EARLY STAND DEVELOPMENT AFTER CLEAR-CUTTING ON THE CAPE BRETON HIGHLANDS

by

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ABSTRACT

Studies on clear-cut forest areas of the Cape Breton Highlands, Nova Scotia indicated that the former predominantly balsam fir stands had originated between 1900 and 1930 as a result of a gradual disturbance. Softwood regeneration on the clear-cuts created when these stands were harvested was again mainly balsam fir which had originated from seed produced prior to 1974. Densities of balsam fir regeneration varied from 800 to 27 500 seedlings/ha with 15-90% of the 4-m^2 quadrats stocked. Stocking levels exceeded 80% in only 15% of the cutover blocks. Rapid growth of balsam fir seedlings began about three years after clear-cutting and increased to about 30 cm/year at age 15. During a 3-to 12-year period after clear-cutting, balsam fir was overtopped by raspberry, pin cherry, birch, and various grasses, herbs, and ferns but general suppression of fir growth by these species could not be demonstrated. Over most of the clear-cuts, densities of noncommercial species had no consistent relationship to growth of fir, suggesting that weeds were not a major limiting factor to growth. Most of the fir regeneration was found on undisturbed soil surfaces while pin cherry and raspberry seedlings tended to arise on soil surfaces disturbed by logging machinery.

RESUME

Des études de zones forestières coupées à blanc dans les hautes terres du Cap-Breton en Nouvelle-Ecosse ont indiqué que les anciens peuplements à prédominance de sapin baumier s'étaient établis entre 1900 et 1930 à la suite d'une perturbation graduelle. Après l'exploitation de ces peuplements, la régénération de résineux sur les terrains de coupe était encore constituée principalement de sapin baumier issus de graines produites avant 1974. La densité de la régénération de sapin baumier variait de 800 à 27 500 semis à l'hectare, et de 15 à 90% des quadrats de 4 m^2 étaient pourvus. La densité relative dépassait 80% dans seulement 15% des blocs. Les semis de sapin baumier ont commencé à se développer rapidement environ trois ans après la coupe, et leur accroissement atteignait environ 30 cm par an à l'âge de 15 ans. Pour une période de 3 à 12 ans après la coupe, le sapin baumier était dominé par des framboisiers, des cerisiers de Pennsylvanie, des bouleaux et diverses graminées, herbes et fougères, mais on n'a pas pu démontrer que ces plantes opprimaient de façon générale sa croissance. Sur la plupart des terrains de coupe, il n'y avait pas un rapport soutenu entre la densité des espèces non commerciales et la croissance du sapin, ce qui indique que la végétation indésirable ne serait pas un facteur limitant pour la croissance. La régénération de sapin se trouvait la plupart du temps à des endroits où la surface du sol n'était pas perturbée, tandis que les semis de framboisier et de cerisier avaient tendance à se développer là où la surface avait été perturbée par les engins d'exploitation forestière.

INTRODUCTION

Development of new forest cover after a major disturbance is of interest to people of many backgrounds. Recent concern about clear-cutting has been the result of the increasing scale of this type of operation and of the increased use of heavy machinery. In areas that had been harvested for pulpwood in eastern Canada, Weetman _et al_. (1973) found evidence of considerable destruction of advance growth of spruce and fir by mechanical logging equipment. Logging operations in northwestern Ontario left exposed mineral soil and bare rock on about 14% of the ground surface, but natural seed-fall soon filled in many gaps in regeneration (Ellis and Mattice 1974). Hatcher (1960) reported adequate regeneration after harvesting of spruce-fir stands of various origins in Quebec but noted a general increase in the proportion of balsam fir over spruce. McArthur (1963) noted the different species composition along old roadways as distinguished from the relatively less disturbed areas where advance regeneration had developed. Soil disturbance associated with roadways has been found to be especially serious in mountainous areas (Smith and Wass 1976).

In the Maritime Provinces, the problems of regenerating clear-cuts vary considerably among regions and forest types. In a successional study in several forest regions of Nova Scotia, soil surface disturbance appeared to be more limiting to natural regeneration than weed species (Wall 1982). Certain forest types are noted for poor regeneration, e.g., the old-field spruce type (Drinkwater 1957). In a recent survey, only 30% of cutovers of old-field spruce were more than 75% restocked.[1] Weed species such as mountain maple (_Acer spicatum_ Lam.)[2] have been shown to suppress softwood regeneration (Baskerville 1961).

The adequacy of natural regeneration on the Cape Breton Highlands and the successful development of a new forest is of special concern for several reasons. The area is the main source of supply for a local pulpmill. The forests, which are almost pure balsam fir (_Abies balsamea_ (L.) Mill), have been devastated by spruce budworm (_Choristoneura fumiferana_ (Clem.) resulting in over 50% mortality by 1981 (Magasi 1982). The budworm epidemic has brought about an accelerated program of clear-cutting for salvage, with a probable increase in exposure to offshore winds. Prior to the budworm outbreak and extensive clear-cutting, regeneration was adequate to excessive (Piene 1982), but the post-budworm situation is uncertain. Wile (1979), in a survey of 15 mature and overmature stands, stated that 80% of the uncut stands were at least 80% stocked with regeneration. However, increasing use of heavy machinery for harvesting plus the increasing degree of exposure on the plateau raise doubts about the survival of these fir seedlings after harvest.

Besides the adequacy of softwood stocking, there are important questions about the new growth developing into productive forests in the shortest possible time. A cover of birch (_Betula cordifolia_ Regel), pin cherry (_Prunus pennsylvanica_ L.), raspberry (_Rubus strigosus_ Michx.), and other commercial species develops very quickly after logging. This cover may, in some locations, suppress growth of softwoods but its presence is necessary to protect the seedlings from exposure. Against claims that partial vegetation removal is beneficial (Allen _et al_. 1978, Baskerville 1961, Crossley 1976) are arguments for the necessity for early colonizers to maintain ecosystem stability through nutrient recycling and erosion control (e.g., Marks 1974). In an exposed region like that of the Cape Breton Highlands, proof of significant suppression of softwoods by weed species should precede

[1]Jablanczy, A. Regeneration of white spruce cutovers in eastern Nova Scotia. Unpubl. Rep., N.S. Dep. Lands and Forests.

[2]Names of plant species according to Roland and Smith (1969).

a large-scale program of vegetation removal.

The present study was intended to determine the adequacy of natural regeneration in areas of the Cape Breton Highlands that have been clear-cut between 1965 and 1980 and to determine the effects on softwood regeneration of noncommercial species.

