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BALSAM FIR AND WHITE SPRUCE REPRODUCTION ON THE GREEN RIVER WATERSHED

by

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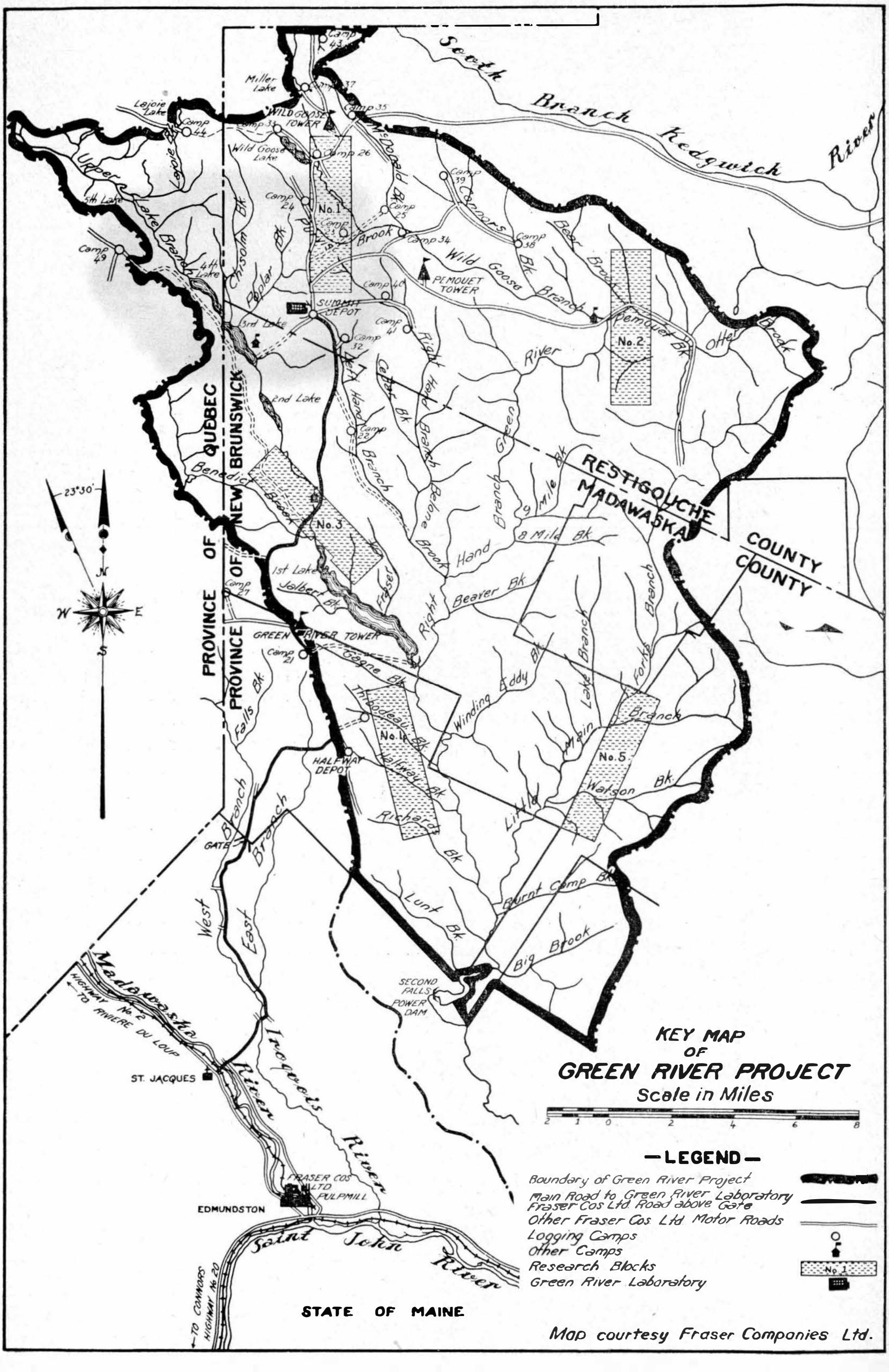
KEY MAP OF GREEN RIVER PROJECT
Scale in Miles
2 1 0 2 4 6 8
—LEGEND—
Boundary of Green River Project
Main Road to Green River Laboratory
Fraser Cos Ltd Road above Gate
Other Fraser Cos Ltd Motor Roads
Logging Camps
Other Camps
Research Blocks
Green River Laboratory
Map courtesy Fraser Companies Ltd.
PROVINCE OF QUEBEC
PROVINCE OF NEW BRUNSWICK
RESTIGOUCHE COUNTY
MADAWASKA COUNTY
STATE OF MAINE
South Branch Kedgwick River
Madawaska River
Iroquois River
Saint John River
EDMUNDSTON
ST. JACQUES
FRASER COS LTD PULPMILL
SUMMIT DEPOT
HALFWAY DEPOT
GREEN RIVER TOWER
WILD GOOSE TOWER
PEMOUET TOWER
SECOND FALLS POWER DAM
GATE
HIGHWAY No 2 TO RIVIERE DU LOUP
TO CONNORS HIGHWAY No 20

Balsam Fir and White Spruce Reproduction on the Green River Watershed

BY

A. B. VINCENT*

INTRODUCTION

Since 1944, the Forestry Branch has conducted a number of studies of reproduction on the Green River watershed in northwestern New Brunswick. These have included stock-taking surveys in cut and uncut stands, studies of the effects of brush piles on reproduction, releasing reproduction from shrub competition, the damage done to reproduction during logging, planting trials, a study of the effects of the spruce budworm outbreak on reproduction, and other minor studies. None of the investigations have been as intensive as, for example, that made by Place (5) at the Acadia Forest Experiment Station, nor as extensive as the regeneration survey reported on by Candy (1). They have been aimed primarily at obtaining an appreciation of the status of reproduction on the watershed and assessing the problems likely to be encountered by the forest manager in obtaining reproduction.

