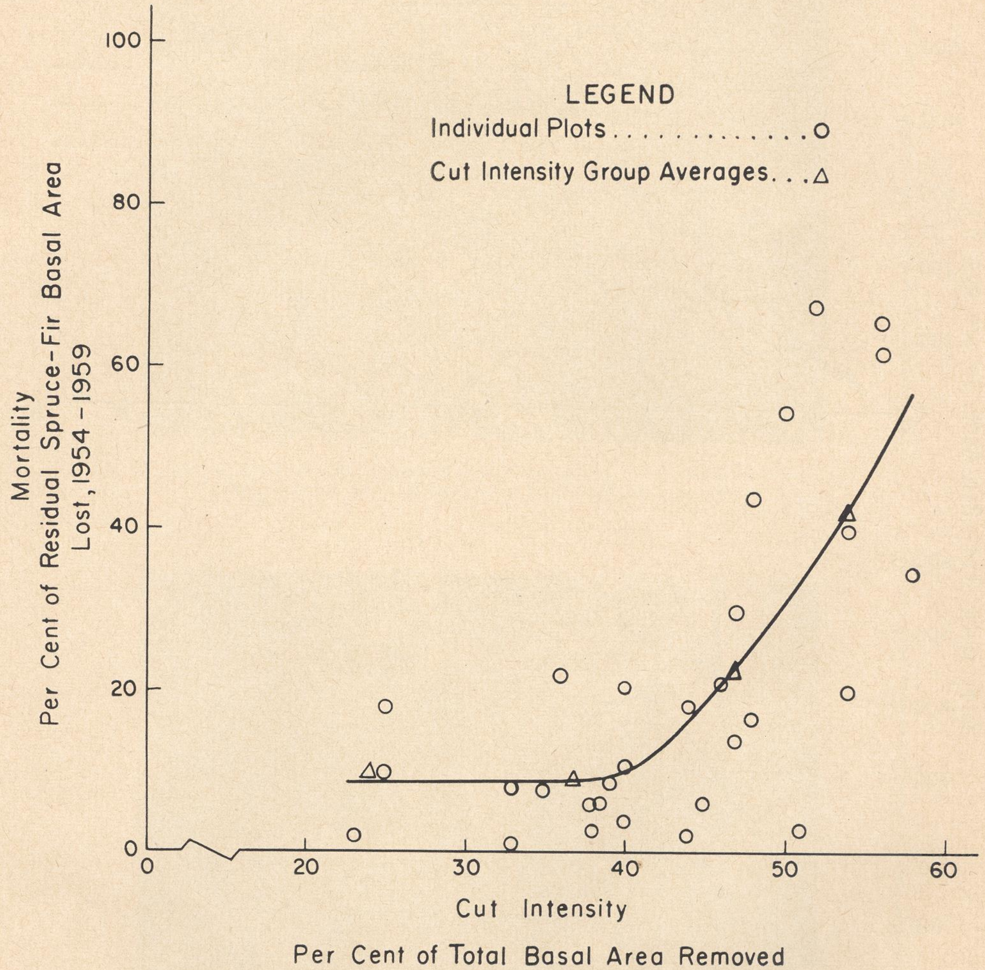

Figure 12. Spruce-fir mortality as a function of cut intensity, Dry-O and H-O sites, and 50-year and uneven-aged age classes combined.