THE STUDY AREA

The study area included the major part of the Cape Breton Highlands forest district (Loucks 1962) which is situated on a plateau about 400 m above sea level. To the north and at slighly higher elevations is a taiga zone dominated by short dense black spruce (Picea mariana (Mill.) B.S.P.) and ericaceous shrubs. To the south are hills of lower elevation covered by hardwood and mixedwood forests. To the east and west are open seas. The terrain of the Highlands district is moderately rolling and intersected by upland streams. The soils are podzols developed from sandy loam parent materials derived from sandstones, conglomerates, igneous and metamorphic rocks (Loucks 1962, Salonius 1981).

The climate is cool and humid, with a short growing season. Frequent heavy fogs retard drying and probably are largely responsible for the almost complete absence of fire on the plateau. Strong off-shore winds limit the height growth of trees, with a resulting low site index (Bailey and Mailman 1972). The forests are almost pure balsam fir with small proportions of heart-leaf birch (Betula cordifolia Regal) and white spruce (Picea glauca Moench (Voss). During the 1970's, most of this forest cover was mature and supported a merchantable volume of 132-170 m^3/ha (Salonius 1981). These stands originated after budworm outbreaks which occurred in the years 1891-96, 1911-15, and 1922-27, (Brown 1970, MacLean 1979). Nichols (1918) mentioned pure stands of balsam fir, mostly less than 70 years of age, with considerable decay and windfall during his 1905-1916 observations.

Vegetation of the region has been described by Nichols (1918) and by Piene (1981). The balsam fir forests have a flora distinct from the nearby barren and taiga. Notably absent or rare are aspens (Populus tremuloides Michx.) and blueberries (Vaccinium spp.) both of which are plentiful in nearby lowlands. Also rare are eastern larch (Larix laricinia (Du Roi) K. Koch.), sugar maple (Acer saccharum Marsh.), and yellow birch (Betula alleghaniensis Britt.), which are present in abundance at slightly lower elevations (Greenidge 1961). In spite of these absences, there is a rich variety of shrub and ground vegetation consisting of numerous herbs, grasses, sedges and ferns. Mountain ash (Sorbus americana Marsh.) pin cherry, red raspberry, skunk currant (Ribes glandulosum Grauer), wild sarsaparilla, (Aralia nudicaulis L.) fireweed (Epilobium spp), wood aster (Aster accuminatus Mich.), bunchberry (Cornus canadensis L.) and goldthread (Coptis trifolia (L.) Salisb.) are common on recent clear-cuts. Pleurozium and Dicranum mosses, wood sorrel (Oxalis montana Raf.), bunchberry and various wood ferns (Dryopteris spp.) often form ground cover in uncut forest stands.

In the central and southern part of the district grazing by cattle is an important factor affecting vegetation. Some cutover blocks in this area appear to have been cultivated or heavily grazed prior to stand development judging by the more frequent occurrence of white spruce and a ground cover dominated by grasses. Cattle are allowed to roam freely over the Highlands each summer, but they remain mostly in these grassy areas.

METHODS

A. General Observations

Sampling and data collection were done in 1978 at equidistant points located along transects beginning at least 20 m from the edges of roadways and extending across the middle of each clear-cut. Clear-cuts were at locations A to Q in Fig. 1. The nearest individual of each regenerating tree species was collected at each sample point and its height was recorded as well as the number of annual rings on a disc cut from the base and observed under a dissecting microscope.

The density of former tree cover was determined by the closest individual method of Cottam and Curtis (1956), noting the stump closest to the sample point and determining mean density for the sampling area according to the formula:

density (trees per hectare) = 10,000/(2 x mean distance in metres)^2. Diameters of each stump also were recorded and if the stump was intact, annual rings were counted.

On blocks A-E, point-quadrats spaced at 20-m intervals were examined in each block. The same information was collected from 50 quadrats each at locations 19 and 20. On locations F to Q, only the ages of regenerating pin cherry and balsam fir were recorded on each of five quadrats at 20-m intervals.

B. Sequential Changes on Permanent Plots

Fifty circular 4-m^2 quadrats were established at locations 19 and 20 (Fig. 1) in 1978 to determine successional trends and relationships among cover types. Both blocks had been harvested the previous summer with a feller-buncher followed by a mobile processor, leaving slash in continuous parallel windrows. On each clear-cut, the 50 quadrats were established at 20-m intervals along transects running diagonally across the rows of slash. Measurements of cover, dominant heights, and regeneration per 4-m^2 plot were taken during early August 1978, 1979, 1980, and 1982. Cover was estimated visually, to the nearest 10%, for each major species, for slash, and for surface cover, i.e., mosses, litter, exposed mineral soil or exposed duff. For dominant heights, the tallest individual of each species was measured to the nearest 0.1 m. Within the 4 m^2 quadrats (1.13 m radius) seedlings of each regenerating tree species, including pin cherry, were counted.

C. Stand Development on Different Aged Clear-cuts

To examine representative clear-cuts, sampling areas were selected along a transect extending from the northeast corner of the district to the southwest corner (locations 1-18, Fig. 1). Sampling areas were located wherever the transect crossed a major clear-cut. On each clear-cut thus selected, 20 quadrats were placed at 10-m intervals in a north-south line beginning 10 m from the top of the roadbank and extending into the middle of the clear-cut. On each 4-m^2 quadrat, cover, dominant heights, and numbers of tree seedlings were recorded as on the succession plots. In addition, a representative pin cherry was collected to determine stand age from growth rings and a representative fir seedling was collected to determine its growth history from internode lengths and ring widths. Annual rings were counted and measured on discs taken from the base of each seedling and examined under a dissecting microscope.

The annual height and diameter increments of balsam fir seedlings were analyzed for each clear-cut and related to cover densities of weed species using class interval techniques as well as correlation and regression analyses.

RESULTS

A. General Observations

Harvesting methods

Large-scale harvesting began around 1965 and intensified yearly. Most of the clear-cutting had been done during snow-free periods, using several types of heavy equipment for both felling and extraction. This provided a wide variety of surface conditions and slash