The purpose of this publication is to present the findings from the investigations and to discuss their significance.

DESCRIPTION OF THE AREA

Location

The Green River watershed is located in northwestern New Brunswick between latitudes 47°25′ and 47°55′N. and longitudes 68° and 68°30′W. The forested area is approximately 400 square miles.

Climate

Weather observations are made daily by the Division of Forest Biology of the Federal Department of Agriculture at the Green River Laboratory (elevation 1,370 feet).

Summers are short and warm, and the winters are long and cold with an average of 8·5 feet of snow.

The mean annual temperature is 36°F. January is the coldest month and July the warmest. Their mean temperatures are 8°F. and 61°F.

The mean annual precipitation is 42 inches; rainfall from May to October is 24 inches.

Prevailing winds are westerly.

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Topography and Soil

The topography is strongly rolling, with long, moderately steep and uniform slopes. Hills are gently rounded or flat-topped. Valleys are typically V-shaped, reflecting origin from erosion of the soft underlying rocks.

Swamps are small and few in number. Six small lakes with deeply eroded feeder streams (see map) drain to the south to join the main Green River.

The parent material is deep to shallow, loose dumped till or residual material, over permeable sandstone and shale bedrock. The soil is stony in texture, and mostly well-drained. The permeable nature of the bedrock usually leads to good drainage even on flat plateau areas. The profile development is a podsol with a moderate mor (2 to 3 inches) humus, over a distinct horizon of elluviation, having the typical fluid instability of the soils of the Maritimes when moistened. The B horizons are well formed with a deep brown colouring and granular structure. A B_1 or iron-humus horizon is usually present. Coarse materials weather to a profile almost equal to that on fine materials, and as a result they are not as droughty as would usually be expected.

Sites and Cover Types

A physiographic site classification for the watershed has been set up by W. G. E. Brown of the Forestry Branch who uses an adaption of the method developed by Hills (2). The site types are described as follows—

A Softwood—The soil is a well-drained loamy till which is usually located in the upper portions of drainage valleys. The ground vegetation is a mixture of herbs and ferns, with *Oxalis montana* and *Dryopteris spinulosa* being predominant. The site type occurs infrequently.

B Softwood—This site type occurs as narrow bands of moist alluvium along some streams. *Alnus rugosa* is the most common shrub. Herbs are minor with *Viola* and *Gallium* species being most common.

C Softwood—(Ci): the soil is a dry sandy till and is usually found near hilltops. The ground vegetation is similar to that of the A Softwood sites. This site occupies only a small area of the watershed. (Cii): this is the most abundant of the softwood sites. It occurs on lower slopes to stream courses and has a dry sandy or washed till. The ground cover is a moss-herb mixture with *Calliergonella schreberi, Hylocomium splendens, Oxalis montana,* and *Cornus canadensis* being the most plentiful species.

E Softwood—This site frequently supports two-storied stands and is usually found on valley flats. The soil is a dry, sandy outwash over a loamy till. The ground vegetation is chiefly feather mosses which are not too thrifty. Scattered *Oxalus montana* occur.

A Mixedwood—This site type is probably the most common. It occupies the major portion of long slopes. The soil is a well-drained loamy till with a shrub-herb ground vegetation. The most constant species are *Acer spicatum* and *Lycopodium lucidulum.*

C and Rc Mixedwood—These sites are fairly common. They are found on upper slopes and hilltops. The soil is a somewhat dry sandy till and shallow till over permeable shale and sandstone bedrock. The ground vegetation is similar to that on the A Mixedwood sites except that the herbs are more vigorous and *Lycopodium* is more abundant.

I Mixedwood—This site type occupies upper terraces of dry, sandy and gravelly outwash, which are few in number. The ground vegetation is similar to that on the C and Rc Mixedwood site type.

No general site classification of the watershed has been prepared, and as yet little has been done to assess the influence of site on regeneration. This work is going forward, but the information presented in this report can be related to the site types only in a general way.

Valley bottoms and lower slopes usually support softwood stands of balsam fir, white birch, and white spruce.* Birch comprises less than 25 per cent of the stand, and many trees have died from birch dieback.

The main portions of the slopes and hilltops are occupied by mixedwood stands of balsam fir, white birch, and infrequent white spruce and yellow birch. Birches make up 25 to 75 per cent of the stand. They have been hard hit by birch dieback.

Hilltops in the southern part of the watershed support pure hardwood stands of sugar and red maple, with a few yellow birch and balsam fir. Beech occur as very scattered stems.

The uncut softwood and mixedwood stands on most of the watershed are overmature and rather open. Most stands are at least 80 years of age, and crown closure seldom exceeds 75 per cent. They now occupy approximately 45 per cent of the forested area of the watershed.

History

Fire on the watershed has been relatively unimportant. About 5,000 acres were burned in 1880 and now support softwood and mixedwood stands averaging 70 years of age. In 1899 a fire burned over about 700 acres which now support dense softwood and mixedwood stands that are 45 years old. Since 1900, less than two square miles have been burned over.

The cutting history extends back to at least 1870; between then and 1935, cutting was chiefly for saw timber. No reliable records are available, but most of the valley bottoms show evidence of cutting which removed only the large softwoods. Cutting of softwoods since 1937 has been mostly for spruce and fir pulpwood. With the exception of some experimental cutting, all spruce and fir over four inches at breast height are felled. A cut averaging 44,000 cords is made annually.

The spruce budworm attacked the area between 1912 and 1919. About 47,000 acres of 35-year-old fir thickets under a thin overstory of spruce and fir now occur as a result. Another infestation has been in progress since 1948.

Birch dieback began in the watershed about 1938; well over half the birch have died since then. Many of the remainder are recovering. Aside from the loss of birch, the most significant effect of the dieback has been the rapid invasion of mixedwood stands by mountain maple.

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* See Appendix for checklist of botanical names.