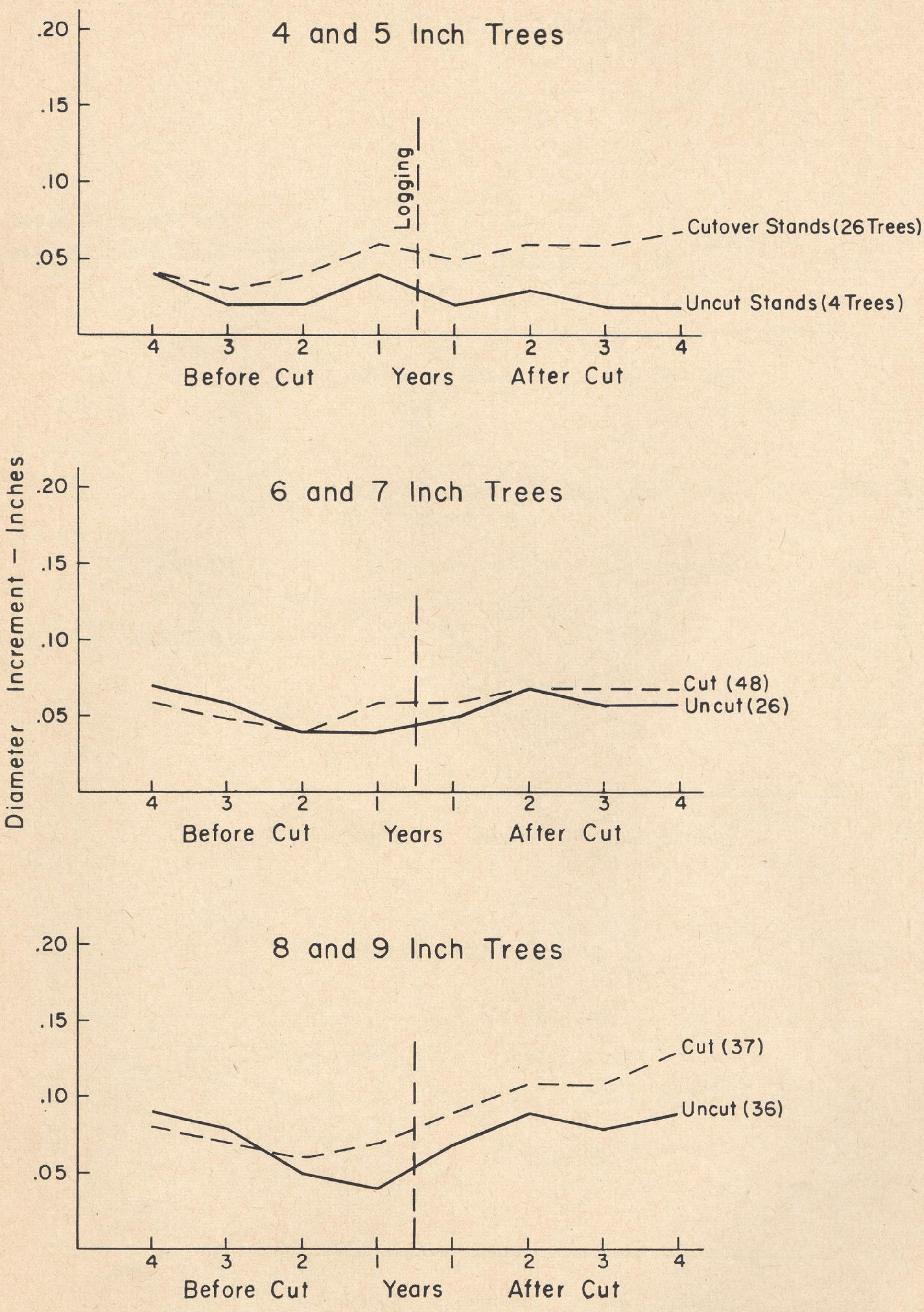

Figure 13. Fir diameter growth, before and after cut. Dry-O type, 70-year age class.