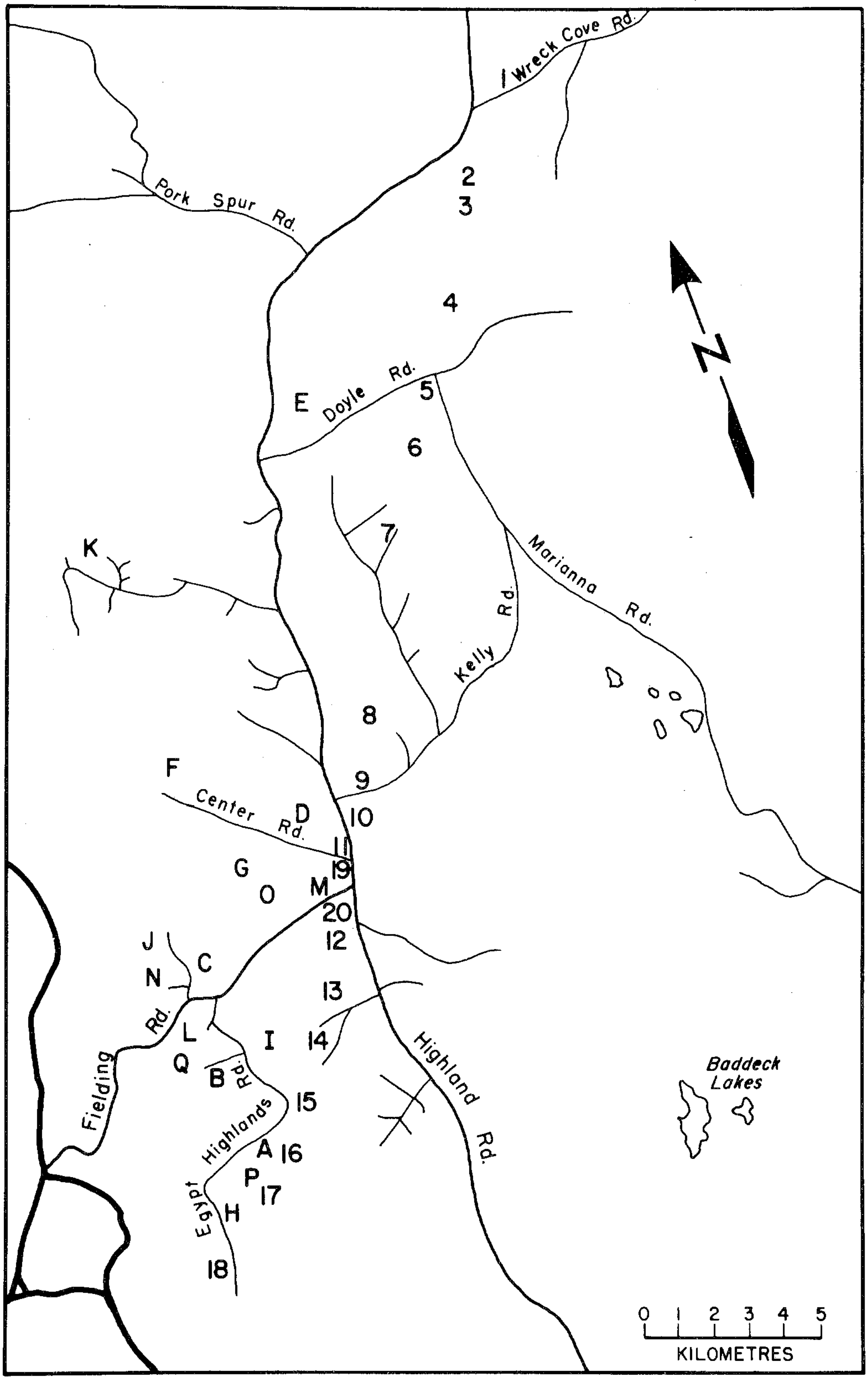

Figure 1. Map of the Cape Breton Highlands showing locations of study areas and sampling points.

distributions. Usually, most of the trees were removed in an operation and the few remaining residuals were felled several years later, rendering the clear-cuts virtually treeless. Contiguous blocks, representing different contracts, were readily distinguished by age differences, roadways, a thin line of standing trees, or some natural barrier.

The former stand

Stumps examined in seven cutover blocks indicated former tree densities of 1041 ± 581 stems/ha according to the point-distance method of Cottam and Curtis (1956). Stump diameters were 27.3 ± 8.4 cm. Counts of annual rings on the 81 intact stumps indicated the time of stand origin as 1915 ± 14 years with more variation between trees within a block than between block means. These age ranges coincide well with dates of recorded spruce budworm outbreaks (MacLean 1979).

Regeneration

Ring counts on basal discs from 110 balsam fir seedlings from 17 clear-cuts indicated that all seedlings had germinated prior to 1974. No recent germinants were found.

Over 70% of the balsam fir seedlings were older than the estimated age of the clear-cut and variation in age within a clear-cut was usually quite high. Pin cherry collected from the same areas had much more uniform age distributions (S.D. $\leq$ 0.5 yr) and the ages generally reflected the estimated age of the clear-cut. The correlation between age of pin cherry and recorded years since logging (r = 0.93) indicated that this was a good tool for estimating ages of young stands. Care had to be taken to avoid pin cherry growing near roadsides, since roadways were often built several years before the actual harvest.

B. Sequential Changes on Permanent Plots

Major cover components

Changes in the major cover components on these two clear-cuts are illustrated in Fig. 2. In terms of frequency and percent cover, raspberry became the dominant species, although collectively the various ferns, herbs, and grasses often provided more cover. Of the tree species, pin cherry was initially most numerous but quickly dropped off to the same levels as fir and birch. Mortality in pin cherry was observed each spring. Often, new shoots arose from buds situated at the base of the stem, so that the overall cover by pin cherry did not decrease and dominant height increased at a rate comparable to birch. The population of balsam fir seedlings was stable. Fir did not begin rapid growth until after the third year and this growth was further limited in some quadrats by grazing. Ten to 15% of the plots were in slash piles which were heavily decayed and beginning to be colonized by raspberry by the end of five years. The cover provided by herbaceous vegetation is exaggerated here since it represents many layers ranging from tiny ground cover plants to herbs and grasses about 1 m tall. After five years, raspberry had formed a dense cover on about 6% of the plots while hardwood cover was light and sporadic by comparison. Softwood cover during this period was scarcely noticeable.

Minor vegetation

Beginning one year after harvesting, frequency of wood ferns, wood sorrel, gold thread, wild sarsaparilla, goldenrod (Solidago purshii Porter), wild lily-of-the-valley (Maianthemum canadense Desf.), and bluebead-lily (Clintonia borealis (Ait.) Raf.) decreased on both clear-cuts without the complete disappearance of any of these species. Skunk current and wood aster were present one year after clear-cutting and increased in frequency while hair cap moss (Polytrichum commune) fireweeds, sheep sorrel (Rumex acetosella L.), and pearly everlasting (Anaphalis margaritacea (L.) C.B. Clarke) appeared 2-5 years after clear-cutting. Collectively, both grasses and sedges increased in abundance, frequency, and percent cover