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METHODS

The data presented in this report have been collected on both mechanically and arbitrarily located plots. The latter were chosen to sample specific conditions. The largest sample has been obtained from five research blocks (see map), each with 640 sample plots set out in a 6- by 10-chain grid. A stocked quadrat tally of reproduction was made on 10 milacre quadrats on each plot.

Other samples contained plots varying in size from one milacre up to transects of 30 milacre quadrats, usually laid out systematically on large plots which sampled a particular condition. Both stocked quadrat and total count tallies of seedlings have been made.

In addition to the sampling of specific areas, many general observations were made.

PRESENTATION OF DATA

Reproduction in Uncut Stands

Two uncut stands are shown in Figures 1 and 2. They are typical of the stands dealt with in the investigations on the Green River watershed.

Data on two-storied and hardwood stands are not included in Tables 1 and 2 because reproduction of spruce and fir is not a problem in these cover types.

TABLE 1—AVERAGE NUMBER OF TREES, BASAL AREA, AND MERCHANTABLE VOLUME PER ACRE OF MATURE SOFTWOOD AND MIXEDWOOD STANDS ON THE RESEARCH BLOCKS

COVER TYPE	Number of Trees						Basal area (sq. ft.)	Softwood merch. vol. (cunits)[1]
	Spruce and Fir			Hardwoods				
	1-3″	4-9″	10″ and over	1-3″	4-9″	10″ and over		
	Research Block 1							
Softwood	124	89	79	25	18	6	102	21·0
Mixedwood	142	85	51	17	14	10	81	14·7
	Research Block 2							
Softwood	283	154	63	17	15	3	98	19·0
Mixedwood	315	75	40	18	24	8	67	11·2
	Research Block 4							
Softwood	—	—	—	—	—	—	—	—
Mixedwood	316	84	13	412	55	27	74	5·0
	Research Block 5							
Softwood	441	166	46	44	14	8	95	14·1
Mixedwood	249	77	23	127	48	25	75	6·7

[1] 100 cubic feet, solid measure.

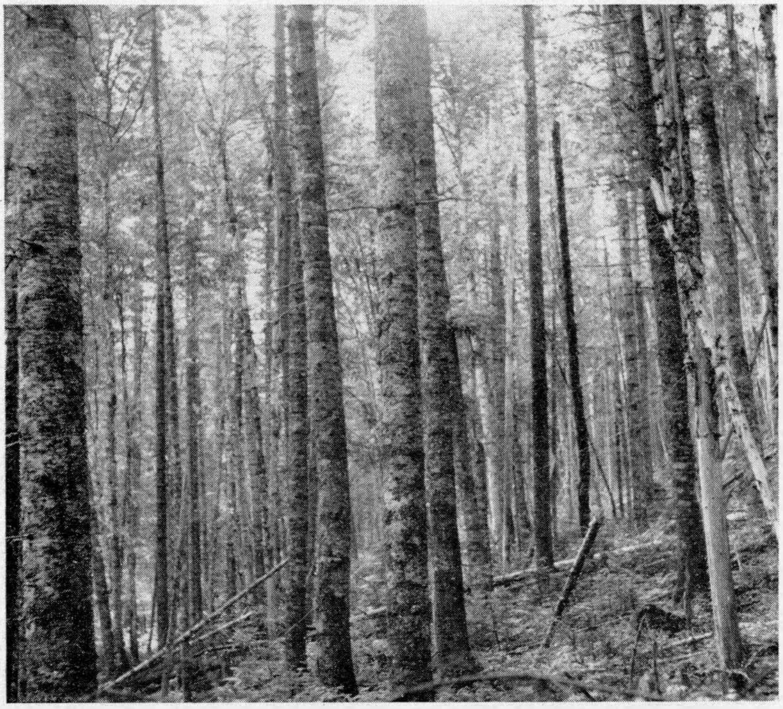

FIGURE 1.—A mature softwood stand on a Cii site. The stand is rather open with fairly good advance growth.

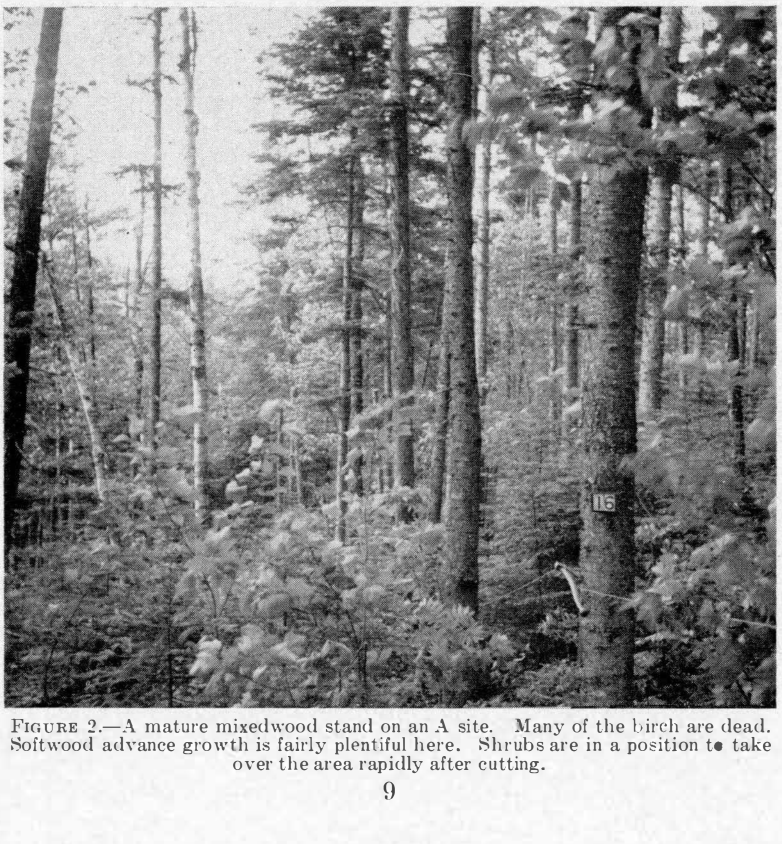

FIGURE 2.—A mature mixedwood stand on an A site. Many of the birch are dead. Softwood advance growth is fairly plentiful here. Shrubs are in a position to take over the area rapidly after cutting.

