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SECONDARY SUCCESSION ON RECENTLY CUT-OVER FOREST LAND IN NOVA SCOTIA

by

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ABSTRACT

Permanent plots on 12 clearcuts in mainland Nova Scotia and southern Cape Breton Island were observed shortly after logging and at intervals thereafter for changes in ground cover. Density of tree regeneration was recorded in the final observation. Regeneration of conifers appeared to be favored by some types of cover but was usually less satisfactory on exposed or scarified areas. No detrimental effects of non-commercial species on regeneration could be found. Two major ground cover types, raspberry and sheep laurel, were evident. The raspberry type was associated with regeneration of balsam fir while the sheep laurel type was associated with black spruce and red maple regeneration.

RESUME

Des placettes permanentes sur 12 terrains déboisés de la partie continentale de la Nouvelle-Ecosse et du sud de l'île du Cap-Breton ont été observées peu après l'exploitation forestière, puis par intervalles, afin de déceler les changements de la couverture vivante. La densité de la régénération des arbres a été enregistrée lors de l'observation finale. La régénération des conifères semblait être favorisée par certains types de couvertures, mais elle était habituellement moins satisfaisante dans les zones exposées ou scarifiées. On n'a observé aucune conséquence néfaste des espèces non commerciales sur la régénération. Deux principaux types de couvertures vivantes, la ronce du mont Ida et le Kalmia à feuilles étroites, prédominaient. La ronce du mont Ida était associée à la régénération du sapin baumier tandis que la Kalmia à feuilles étroites était associé à la régénération de l'épinette noire et de l'érable rouge.

INTRODUCTION

Predictability of the responses of various forest types to logging is needed to ensure adequate stand establishment at low cost. Candy (1951) indicated that, in the Maritime Provinces, cut-over land not subsequently affected by fire regenerates well. However, in the past few decades, harvesting methods have changed considerably with the advent of larger harvesting machines and larger cutting operations. Clearcutting is an accepted practice, but often destroys existing regeneration as well as the seed sources for subsequent regeneration. Shrubs and hardwoods commonly invade clear-cut sites and temporarily suppress softwood regeneration. On the other hand, overstocking to softwoods can also suppress growth.

Documentation of the effects of clearcutting is sketchy. McArthur (1963) noted the destruction of balsam fir advance regeneration on haul roads and the effects of this on the subsequent forest. Weetman et al. (1973) observed the destruction of advance growth of spruce and fir through careless use of logging equipment. Scarification of the soil surface may be desirable in some instances to encourage seedling establishment of species such as birches[1] (Marquis 1965), pines, and spruces (Jarvis 1966) if direct seeding is to be carried out or if a natural seed source is available from nearby stands, residual seed trees, or cone-bearing slash.

There is scattered evidence that noncommercial species significantly suppress softwood regeneration. Place (1952) demonstrated increased numbers of seedling spruce by removing dense cover of bracken fern. Baskerville (1961) showed a growth response of spruce and fir to removal of competing shrubs, mainly mountain maple. Strang[2], associated poor regeneration success in southwestern Nova Scotia with the dominance of huckleberry and sheep laurel cover and Damman (1971) demonstrated a loss in fertility from sites dominated by ericaceous vegetation. On the other hand, beneficial effects of noncommercial species have been shown; for instance, pin cherry forms a temporary cover after logging or fire and has an important role in nutrient cycling (Marks 1974).

Overstocking can limit productivity as much as understocking in forests of the Maritime region. Densities of 40 to 80 thousand stems per hectare have been recorded for balsam fir (Hart 1961, Piene 1978). Hardwood regeneration of up to 120 000 stems/ha has been observed by Drinkwater (1957). Thinnings in dense stands have produced growth responses of more than 100% (Piene 1981). Spacing costs are now a major consideration in stand management (Baskerville 1966, Routledge[3]). It is difficult to visualize harvesting operations that would produce optimal spacing initially, but excessive density or extremely uneven spacing might be avoided.