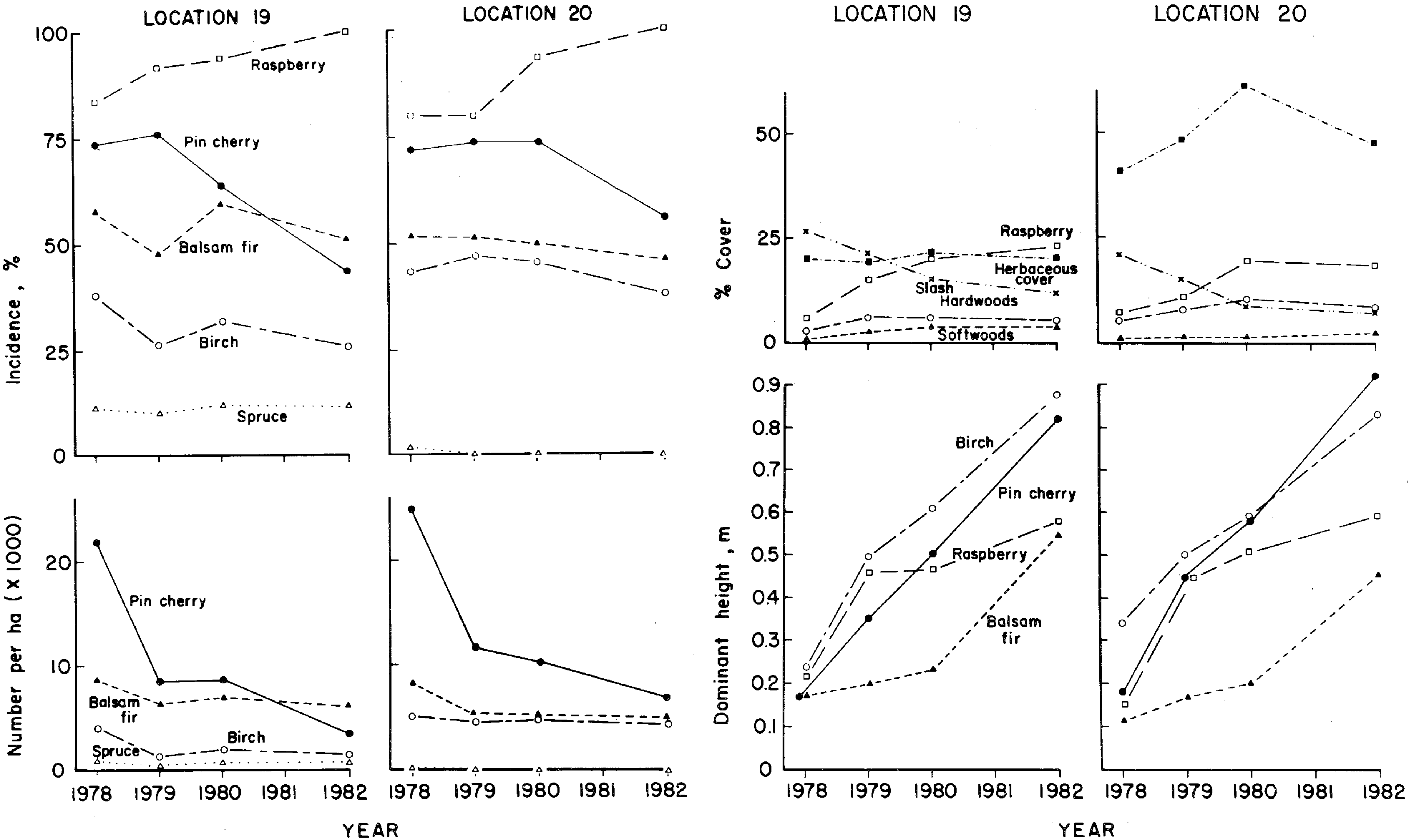

Figure 2. Development of major cover components during the first five years after clear-cutting on two locations on the Cape Breton Highlands.

but attained dominance in very few quadrats.

Relationships among cover components and surface features

Table 1 shows the correlations in 1978 among major cover components from the two clear-cuts, based on 100 observations for each. Trends were similar for individual clear-cuts, the most notable being the positive correlations between fir and spruce, pin cherry and raspberry, and pin cherry and exposed mineral soil. Negative correlations occurred between factors that would be expected to be mutually exclusive, e.g., between an exposed mineral soil surface and surfaces occupied by mosses, litter, or duff.

In Table 2, the distribution of regeneration according to predominant surface features is shown. Two-thirds of the quadrats with more than 10 fir seedlings had predominantly moss or litter cover. Over one-half of the quadrats with more than 10 pin cherry seedlings had predominantly exposed soil surfaces. Eighty-eight percent of the quadrats with predominantly exposed soil surfaces supported more than 10 raspberry seedlings. This preference of fir for undisturbed microsites and of pin cherry and raspberry for disturbed microsites was readily observed in the field, the former being found in mossy areas near the bases of stumps while the latter two species were often found along the edges of wheel ruts. Birch

Table 1. Correlation matrix of major cover components one year after clear-cutting on permanent sample plots, locations 19 and 20, Cape Breton Highlands

	1 Fir	2 Spruce	3 Birch	4 Pincherry	5 Raspberry	6 Ferns	7 Forbs	8 Slash	9 Mosses	10 Litter	11 Duff
	Number				Percent						
Fir											
Spruce	+0.51*										
Birch	+0.21	+0.05									
Pin cherry	+0.02	+0.04	+0.16								
Raspberry	-0.13	-0.06	+0.18	+0.46*							
Ferns	-0.10	-0.11	-0.04	-0.07	-0.13						
Forbs	+0.09	+0.01	0.00	-0.20	-0.22	+0.24					
Slash	-0.10	-0.08	-0.19	-0.36*	-0.31*	-0.05	-0.12				
Mosses	+0.14	+0.16	-0.04	-0.17	-0.18	-0.16	+0.12	-0.29*			
Litter	+0.05	+0.01	+0.05	-0.22	-0.04	+0.20	+0.25	+0.32*	-0.34*		
Duff	-0.05	-0.03	-0.05	+0.02	-0.03	-0.04	-0.13	+0.15	-0.14	+0.11	
Mineral soil	-0.13	-0.10	-0.09	+0.34*	+0.26*	-0.10	-0.16	-0.34*	-0.29*	-0.39*	-0.03

*Significant value of r at $p = 0.01$.

showed less distinct preferences, probably because it was present both as seedling and coppice growth. These microsite differences were most noticeable one year after clear-cutting. Mortality of seedlings on exposed microsites and more rapid growth of seedlings on nutrient-rich or protected microsites tended to obscure the differences over the ensuing five years.