Table 1 shows average figures for the softwood and mixedwood stands on the research blocks. No data for Research Block 3 are included because of lack of mature stands. Basal areas of individual stands may range from 80 to 190 square feet per acre for softwood stands and 50 to 150 square feet per acre for mixedwood stands. Merchantable volumes of spruce and fir may range from 12 to 30 and 5 to 20 cunits per acre, respectively. Much of the range is caused by differences in the distribution of trees in the various diameter classes rather than by large differences in the total numbers of stems. Most of the variation in basal area in mixedwood stands is caused by the mortality of birch.

Small conifers are often more abundant in mixedwood than in softwood stands. This is probably a result of the birch dieback. The death of birch released the larger advance reproduction before the growth of deciduous shrubs became rank enough to suppress it. The smaller seedlings are now severely suppressed.

Reproduction under the stands on Research Blocks 1 and 2 is shown in Table 2. The stocking on Blocks 4 and 5 is as good as or better than that for the two shown.

TABLE 2—REPRODUCTION STOCKING IN MATURE SOFTWOOD AND MIXEDWOOD STANDS ON THE RESEARCH BLOCKS

COVER TYPE	Stems per acre[1]		Per cent quadrats stocked	
	Spruce and fir	Hardwoods	Spruce and fir	Hardwoods
	Research Block 1			
Softwood	2,430	380	57	10
Mixedwood	1,870	380	38	10
	Research Block 2			
Softwood	3,370	130	46	No data
Mixedwood	2,150	387	38	No data

[1] Includes all stems up to 0·5 inch d.b.h.

The softwood and mixedwood stands are moderately well stocked with spruce and fir reproduction. Spruce comprises from 5 to 25 per cent of the total reproduction.

Reproduction in Cut-over Stands

The usual logging methods employed in the area are stump-cutting in the dense stands and horse-yarding by tree lengths in the more open stands (see Figures 3 and 4). In either method, all trees are supposed to be removed which will produce three bolts of 4-foot wood to a 4-inch top inside bark (according to undersize permit regulations of the New Brunswick Department of Lands and Mines). In practice, a number of trees of merchantable size are usually left.

FIGURE 3.—A stump-cut area on a Cii Softwood site. Note the windrows of brush. The area was cut in 1952.

FIGURE 4.—Cut-over on an A Mixedwood site. The area was horse-yarded. The prolific growth of mountain maple will soon occupy most of the area.

These are large trees that appear to the cutter to be unsound, and small trees near the lower limit of merchantability which the cutter judges to be too small. The volume involved is usually one to two cords per acre of wood of merchantable size.

Table 3 shows the number of saplings (trees 1 inch to 3 inches d.b.h.) and the percentage of stocked quadrats in cut-over softwood stands of various ages.

TABLE 3—SAPLING STAND PER ACRE, AND PERCENTAGE STOCKING OF SOFTWOOD SEEDLINGS AND SAPLINGS ON SOFTWOOD CUT-OVERS OF VARIOUS AGES

Plot	Years since cut	Saplings per acre				Per cent stocked quadrats	
		Fir	Spruce	Birch	Cherry and Mt. Ash	Seedlings only	Seedlings and saplings
1	14	1,327	140	80	347	89	96
2	16	2,870	288	175	652	91	92
3	11	1,345	220	105	590	63	88
4	6	292	67	—	—	94	95
5	8	2,022	187	15	122	85	92
6	8	807	105	10	10	59	70
7	5	1,467	57	107	70	71	81

Most of the plots on which the above values were obtained were located on Cii Softwood sites. They were arbitrarily located to sample average conditions in each age of cut-over. Plots were two chains on a side and were crossed at equal intervals by four lines of milacre quadrats. The sapling tally is from the main plot, and the stocked quadrat tally from the 80 quadrats on each plot.

Stocking of conifers is good on most plots, although plots 4 and 6 have suffered from frost. Regeneration tends to be patchy in the new stands, with many small areas being sparsely stocked. This is discussed further in a subsequent section.

The percentages of spruce and fir established before cutting are shown in Table 4. Most of the stems now over two feet high were on the ground when the stands were cut. Approximately half of those from one to two feet high have come in since cutting, and most of those under one foot are younger than the age of the cut-over. Apparently some softwood regeneration becomes established following cutting, but it forms a rather small part of the new stand.

Total volume growth on the plots has been excellent (Table 5). The total softwood volume on the plots now averages 533 cubic feet per acre. Assuming that about 200 cubic feet were left after cutting, this indicates an average net increment of 33 cubic feet per acre per year. There is of course little or no growth in merchantable volume, but the average diameter growth is now one inch in 10 years for the saplings. Many saplings will soon be entering the merchantable size class, thus providing an abrupt rise in increment of merchantable volume.

The average number of trees and stocking of regeneration is adequate on cut-overs (Table 6), but the distribution of these stems is patchy. It is estimated that about two-thirds of the cut-over land is overstocked and one-third is understocked.

TABLE 4—PERCENTAGE ESTABLISHED BEFORE CUTTING

Plot	Years since cut	Balsam fir	Spruce
		%	%
1	14	58	86
2	16	92	100
3	11	91	100
4	6	81	67
5	8	90	100
6	8	91	88
7	5	74	100
Mean	10	78	90

TABLE 5.—YEARS SINCE CUTTING AND TOTAL SOFTWOOD VOLUME IN CUBIC FEET PER ACRE

Plot	Years since cut	Volume in cubic feet	
		Fir	Spruce
1	14	1,127	36
2	16	847	203
3	11	302	76
4	6	33	3
5	8	500	39
6	8	161	15
7	5	382	9
Mean	10	479	54

TABLE 6.—AVERAGE NUMBER OF CONIFEROUS TREES AND PERCENTAGE STOCKING OF REPRODUCTION ON CUTS MADE BETWEEN 1937 AND 1945

Research block	Spruce & fir over 0·5″ d.b.h. (per acre)		Per cent stocked quadrats			
			Spruce & fir		Hardwoods	
	Softwood cut-over	Mixedwood cut-over	Softwood cut-over	Mixedwood cut-over	Softwood cut-over	Mixedwood cut-over
1	1,651	355	47	46	14	10
3	1,129	—	63	—	—	—
4	1,526	815	51	50	26	45

Logging Damage to Softwood Reproduction

Information on logging damage has been obtained from three studies (6, 7, 11). The first of these was a shelterwood cutting experiment, the second was a diameter-limit cutting experiment, and the third was a study of logging damage during clear cutting (for practical purposes, cutting to a 5-inch d.b.h. limit).