This paper describes observed associations among ground cover vegetation, natural regeneration, and surface disturbances that resulted from the harvesting operation on 12 clearcuts in mainland Nova Scotia and lowland Cape Breton Island. No attempt was made to evaluate all possible variables, e.g., type of harvesting machinery, season of harvest, forest type, or stand history, but the major situations existing in the clearcutting operations of the 1970's were examined. In all cases, observation plots were established as soon as possible after logging and successive vegetative changes were recorded on these plots. Previous successional studies of this type are reported by Martin (1955, 1956) and Taylor (1959) for Nova Scotia. Most studies of this nature have used simultaneous measurement of young stands of different ages (Ellis and Mattice 1974; Smith and Wass 1976; Weetman et al. 1973; Martin 1956) rather than a succession of observations at fixed points. An earlier report (Wall 1977) outlined initial changes in three of the study areas reported in this paper.

METHODS

Study areas established in the major pulpwood producing areas of mainland Nova Scotia and southern Cape Breton Island are shown in Fig. 1. The following forest types according to Loucks (1962) classification (Table 1) were represented: the Mersey River district of the Clyde River-Halifax ecoregion, the Eastern Shore district of the Atlantic Shore ecoregion, the Chignecto district of the Fundy Bay ecoregion, the Sheet Harbor and St. Mary's River districts of the Maritime Lowlands ecoregion, and the Pictou Uplands and Musquodoboit Hills districts of the Maritime Uplands ecoregion. Stands before harvest were predominantly spruce with varying amounts of balsam fir, red maple, paper birch, yellow birch, white pine, larch, and aspen, and were generally uneven aged (Table 2). The clearcuts were 5 ha or more and were cut within one season. Several areas were not strictly clearcuts in that standing residuals were left on the site but these were either scattered hardwoods and small diameter softwoods or clumps of softwoods (Table 3). Soils were generally sandy and overlain by well-developed organic horizons (Appendix I).

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[1] For scientific names of species, see Table 6.

[2] Strang, R.M. 1971. Re-establishment of productive forests in western Nova Scotia. For. Res. Lab. Fredericton, N.B. Int. Rep. M-65.

[3] Routledge, H.T. Nova Scotia Forest Industries Ltd., Port Hawkesbury, N.S. Unpublished information.