C. Stand Development on Different Aged Clear-cuts

Cover development and regeneration of softwoods

The 18 selected clear-cuts varied with respect to time of harvest, method of harvesting, and stand history. Stands had been harvested 2 to 15 years previously, with 50% of them in the 3- to 4-year age category. Age classes were fairly well distributed along the 35-km transect thus minimizing the effects of location. Although harvesting methods had changed over the 15 years, with the increasing use of heavy equipment, none of the selected clear-cuts had been subjected to whole tree logging which would have resulted in no slash on the site and possibly very little advance regeneration. All of the stands had been predominantly balsam fir with age structures as described under GENERAL OBSERVATIONS. Locations 9 and 10 showed evidence of former grazing and cultivation, i.e., ground cover predominantly grasses, few pin cherry, and poor natural regeneration of softwoods. Stands harvested since the mid 1970's had been severely defoliated by the spruce budworm before harvest and this probably had an effect on balsam fir regeneration. Frost damage was evident on the current year's shoots of balsam fir on many of the clear-cuts. Natural regeneration for individual clear-cuts is shown in Table 3. Only three of the 18 stands were over 80% stocked to softwoods, while 14 were over 40% stocked. While numbers of spruce were low, stocking figures indicated that they were well distributed. Of the 11 areas harvested since 1976, one was over 80% stocked and eight were over 40% stocked to softwoods.

Table 2. Distribution of regeneration of major cover species on 4-m^2 quadrats with different surface characteristics, locations 19 and 20, 1978

Predominant soil surface[1]	Total quadrats	Number of quadrats with > 10 stems of Fir	Birch	Pin cherry	Raspberry
Mosses	19	3	1	3	10
Litter	41	3	3	5	13
Exposed duff or mineral soil	26	1	1	18	23
Other[2]	14	2	1	5	9

[1]More than 50% of surface area of 4 m^2 quadrats.
[2]Usually an almost equal proportion of mosses, litter, and exposed soil.

Table 3. Regeneration of tree species on clearcuts of different ages

Years since harvest[1]		Number per hectare[2] (1000's)				% Stocking		
		Fir	Spruce	Birch	Pin cherry	Fir	Spruce	Birch
2	(6)	19.4 ±22.0	0.1 ±0.6	10.5 ±17.7	0.8 ±2.0	90	5	75
	(9)	1.3 ± 4.6	0 0	0.0	0.0	40	5	0
3	(2)	3.5 ± 9.5	0.0	8.8 ± 9.3	1.4 ±3.1	25	0	80
	(3)	7.9 ±11.2	0.5 ±1.7	9.4 ± 7.6	2.8 ±3.6	65	10	85
	(4)	1.3 ± 2.2	0.3 ±0.8	5.6 ±12.0	0.1 ±0.6	30	10	40
	(15)	0.8 ± 2.0	0.0	0.6 ± 1.6	1.6 ±3.3	15	0	65
	(18)	5.6 ± 3.7	0.0	16.6 ±12.5	2.4 ±4.5	80	0	90
4	(5)	8.8 ±16.4	0.1 ±0.6	0.5 ± 1.8	0.1 ±0.6	45	5	10
	(8)	7.6 ±12.8	0.0	13.3 ±15.4	5.8 ±6.7	60	0	75
	(11)	7.0 ±13.8	0.3 ±0.3	15.3 ±17.4	1.9 ±3.0	45	10	80
	(13)	12.0 ±13.2	0.0	12.4 ±11.4	3.8 ±6.8	75	0	80
5	(1)	14.1 ±19.6	0.0	18.7 ±19.3	3.2 ±5.3	50	0	80
	(12)	22.8 ±20.7	0.0	8.3 ±12.2	1.4 ±1.9	75	0	65
6	(14)	23.8 ±24.5	0.8 ±1.2	4.4 ± 6.4	4.9 ±4.6	90	30	50
	(17)	27.5 ±24.0	0.0	4.3 ± 4.9	5.0 ±7.6	95	0	60
8	(16)	3.1 ± 4.9	0.0	7.1 ± 8.6	6.9 ±6.6	35	0	60
13	(7)	11.5 ±11.3	0.0	6.1 ± 8.1	4.9 ±4.8	75	0	60
15	(10)	2.8 ± 7.2	0.3 ±1.1	0.0	0.0	40	5	0

[1]Location numbers in brackets. Refer to Fig. 1.
[2]Mean ± standard deviation.

Another important trend was the general deterioration in the health of pin cherry and birch since 1978. Extensive shoot blight and mortality were observed in pin cherry of all ages in 1979, 1980, and 1981. This occurred throughout the growing season on the Highlands but was not observed in lowland areas of Cape Breton. Considerable leaf scorch was observed on birch of all ages during the summer of 1981. Thus, cover by these two species is considerably lower than would have been recorded in 1978 or earlier. Causes of pin cherry shoot blight and birch leaf scorch were not determined.

Changes in height and cover with age of clear-cut are shown in Fig. 3. There were strong time-related trends in heights of slash piles ($\underline{r}$ = -0.65), pin cherry ($\underline{r}$ = 0.79), birch ($\underline{r}$ = 0.87) and balsam fir ($\underline{r}$ = 0.84). Raspberry grew rapidly over the first 5 years ($\underline{r}$ = 0.71), but from 5 to 15 years appeared to decrease slightly in average height ($\underline{r}$ = -0.42). Changes in percent cover of slash, raspberry, and fir showed similar trends. Raspberry was clearly dominant during the 4 to 10 year period after harvesting and thereafter balsam fir began to dominate. Pin cherry and birch were dominant with respect to height