The shelterwood cutting involved removing 30 and 60 per cent of the merchantable softwood volume from a 65-year-old stand with basal area averaging 128 square feet and softwood volume averaging 1,530 cubic feet per acre. The average diameter at breast height was 6·9 inches. Cutting was done on six 1-acre plots—three of each cutting intensity. All plots were yarded. There were 37,000 fir and 260 spruce per acre under 0·5 inch d.b.h. and about 145 trees in the 0·5- to 3·5-inch d.b.h. class (saplings). Topography was gently rolling. Reproduction was tallied on 125 milacre quadrats systematically distributed on each plot.

In the diameter-limit cut, four 0·4-acre plots were cut to a 10-inch stump diameter limit and four to a 5-inch limit. Two plots of each intensity were in softwood stands and two were in mixedwood stands. All plots were yarded. Reproduction was recorded on 60 regularly distributed milacre quadrats on each plot.

The study of logging damage was made on 0·2-acre plots, with eight plots in mixedwood stands and five in softwood stands. Those in mixedwood stands were yarded and the others were stump-cut. All were located in regular operational areas where all merchantable trees were supposed to be cut. Reproduction was recorded on 30 systematically located milacre quadrats on each plot.

Table 7 gives a good illustration of variations in the amount of spruce and fir reproduction as well as the amounts of logging damage caused by different intensities of cutting. All except the 5-inch limit and stump-cutting areas were horse-yarded by tree lengths.

A correlation analysis of the data from the clear-cutting operation indicated that the larger the number of seedlings present the greater was the logging damage suffered. The number of trees, basal area, and volume removed were not significantly correlated with the number of saplings destroyed. This agrees with the findings of Mowat (4) in a study of logging damage during cutting of ponderosa pine.

TABLE 7—SOFTWOOD REPRODUCTION (UNDER 0·5" D.B.H.) PER ACRE AND PERCENTAGE OF STOCKED QUADRATS BEFORE AND AFTER SHELTERWOOD, DIAMETER-LIMIT, AND CLEAR CUTTING

—	Shelterwood		Diameter-limit		Clear Cut	
	30% cut	60% cut	10" limit	5" limit	Yarded	Stump-cut
			Stems per acre			
Before	33,040	40,992	5,708	7,583	8,704	16,693
After	25,582	32,055	5,500	7,133	3,615	6,812
Per cent destroyed	22	22	4	6	58	59
			Percentage stocked quadrats			
Before	98	99	70	77	87	97
After	94	93	62	63	57	75

Chi-square tests of the differences in mortality of regeneration between the two intensities of shelterwood cutting, and yarding and stump-cutting in the clear-cutting operations, indicated that total logging damage to reproduction was not significantly affected by changes in the cutting intensity or logging method. The greatest damage was suffered by stems one to six feet high during yarding, but there are indications that the larger seedlings suffer somewhat more during stump-cutting than during yarding. Probably this is because more room is needed for pulpwood piles and strip roads during stump-cutting.

The site type has two indirect effects on the amount of logging damage· Site determines in part the amount of advance growth present and the method of logging used because of its influence on stand volume. Only the first item seems to be important, but as mentioned before, too little work has yet been done for an assessment of its importance. General quantitative data that are available are not related to specific site types.

Effects of Slash Piles on Softwood Reproduction

A study of the effects of slash piles on spruce and fir reproduction (13) was made in 1953. Ten plots of a size and shape to encompass one slash pile on each of 10 areas were examined along with accompanying plots on adjoining slash-free areas. Slash density was recorded as square feet of branch surface per square foot of ground surface. Each seedling on the plot was cut just above the root collar and its age determined. Diameter and height growth before and after cutting were recorded. Plots were located on the Cii Softwood site in stump-cut areas.

Tabular data are not shown here, but the findings are described. The impression gained by observing the distribution and size of slash piles in various areas is that the slash is most dense where advance reproduction was least. That is, the cutters tended to throw the slash where sizable advance growth did not interfere with easy piling. Regeneration on the older cut-overs (areas examined ranged from two to 10 years since cutting) has been greater than on the younger. Most of the regeneration since cutting occurs around the edges of the slash piles where the litter of needles, twigs, and branches is thinner than towards the centre of the pile. The decomposition rate is more rapid at the edges of the slash piles and seedbed conditions are better. Morais (3) concludes that the life of slash in normal conditions on the Causapscal River watershed is about eight years, but Westveld (17) writes that slash piles do not allow favourable conditions for regeneration until after 15 years. On the Green River watershed, conditions at the centres of slash piles do not become favourable for regeneration for at least 15 years.

Examination of the slash piles disclosed few dead stems that could be attributed directly to the crushing or smothering effects of dense slash. Indeed, mortality was found to be greater on some of the adjoining slash-free plots. Apparently slash piles are not particularly harmful to advance growth that is over three feet high at the time of cutting. The mortality that did occur was mainly from slash breaking the stems.

Height growth measurements indicated that growth since cutting is not affected by the presence or absence of slash.

Dense slash apparently coincides with heavy logging damage, but this may be in part owing to the cutter throwing the slash into spots where advance reproduction has been removed during cutting and so making slash piling easier.