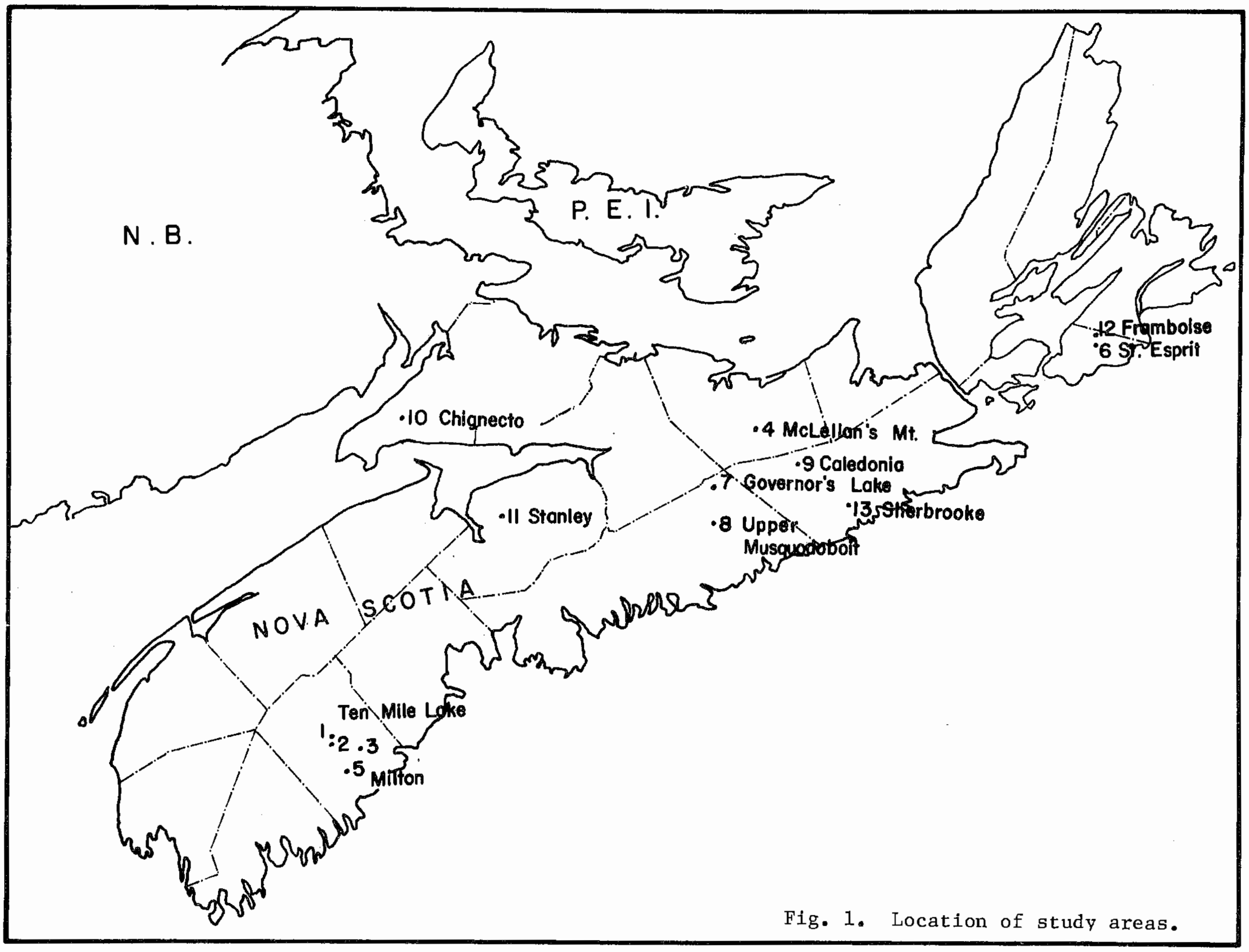

Fig. 1. Location of study areas.

Table 1. Locations and dates of establishment of the study areas

Study area	Date established	Place name	County	Forest district[1]	Ecoregion[1]
1	6-6-72	Ten Mile Lake	Queens	Mersey River	Clyde River-Halifax
2	15-6-72	Six Mile Bog	Queens	Mersey River	Clyde River-Halifax
3	10-7-72	Four Mile Road	Queens	Mersey River	Clyde River-Halifax
4	1-8-72	McLellan's Mountain	Pictou	Pictou Uplands	Maritime Uplands
5	9-7-74	Milton	Queens	Mersey River	Clyde River-Halifax
6	30-7-74	St. Esprit	Richmond	Eastern Shore	Atlantic Shore
7	12-9-74	Governor Lake	Halifax	Musquodoboit Hills	Maritime Uplands
8	12-9-74	Upper Musquodoboit	Halifax	Sheet Harbour	Maritime Lowlands
9	13-9-74	Caledonia	Guysborough	St. Mary's River	Maritime Lowlands
10	3-10-74	Chignecto	Cumberland	Chignecto	Fundy Bay
11[2]	24-6-75	Stanley	Hants	Windsor - Truro	Maritime Lowlands
12	9-7-75	Framboise	Richmond	Eastern Shore	Atlantic Shore
13	10-7-75	Sherbrooke	Guysborough	Eastern Shore	Atlantic Shore

[1] After Loucks (1962).
[2] Abandoned after heavy scarification.

Table 2. Stand characteristics of the study areas before logging

Study area	No. of trees per hectare	Species[2] and percentage	Mean diameter (cm)	Age Low (Mean) High
1	1400	bS[3](58), bF(24), rM(13) nrO(2), wB(2)	15.8	63 (68) 72
2	1376[1]	bS (33), bF(33), rM(26) wP(4), wB(2), tA(1)	19.5	51 (70) 95
3	850	bS(64), rM(29), tA(3) bF(1), eH(1), eL(1)	17.5	68 (73) 77
4	902	wS(74), bF(26)	27.7	28 (52) 85
5	1222	rS[3](57), rM(20), bF(12) wP(8), eH(2), tA(2)	23.5	82 (91) 110
6	1481	bS[3](52), bF(38), wB(10)	15.3	53 (67) 84
7	1136	rS(73), wP(11), bS(9) rM(5), wB(2)	20.1	
8	783[1]	bF(50), rS[3] (47), yB(3)	24.5	50 (59) 73
9	1529	bS(93), bF(7)	19.8	38 (59) 70
10	1076	rS(76), bF(14), wB(6) yB(4)	23.8	35 (94) 135
12	1740	bS(74), bF(24), wB(2)	16.8	55 (74) 92
13	2715	bF(46), bS(44), rM(8), wB(2)	16.5	100 (118) 155

[1] Determined by the point-distance method of Cottam and Curtis (1956).