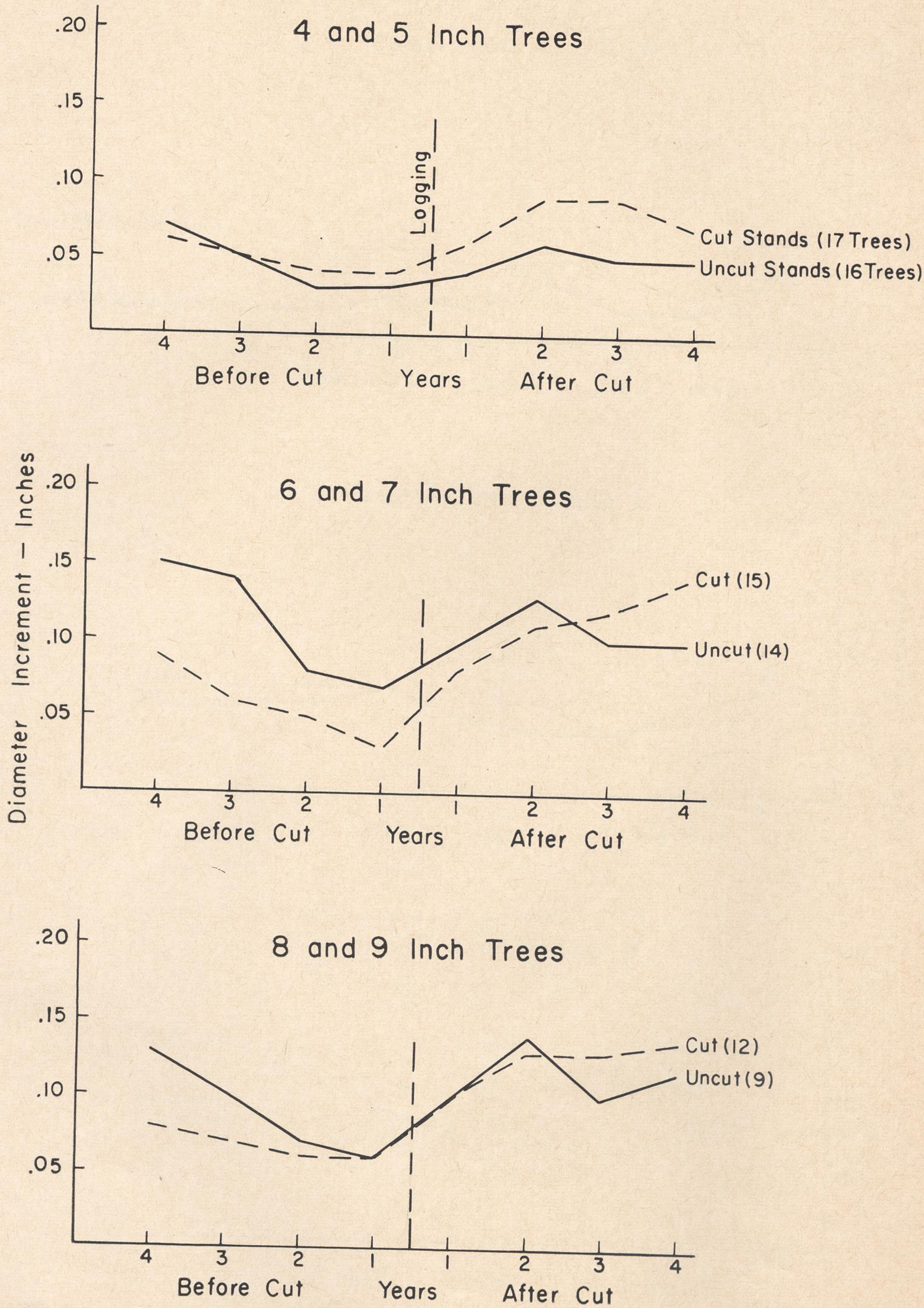

Figure 14. Fir diameter growth, before and after cut. Dry-O type, 50-year age class.