There is some indication that white spruce seedlings are better able than fir to withstand the shock of sudden exposure, but the data are not sufficiently comprehensive to establish this definitely.

Effects of Shrubby and Herbaceous Vegetation on Reproduction

A number of studies have established that shrub vegetation is an important factor in the regeneration of stands on the Green River watershed. Mountain maple and raspberry are important on mixedwood cut-overs, and raspberry and pin cherry on softwood cut-overs.

Mountain maple closes in rapidly on mixedwood cut-overs, spreading by seed, root shoots and layering (8). Its growth rate is so rapid (one foot or more annually from seed) that it quickly overtops spruce and fir reproduction which it suppresses for 30 to 40 years. In addition to suppressing established advance reproduction, it hinders successful regeneration of spruce and fir by casting dense shade and giving rise to a very poor seedbed of flatly compressed leaves.

In 1949, an experiment (10) was set up in a 9-year-old cut-over on an A Mixedwood site to test the response of spruce and fir reproduction to release from shrub competition. Each stem of spruce and fir on a 1-acre plot was released by clearing a circle about it three feet in radius. An adjacent 1-acre plot was set up for control. The treated plot supported about 800 spruce and fir between six inches and 10 feet high, and the control plot about twice that number. Mountain maple formed a closed canopy about 10 feet high before treatment. Table 8 shows the total height growth for fir on the treated and control plots for 4-year periods before and after treatment.

TABLE 8—HEIGHT GROWTH OF BALSAM FIR REPRODUCTION DURING THE 4-YEAR PERIODS BEFORE AND AFTER RELEASE FROM SHRUB COMPETITION IN 1949

1949 height class	4-year height growth				Number of stems measured	
	Before treatment		After treatment			
	Treated	Control	Treated	Control	Treated	Control
(feet)	(feet)	(feet)	(feet)	(feet)		
2·1 – 2·5	0·9	0·9	2·7	0·5	77	113
2·6 – 3·0	1·1	1·1	3·0	0·8	49	91
3·1 – 3·5	1·4	1·2	3·4	0·8	45	89
3·6 – 4·0	1·5	1·4	3·4	1·1	46	71

Height growth on the treated plot after release was about three times as rapid as on the control plot. Growth on the control plot decreased during the four years after treatment. Although only four size classes are shown in Table 8, all classes of both spruce and fir up to six feet showed similar increases. Trees over six feet at the time of treatment showed little or no increase in height growth. A number of larger stems in an adjacent area have since been treated by clearing an area of 6-foot radius about each to determine whether the earlier treatment was or was not sufficient for these larger stems, but no results are yet available.

An interesting feature of this experiment is that the mountain maple, and raspberries, closed in on the released reproduction within two years without causing any noticeable slowing of height growth. This seems to indicate that a chemical control method that would kill some shrubs and retard the remainder for four or five years would be successful in providing the necessary release for spruce and fir reproduction. This would of course be only for those areas where shrubs are the cause of suppression.

Raspberry sometimes fills in holes on mixedwood cut-overs not covered by mountain maple, but it is not too important there. In softwood stands, raspberry may have a much greater influence. It becomes dense after cutting and often forms a dense canopy up to four feet high with more than 100,000 canes per acre. Little light reaches the soil under such conditions, and the litter of leaves and dead canes provides an extemely poor seedbed. Spruce and fir reproduction that reach above the raspberry are apparently not affected, but overtopped reproduction is strongly suppressed. The establishment of new seedlings is practically nil. For instance, on a 1-acre plot on an A Softwood site clear cut seven years ago, there were only 454 spruce and fir under six inches high (15). There were 6,400 per acre on an adjoining uncut plot on the same site. Those that did occur on the cut-over were mostly in the shade of larger stems where raspberry was not dense.

Pin cherry becomes rather prolific on softwood cut-overs where there is no dense reproduction. It grows rapidly and overtops the softwood reproduction that does occur, but the shade cast by its open canopy appears to be beneficial. Established spruce and fir under it are usually very thrifty. Establishment of new seedlings may be retarded, but the seedbed appears to be considerably better than that under mountain maple or raspberry.

In 1951, an experiment (14) was initiated to determine whether stand replacement after moderate to heavy pulpwood cutting could be forecast from early records of seedling establishment. One hundred and five milacre quadrats in groups of five to 20 were set out in the diameter-limit cutting area referred to earlier, and 50 quadrats in groups of 10 were set out in a clear-cut area. Brush and advance growth were removed at establishment, and germination and mortality records were kept for each of the next four growing seasons. The project was closed this year* because a number of factors indicated that it would be impossible to achieve the purpose. Although the seed supply on both areas was reasonably adequate, regeneration was good on only one group of quadrats in each area. Both were set out in the shade of fairly open 3- to 5-inch fir which apparently provided enough shade to prevent the growth of shrubs but not enough to prevent the establishment of spruce and fir seedlings. The remaining 12 groups were covered either with dense raspberry growth or a very luxuriant growth of herbaceous vegetation such as bracken, bunchberry, Clintonia, common wood fern, and false-lily-of-the-valley. The raspberry cast very dense shade and made a poor seedbed. The herbaceous vegetation gave some shade, but its chief adverse effect was the formation of a mat under the snow which crushed the seedlings. This mat usually decomposed during the summer although too late for the seedlings to survive. Deer browsing and trampling were also prominent factors in preventing regeneration. It appears that the lack of sizable seedlings and brush on the quadrats permitted an unusually luxuriant growth of shrubs and herbs and in some way made the quadrat areas particularly attractive to deer. Evidence of deer browsing and trampling was much less apparent in surrounding areas.

Plantations

Planting experiments in the watershed have been on a limited scale. In June, 1950, a one-acre plantation (9) of red and black spruce was established on a C Mixedwood hilltop site. Natural stock obtained from a *Sphagnum* bog on the Acadia Forest Experiment Station was used. It was separated into two height classes—five to 10 inches and 10 to 15 inches. The plot was divided into eighths and each size class assigned to half the plot at random. Spacing was 6 by 6 feet and the hole planting method was used because of the stony shallow soil.