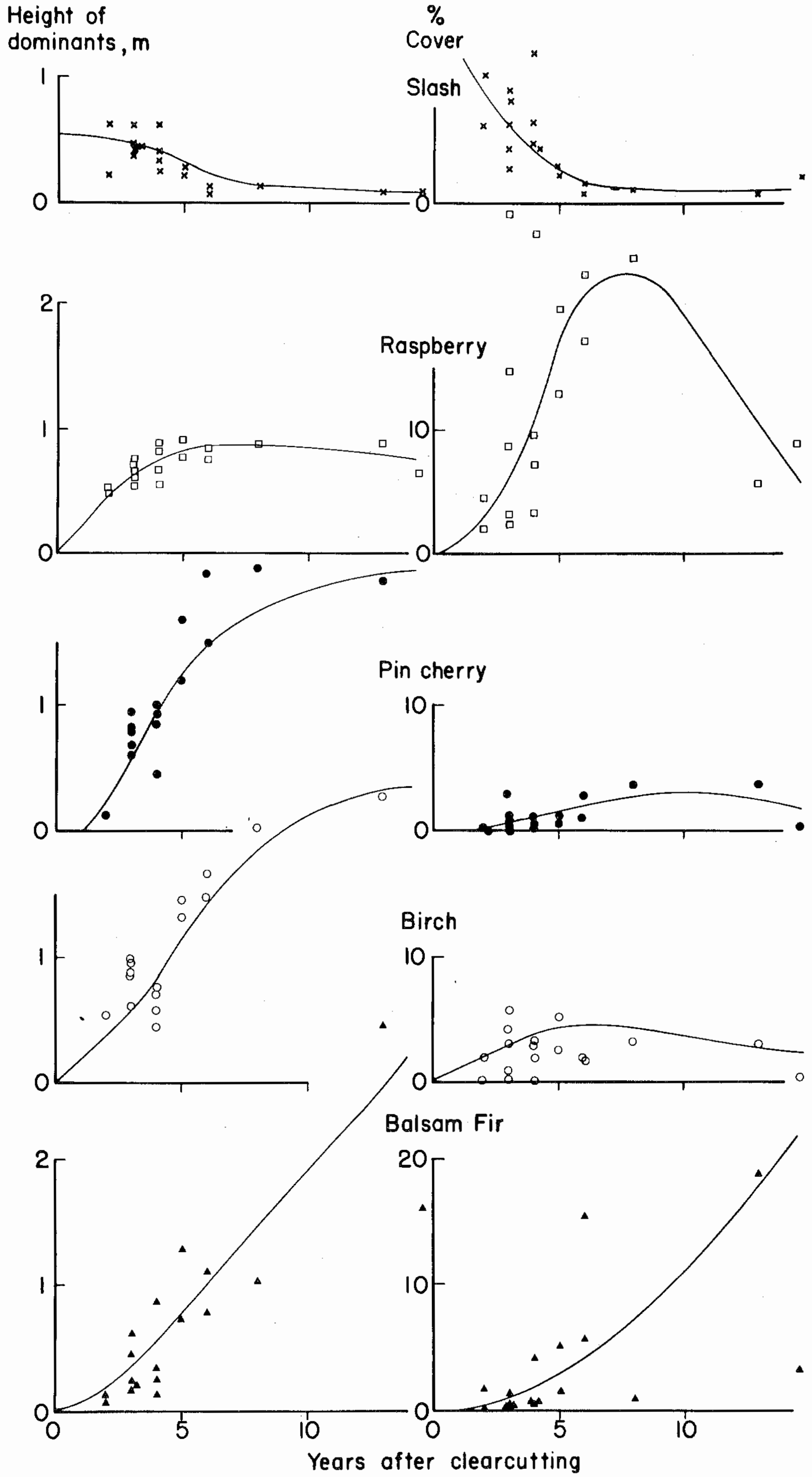

Figure 3. Changes in height and percent cover of the major cover components on clear-cuts on the Cape Breton Highland. Solid lines were fitted from stepwise regression equations.

during the 3 to 10 year period but formed a light cover. Again, it should be emphasized that average pin cherry - birch cover would have been greater had the survey been done in 1978 or earlier.

Rapid height growth in balsam fir began about 3 years after clear-cutting and reached 25-30 cm/year at 12-15 years of age (Fig. 4). At nearby Crowdis Mountain, comparable height increments were reported by Piene (1981) in 25- to 30-year-old trees.

Effects of noncommercial species on balsam fir regeneration

The distributions of cover within the 18 locations measured in the 1981 survey are shown in Figs. 5 and 6. Tall cover, consisting mainly of pin cherry and birch and in later years of balsam fir could be considered dense in no more than 24 of the 360 quadrats. Low cover, consisting of raspberry, other low shrubs, and herbaceous vegetation was dense in over 50% of the quadrats but actual shading was much less than indicated because these figures are composites of the many layers of vegetation. Raspberry, the dominant cover in most locations, could be considered dense in 13% of the plots and formed an intermediate to dense cover in 40% of the plots (Fig. 6).

Effects of cover on fir growth were analyzed within individual clear-cuts. There were no consistent and few significant relationships between any measure of cover and current growth rates of fir. Growth of fir was negatively correlated with cover in some clear-cuts and positively correlated in others. Quadrats in the 4- to 8-year age class were classified as light and dense categories with respect to raspberry cover (Fig. 7). In location 11, fir grew significantly better under dense cover than under light cover. On the other clear-cuts there were no significant differences. Although the data do not fully clarify effects of cover on fir seedling development, there is little doubt that beneficial effects are as frequent as detrimental ones. Similar comparisons were attempted for "total" cover and for other cover components but no consistent relationships were found.

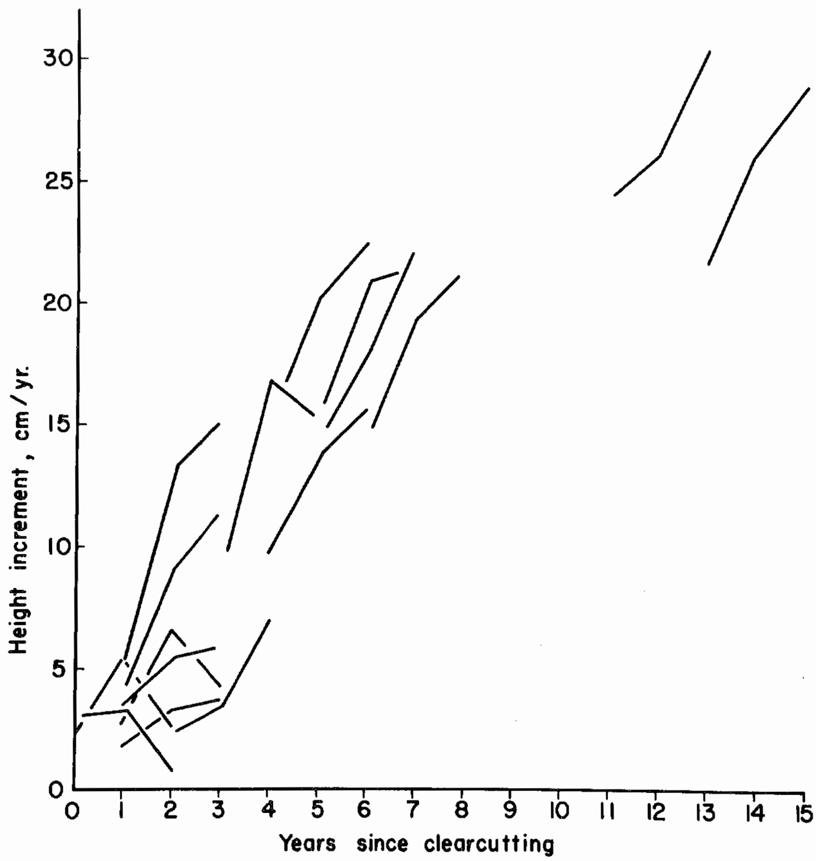

Figure 4. Height increments of balsam fir during the 1979, 1980, and 1981 growing seasons on clear-cuts of different ages.