[2] bS = Picea mariana, rS = Picea rubens, wS = Picea glauca, bF = Abies balsamea, wP = Pinus strobus, eH = Tsuga canadensis, eL = Larix laricina, rM = Acer rubrum, wB = Betula papyrifera, yB = Betula alleghaniensis, nrO = Quercus rubrum, tA = Populus tremuloides.

[3] May include a few other species of spruce.

Table 3. Harvesting methods used on study areas

Study area	Approx. time of harvest	Felling method	Extraction method	Standing residuals: Major species	Standing residuals: % of original stems
1	Winter, 1970-71	Manual	Skidder	bS	46
2	Spring, 1972	Manual	Skidder	rM	24
3	Spring, 1972	Manual	Skidder	bS	48
4	Spring to fall, 1971		Feller-forwarder + stationary processor	bF	12
5	Spring, 1974	Manual	Skidder	rM	30
6	Summer, 1974	Manual	Mobile processor	bF	2
7	Summer, 1974	Manual	Skidder	bS	9
8	Summer, 1974	Manual	Skidder	-	0
9	Winter, 1973-74	Manual	Skidder	-	0
10	Summer, 1974	Manual	Skidder	yB	14
12	Spring, 1975	Manual	Skidder	-	0
13	Autumn, 1974	Feller-buncher	Mobile processor	bF	4

On each study area, 30-90 circular plots were established at equidistant intervals (4-40 m) across the clearcut. Records of ground cover were taken on 1-m^2 plots (0.56 m radius). Regeneration was counted on 4-m^2 plots (1.13-m radius) or 10-m^2 plots (1.78 m radius), and stumps and residual trees were counted on 40-m^2 plots (3.37-m radius). Ground cover components including slash, plant species, and surface features such as moss, litter, exposed duff, and exposed mineral soil were recorded according to estimated percent cover and maximum height. For tree regeneration, the height of the tallest individual of each species and the number of trees per 4 m^2 were recorded. During the study, the point-distance method, as described by Cottam and Curtis (1956) was tried and found to be fairly reliable for tree or stump counts but gave estimates of regeneration that varied considerably from plot counts. Diameters of tree stumps and counts of annual rings on representative stumps were recorded. Successive records were taken shortly after logging, 1 year later, 2 years, 5 years, and for some areas, 7 or 8 years later. Records were taken during the latter part of July or early August when plants were fully developed for the season and before autumn senescence.

RESULTS

Regeneration of Tree Species

Densities of regeneration of different species are given in Table 4. These figures are based on plot counts in the final year of observation, and include young seedlings, advance regeneration, and vegetative reproduction. Total regeneration varied from 4000 to 25 000 stems/ha with softwoods contributing 1500 to 13 000/ha, of which 400 to 6000 were spruce. In seven of the 12 areas, fir exceeded spruce but in only four stands did hardwood regeneration exceed softwoods. Spruce regeneration predominated only in locations 1 and 3, which were formerly black spruce stands in the Mersey River district. Fir regeneration predominated at McLellans Mountain (formerly a stand of old-field white spruce), at St. Esprit and Sherbrooke in the Eastern Shore district, and at Upper Musquodoboit. The predominant type of regeneration bore little resemblance to the composition of the previous stand (Table 2). There was some correlation between former stand density and density of regeneration ($r = 0.59$). There were no significant correlations between different species or between ratios of species or groups. Red maple regeneration (mainly stump sprouts) was correlated ($r = 0.86$) with density of red maple in the former stand but other species were weakly correlated and spruce regeneration showed a slight negative correlation with the original density of spruce.

Overall regeneration, in terms of density, appeared to be adequate in all but three areas (Caledonia, McLellan's Mountain, and Chignecto). Examination of stocking levels (Table 5) confirmed this. However, stocking to spruce was generally poor, not exceeding 76%, and was highest on the Mersey River sites, locations 1, 2, and 3.