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* 1955.

Mortality at the end of one year—one growing season plus one winter—was 37 and 48 per cent for small and large stock respectively. At the end of the second growing season, total mortality was 51 per cent for both size classes, no differentiation being made between species.

The most noticeable cause of mortality was the crushing of the smaller stems under a mat of bracken during the winter. Much of the remaining mortality appeared to be the result of the combined effects of the shallow soil and exposure. Mortality was much greater where the plants were not protected from direct insolation by small shrubs.

Most of the survivors are thrifty, and many put on more than a foot in height during the third growing season after planting.

A second planting project (12) was started in 1953. The purpose of this is to determine whether there are any problems in reforesting strip roads with white spruce to increase the spruce content of the stands. About 2,400 2-2 white spruce from the nursery at the Acadia Forest Experiment Station are being planted each year for five years. Most of the planting is being done on Cii Softwood sites, although some planting will be done on the A and B Softwood sites and the A Mixedwood site where the stump-cutting method has been used.

Each plantation consists of three rows of seedlings planted by the hole method on each of four strip roads. About 100 seedlings per strip road are planted. One row is in the centre of the strip and the other two along either side. Spacing between rows varies from five to eight feet. Seedlings are spaced six feet apart along the rows.

A mortality count of the stock planted in 1953 from seed obtained at the Riding Mountain National Park indicated that mortality after one year varied from 4 to 15 per cent except where planting was done in dense raspberries; mortality here averaged about 30 per cent. Competition from herbaceous and shrubby vegetation is probably the chief cause of mortality. A luxuriant vegetation appears on the strip roads soon after cutting, and crushes the smaller seedlings during the winter. Some of the crushed seedlings recover, but most do not. It seems useless to plant 2-2 seedlings less than six inches high. The best survival is obtained when the planting stock is more than 8 to 10 inches high. The weather at the time of planting has a noticeable effect on survival. When planting is done during bright warm days, the seedlings have difficulty obtaining adequate moisture and dry quickly. They are in much better condition following planting during wet or overcast weather.

The Effects of the Spruce Budworm on Softwood Reproduction

In 1954, a study (16) was initiated of the effects of the current spruce budworm infestation on spruce and fir from the seedling stage up to 3·5 inches at breast height. A grid of 4-milacre quadrats was established on each of four 20-acre plots set up by the Division of Forest Biology. Spacing of the grid was 2- by 2-chains, giving about 64 sample units per plot. Each plot is in a different intensity of budworm infestation. The young softwoods were tallied by species in 6-inch height classes and the following total defoliation classes; 0 to 25 per cent, 26 to 50 per cent, 51 to 75 per cent, 76 to 95 per cent, more than 95 per cent, and dead from budworm defoliation.

TABLE 9—TOTAL SPRUCE AND FIR REPRODUCTION AND BUDWORM-KILLED REPRODUCTION PER ACRE

Plot	Height class (feet) and stems per acre						
	0 - 0·5	0·5 - 1	1 - 5	5 - 10	10 - 15	15 - 20	20+
G-9 Total	6,505	2,767	3,465	400	67	10	—
Killed	104	156	297	42	5	—	—
Per cent killed	1·6	5·6	8·6	10·5	7·5	—	—
G-13 Total	22,848	1,960	1,507	978	477	298	276
Killed	—	4	4	—	—	—	—
Per cent killed	—	0·2	0·3	—	—	—	—
K-1 Total	9,645	1,591	1,559	600	333	388	253
Killed	138	92	696	267	54	17	12
Per cent killed	1·4	5·8	44·6	44·5	16·2	4·4	4·7

The fourth plot, G-6, has not suffered severe defoliation and there has been no mortality of reproduction.

Plot	Years since severe defoliation started
G-9	3
G-13	2
K-1	5

Most of the reproduction and mortality that has occurred has been in stems one foot to 10 feet high (Table 9). It seems fairly certain that the damage to reproduction is directly related to the degree of infestation in the main stand. Plot G-9 was sprayed from the air with DDT in 1953. Much of the 1954 foliage survived, and there was a marked beneficial effect on reproduction. Many of the stems that had suffered almost complete defoliation before 1954 had a fringe of new foliage in that year. It is possible that if re-infestation is not too severe some of these stems will survive. Plot K-1 is in the epicentre of the infestation which is damaging stands on the watershed; mortality occurred in the main stand for the first time in 1954.

Reproduction below one foot in height has suffered least, and the defoliation of larger stems increases with the degree of infestation. For instance, about 60 per cent of living stems above one foot on plot K-1 had lost more than 95 per cent of their foliage by 1954. Corresponding defoliation for plots G-9 and G-13 was 8 and 3 per cent respectively. Less than one per cent of spruce and fir under one foot on plots G-9 and G-13 were in the highest defoliation class; one per cent of trees this size on Plot K-1 were in this class.

Few spruce seedlings on any plot have been more than 50 per cent defoliated. Only one budworm-killed spruce was found on Plot K-1, and none was found on the others.

The immediate effect of the aerial spraying program is to give the softwood reproduction a new lease on life, but the long-term effects can be determined only by repeated remeasurements.

DISCUSSION

The number of spruce and fir seedlings on areas where the former stand was a mixture of fir and white birch in roughly equal proportions (A and C Mixed-wood sites) is usually adequate to form a new stand of reasonable density. However, the luxuriant growth of mountain maple on these cut-overs greatly lengthens the regeneration period by suppressing the softwoods. This is the more serious in that conditions favouring the establishment of spruce and fir under the uncut mature stand also favour the establishment of the more rapid-growing mountain maple.

The condition of reproduction on softwood cut-overs (A and Cii Softwood sites) is generally good. It tends to be somewhat patchy with groups of tree seedlings interspersed with patches of pin cherry and small openings having bare litter or herbaceous growth; however, the new stand on most softwood cut-overs should be reasonably dense.