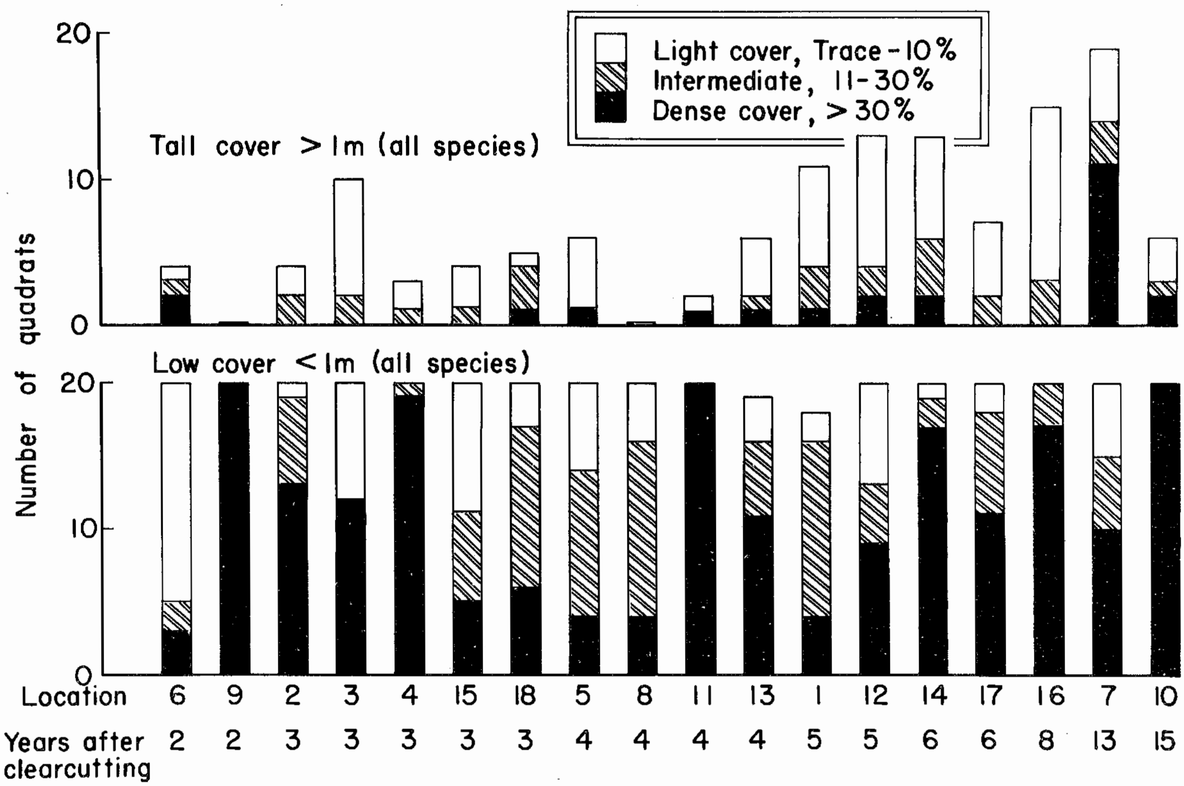

Figure 5. Distribution of cover classes in 1981 on clear-cuts of different ages on the Cape Breton Highlands, Nova Scotia.

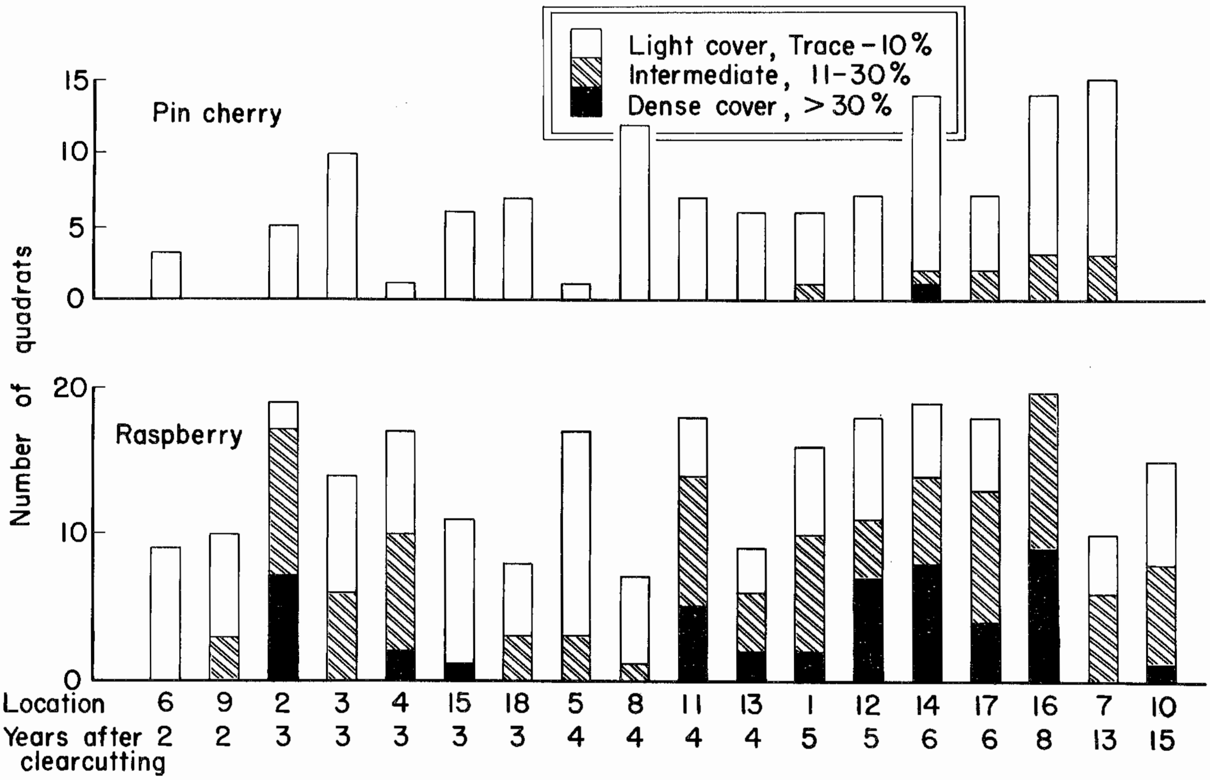

Figure 6. Distribution of raspberry and pin cherry cover in 1981 on clear-cuts on the Cape Breton Highlands, Nova Scotia.