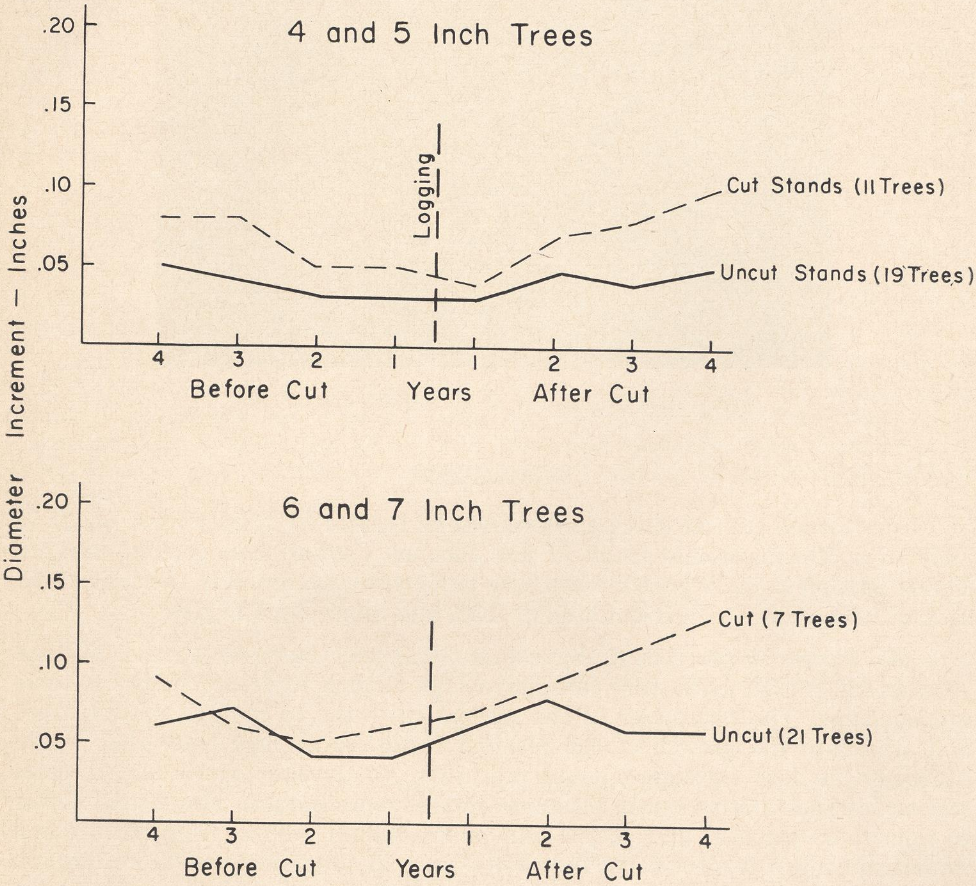

Figure 15. Fir diameter growth, before and after cut. H-O type, 50-year age class.

Figure 16. A typical view of the clear-cut area in 1959.

SUMMARY

Commercial partial cutting operations in balsam fir stands were begun in 1953 in a 50-square-mile block of the Jacques Cartier management unit, in Forest Section B.1a. A grid of tenth-acre plots was established in the partial-cut area in 1954, and in a clear-cut area in 1955, and remeasured in 1959.

The forest, 75 per cent fir by volume, had been cut over about 1925 and subsequent growth rates were considered high enough to justify more intensive management. The objectives of the partial cut were to remove mature trees and stimulate the growth of the residual stand, to salvage trees that would otherwise be lost through natural mortality, to develop wind- and disease-resistant stands and to assure adequate conifer reproduction. The intention was to remove 35 per cent and 40 per cent of the conifer volume from mature and immature stands respectively. The actual quantity removed was more than 50 per cent, in both age classes.

The cutting failed in mature 70-year-old stands owing to high mortality. Cutting was more successful in immature 50-year-old stands and uneven-aged stands, and a relationship has been established between cutting intensity and post-cut mortality. Cutting less than 40 per cent of the total basal area will probably prevent the occurrence of high mortality for the first 5-year period after cutting.

Stocking of reproduction has increased since the partial cutting and is considered more than adequate to provide fully-stocked stands. Stocking on the clear-cut area is less than on the partial-cut area but it is too early to determine which of the two will provide the most desirable stand density in future.

RÉSUMÉ

On a entrepris, en 1953, des opérations commerciales de coupe partielle de peuplements de sapin baumier dans un bloc de 50 milles carrés de l'unité d'aménagement Jacques-Cartier sise dans la section B-1a. On a établi des quadrillés de places d'un dixième d'acre chacune, un en 1954 dans la superficie ayant subi une coupe partielle et un en 1955 dans une superficie ayant subi une coupe rase, et on a effectué de nouveaux mesurages en 1959.

La forêt, composée de 75 p. 100 de sapin en volume, avait été exploitée vers 1925 et les taux subséquents de croissance furent jugés assez élevés pour justifier une exploitation plus intensive. Les buts de la coupe partielle étaient les suivants: enlever les arbres mûrs et activer la croissance du peuplement résiduel, récupérer des arbres qui autrement périraient de mort naturelle, développer des peuplements capables de résister aux vents et aux maladies, et assurer la reproduction convenable des résineux. On voulait enlever des peuplements mûrs et des peuplements non mûrs, 35 et 40 p. 100 du volume des résineux, respectivement. De fait, on a enlevé plus de 50 p. 100 dans les deux classes d'âge.

La coupe n'a pas été un succès dans les peuplements mûrs âgés de 70 ans par suite d'une mortalité élevée. La coupe a eu plus de succès dans les peuplements jeunes de 50 ans et dans les peuplements inéquiennes, et on a pu établir un rapport entre l'intensité de la coupe et la mortalité après la coupe. Une coupe de moins de 40 p. 100 de la surface terrière totale empêcherait probablement la mortalité d'être élevée durant les cinq premières années consécutives à la coupe.

La densité de la reproduction a augmenté depuis la coupe partielle et elle est maintemant jugée plus que suffisante pour assurer des peuplements pleins. La densité est moindre dans la superficie ayant subi une coupe rase que dans la superficie ayant subi une coupe partielle, mais il est trop tôt pour pouvoir dire laquelle des deux réussira à assurer la meilleure densité de peuplement.

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