The following are among the most important factors influencing the condition of reproduction on the Green River watershed.

(1) Effects of the density, age, and composition of the original stand on the abundance and distribution of advance growth.
(2) Suppression of reproduction in mixedwood cut-over by mountain maple.
(3) Effects of slash piles in discouraging regeneration, and, to a lesser extent, in smothering advance growth.
(4) Destruction of advance growth during logging.
(5) Effects of site as expressed by the distribution of cover types in relation to topography, soil, and local climate.
(6) Effects of sun and frost in preventing establishment of spruce and fir regeneration.

Advance growth may be too dense or not dense enough on both softwood and mixedwood cut-overs, but regeneration problems on each are different. The chief problem on mixedwood cut-over is the control of mountain maple. The other factors enumerated above are relatively minor. The shade cast by mountain maple, and the hardwood leaf litter, are formidable obstacles to small spruce and fir seedlings.

Reproduction on softwood cut-over is generally adequate, but without too much effort it should be possible to secure establishment of stands that would take full advantage of the possibilities offered by the softwood sites. Assuming that no pre-harvest cutting is likely, the problem is to protect advance growth and make some provision for subsequent regeneration in the openings and on the logging roads.

Lopping tops and scattering slash on logging roads and other openings should assist in improving seedbed conditions by reducing the high surface temperatures and drying of the litter. The accompanying reduction of slash piles would also be beneficial. Some protection would be provided against frost for small seedlings in the minor hollows which often are frost pockets. Although logging damage to advance growth is not excessive, some advantage might be gained by more care in cutting and yarding.

Planting may have its place for reforesting logging and strip roads when regeneration is slow or absent. If spruce is planted, it might have the further benefit of providing a stand less susceptible to insect injury.

CONCLUSIONS

From the foregoing, it is concluded that:

(1) Reproduction of spruce and fir on the cut-over lands of the Green River watershed is generally adequate enough to provide a fairly good new stand.

(2) The new stand may not be as uniform as the previous one, being too dense in some places and too open in others.

(3) On mixedwood sites, treatment of shrubs is necessary to reduce the establishment period for the new stand by releasing the advance reproduction which is suppressed.

(4) The condition and distribution of seedlings on softwood cut-over may be improved by more care during cutting, and by lopping tops and scattering slash.

(5) The factors contributing most to the variations in reproduction are: (a) site; (b) density, age and composition of the former stand; (c) retarding of regeneration by slash piles; (e) the heating and freezing effects of sun and frost in openings and small hollows; and (f) destruction of advance reproduction during cutting.

(6) Where planting is done to reforest logging and strip roads, no more than one growing season should pass before planting, and planting stock at least 8 inches high should be used.

SUMMARY

A number of reproduction surveys and more detailed studies have been made on the Green River watershed in northwestern New Brunswick during the past 11 years. These have included surveys of stocking on 4,000-acre research blocks in cut and uncut stands, and studies of a number of factors affecting softwood reproduction, including studies of logging damage, the effects of slash piles, and the effects of the spruce budworm. Some small plantations of spruce have been set out.

The uncut mature softwood and mixedwood stands usually have enough softwood advance reproduction to replace the stand after cutting for spruce and fir pulpwood. Some logging damage to reproduction occurs during cutting, but the advance reproduction of spruce and fir is not seriously depleted. However, it does make the distribution of advance growth even more patchy. The numbers of seedlings destroyed during cutting are in direct proportion to the numbers present before cutting. Logging damage increases as the abundance of reproduction increases. More care during cutting, lopping the tops, and scattering the brush should help to decrease the patchiness of the new stand. Regeneration after cutting apparently provides only a small part of the new stand. Some simple cultural measures such as those just mentioned might bring about more regeneration in softwood cut-over.

Mountain maple spreads rapidly after cutting in mixedwood stands and suppresses advance reproduction for many years, thus lengthening the stand replacement period. The maple also retards or prevents regeneration. Spruce and fir seedlings released from mountain maple double or triple their height-growth rate within two years after release.

The dense growth of raspberry on softwood cut-over retards regeneration and suppresses small advance growth, but does not appear to affect seedlings which it does not overtop. Pin cherry is prevalent on softwood cut-over but does not seem to have much adverse effect on established reproduction. It may retard subsequent regeneration slightly.

Where very luxuriant herbaceous growth is present, it may retard regeneration by forming a mat of dead leaves and stems under the snow and crush or smother small seedlings. The mat decomposes during the summer, but many of the seedlings fail to survive.

Results from the small spruce plantations established on the watershed indicate that planting should be done not later than one growing season after cutting, and that seedlings more than 6 or 8 inches high should be used. Otherwise, the vegetation that springs up soon after cutting will suppress and crush the seedlings and cause too much mortality.

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APPENDIX

Checklist of Botanical Names*

Balsam fir	*Abies balsamea* (L.) Mill.
White spruce	*Picea glauca* (Moench) Voss
Red spruce	*Picea rubens* Sarg.
Black spruce	*Picea mariana* (Mill.) BSP.
White birch	*Betula papyrifera* Marsh.
Yellow birch	*Betula lutea* Michx. f.
Sugar maple	*Acer saccharum* Marsh.
Red maple	*Acer rubrum* L.
Mountain maple	*Acer spicatum* Lam.
Beech	*Fagus grandifolia* Ehrh.
Pin cherry	*Prunus pensylvanica* L.f.
Mountain Ash	*Pyrus americana* (Marsh.) DC.
Raspberry	*Rubus idaeus* L.
Bracken	*Pteridium aquilinum latiusculum* (Desv.) Underw.
Bunchberry	*Cornus canadensis* L.
Clintonia	*Clintonia borealis* (Ait.) Raf.
Wood fern	*Dryopteris spinulosa* (O.F. Muell.) Watt
False-lily-of-the-valley	*Maianthemum canadense* Desf.

* According to FERNALD, M. L. 1950. Gray's Manual of Botany. lxiv + 1632 pp. American Book Company, New York, 8th ed.

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