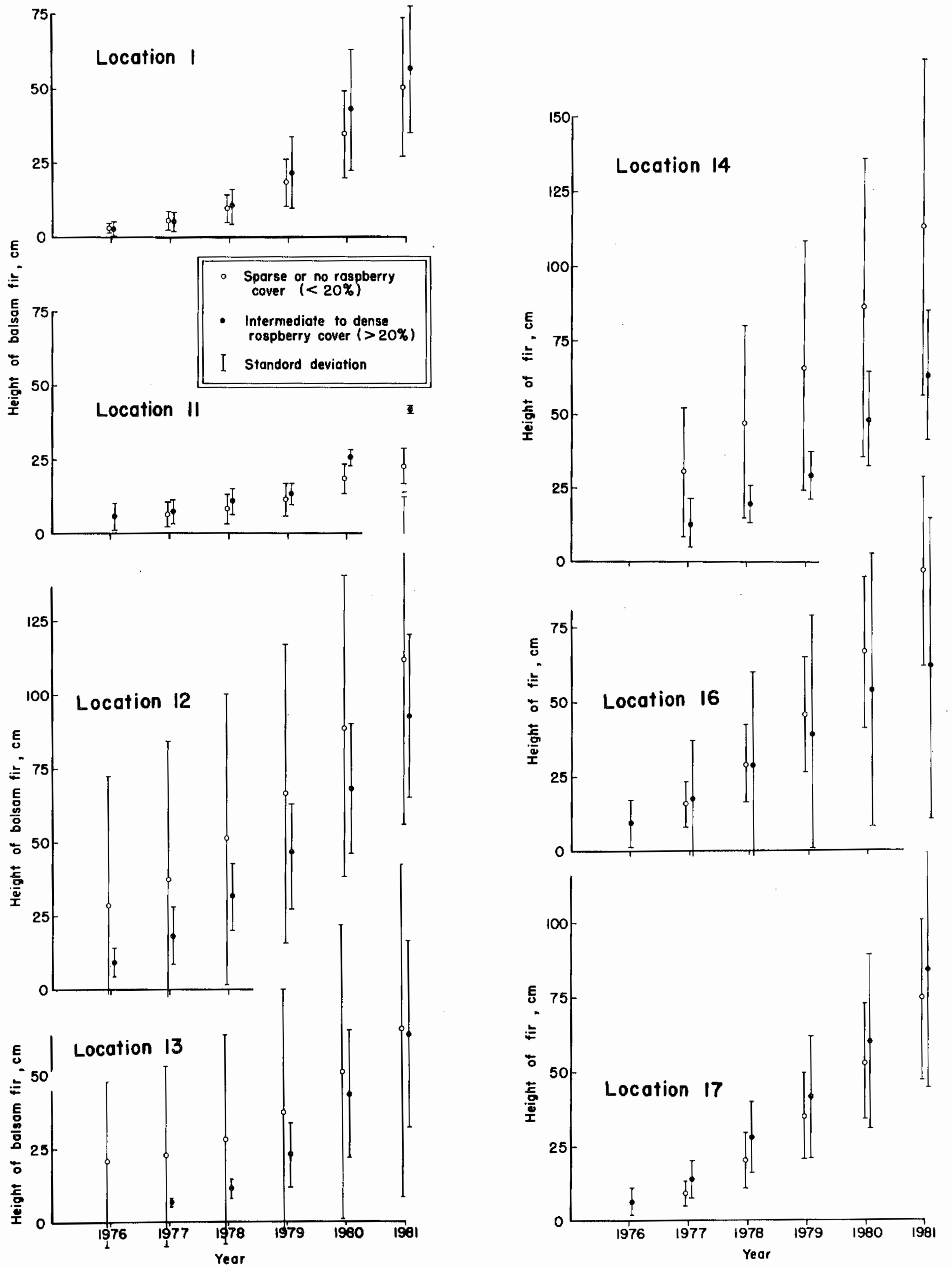

Figure 7. Height growth of fir in quadrats with light raspberry cover in 1981 in comparison to quadrats with intermediate to dense raspberry cover.

DISCUSSION

One of the foremost questions addressed by this study is the adequacy and performance of softwood regeneration on the Cape Breton Highlands. Sixteen of the 20 clear-cuts sampled were over 40% stocked to softwoods but only three were over 80% stocked. Only seven clear-cuts had densities of over 10 000 stems/ha or sufficient densities to warrant spacing treatments (Piene 1982). The relatively low stocking in the more recent clear-cuts is probably due to budworm damage, to destruction of advance regeneration during harvesting operations, and to subsequent exposure, but the relative importance of each factor is not known. Fir seedlings that survived the first year after harvesting tended to survive thereafter.

After an initial lag period of 2 to 4 years, growth of balsam fir regeneration was fairly good, comparing favorably with that in other young balsam fir forests in eastern Canada (Baskerville 1966, Hatcher 1960). Height increment increased yearly to a probable maximum of about 30 cm/year but severe wind conditions may severely limit height increment in the more recent clear-cuts. Increasing size of contiguous clear-cuts and widespread mortality of pin cherry and birch will increase exposure. Nevertheless, it is likely that a balsam fir forest comparable to the preceeding one will develop but there will be temporary gaps and the age structure may be more varied. The gaps and varied age structure will be largely a consequence of the present lack of seed, there having been very little seed produced since the early 1970's.

Appropriate methods of increasing softwood growth and thereby shortening rotation ages on the Cape Breton Highlands have been studied by others. Spacing of dense stands (>10 000 stems/-ha) at an early age has shown definite benefits (Piene 1981, 1982). Application of fertilizers has shown no benefit in semimature stands (Salonius 1981) but has not yet been fully tested in young stands. Partial removal of noncommercial vegetation through the use of herbicides is a third alternative not yet tested on the Highlands but is a treatment of doubtful value in light of results outlined above.

The period of rapid increase in height increment of balsam fir was during the 3- to 10-year period after clear-cutting when cover by noncommercial species was greatest. No general growth suppression by other vegetation could be found. Only under extreme densities, found by searching numerous clear-cuts, has measurable growth suppression been demonstrated[3]. The reasons for this apparent lack of suppression may be the initial microsite differences between balsam fir and the major "weed" species and/or phenological differences between fir and other species. Balsam fir is a determinate species, completing height growth in early August (Baldwin 1931). Many of the other species are indeterminate, continuing shoot elongation until the end of the growing season and reaching full cover in August. Bicknell (1982) has pointed out this difference in growth strategy between tolerant and intolerant species in northern hardwood ecosystems.

There appears to be no justification at present for vegetation removal on the Cape Breton Highlands beyond the experimental level. Removal of existing cover would increase exposure and leave the site open to other weed species, e.g., grasses which will attract grazing animals or fireweeds which are major alternate hosts of balsam fir needle rust (Van Sickle 1973). The existing vegetation might, of course, hinder the growth of planted softwood trees more than that of natural regeneration, but this is beyond the scope of the present study.

The recent series of disturbances (severe defoliation plus clear-cutting) may be unique in the history of the Cape

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[3]Wall, R.E. Unpublished data on file at the Maritimes Forest Research Centre, Fredericton, N.B.

Breton Highlands. Previous forest renewal apparently resulted from severe defoliation, mortality, and decay of mature and overmature timber. Such a gradual disturbance would not expose young growth to severe off-shore winds or to frost damage. Although this study has not indicated any necessarily permanent consequences from the present disturbances, there remain some concerns over future stand development on the Cape Breton Highlands, and further studies are definitely warranted.

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