Ground Cover Changes

All species tallied in the 1-m^2 plots are listed in Table 6. Most species increased in incidence, while a few, namely, liverwort, red spruce, goldthread, wood sorrel and partridge berry declined in incidence after the first or second year following logging. The most frequent invaders were raspberry, bunchberry, blueberry, Schreber's moss and hair-cap moss. Study areas with the most diverse ground cover either were more variable than others in soil type and drainage (e.g., location 2), or were, as in the old-field site at location 4, quickly colonized by grasses and herbaceous weeds after cutting. Location 10, a species poor site, was rapidly occupied by birch regeneration after harvesting. Overall, a general increase in species occurred during the first 5 years. The early appearance of some cut-over areas are illustrated in Fig. 2.

Associations were evident at the study area level among some of the most frequently found species, namely Schreber's moss, bracken fern, raspberry, bunchberry, and sheep laurel. There were positive correlations between bunchberry and Schreber's moss ($r = 0.67$), and between bracken and sheep laurel ($r = 0.76$). Negative correlations were found between raspberry and sheep laurel ($r = -0.88$) and between raspberry and bracken ($r = -0.85$). Tree species (regeneration) associated with raspberry were balsam fir ($r = 0.46$) and yellow birch ($r = 0.43$). Tree species associated with sheep laurel were black spruce ($r = 0.80$) and red maple ($r = 0.43$). White pine was found only on sheep laurel sites.

The changes in major cover components are shown in Fig. 3 where study areas are divided, for convenience, into Mersey River (locations 1, 2, 3 and 5), north-central (locations 4, 7, 8 and 9), and coastal (locations 6, 10, 12 and 13) areas (see Fig. 1). Slash piles disappeared rapidly on most sites and after 5 years were barely detectable (Fig. 3). Sheep laurel density was highest on Mersey sites (locations 1, 2, 3 and 5). In the other two regions, sheep laurel was most frequent where raspberry was least and where bracken occurred. Bracken cover was light on coastal areas. Fir was dominant at the Milton (location 5), McLellan's Mountain (location 4) and Sherbrooke (location 13) sites, while hardwoods quickly become dominant at the Chignecto site (location 10). Mosses appeared to increase in cover after logging, but in many cases they may have initially been buried by slash and litter. Hair-cap moss developed on clearcuts where mineral soil was exposed. Some of the changes on specific spots are illustrated in Fig. 4.

Table 4. Regeneration of cut-overs used as study areas

Location	Years after logging	Number per hectare[1,2,3] Spruce	Fir	Other conifers	Total conifers	Red maple	Birch	Other hardwoods	Total hardwoods	Total tree species
1. Ten Mile Lake	8	5733	3511	111	9355	2133	289	111	2533	11888
2. Six Mile Bog	7	4056	1433	744	6233	4433	1578	255	6266	12499
3. Four Mile Road	7	5171	114	14	5299	3914	57		3971	9270
4. McLellan's Mountain	8	1048	2905		3953	857	214	143	1214	5167
5. Milton	5	2267	3600	634	6501	4333	317	516	5166	11667
6. St. Esprit	5	1845	10892	238	12975	60	4881	60	5001	17976
7. Governor's Lake	5	6250	852	341	7443	1307	7443		8750	16193
8. Upper Musquodoboit	5	417	5083		5500	2000	3667		5667	11167
9. Caledonia	6	714	3357	36	4107	71	36		107	4214
10. Chignecto	5	1140	340		1480	160	17420	20	17600	19080
12. Framboise Intervale	5	1900	5400	900	8200		7300		7300	15500
13. Sherbrooke	6	2150	11200		13350	5450	5800		11250	24600

[1]Based on counts in 4-m^2 or 10-m^2 plots.
[2]Does not include planted trees.
[3]For species, see Table 6.

Fig. 2 Photographs of typical cut-over areas. A. Location 1, Ten Mile Lake; B. Location 3, Four Mile Road; C. Cut-over old-field spruce stand near Antigonish, N.S. D. Ground cover vegetation one year after clear-cutting on the old-field site (location 4) at McLellan's Mountain.

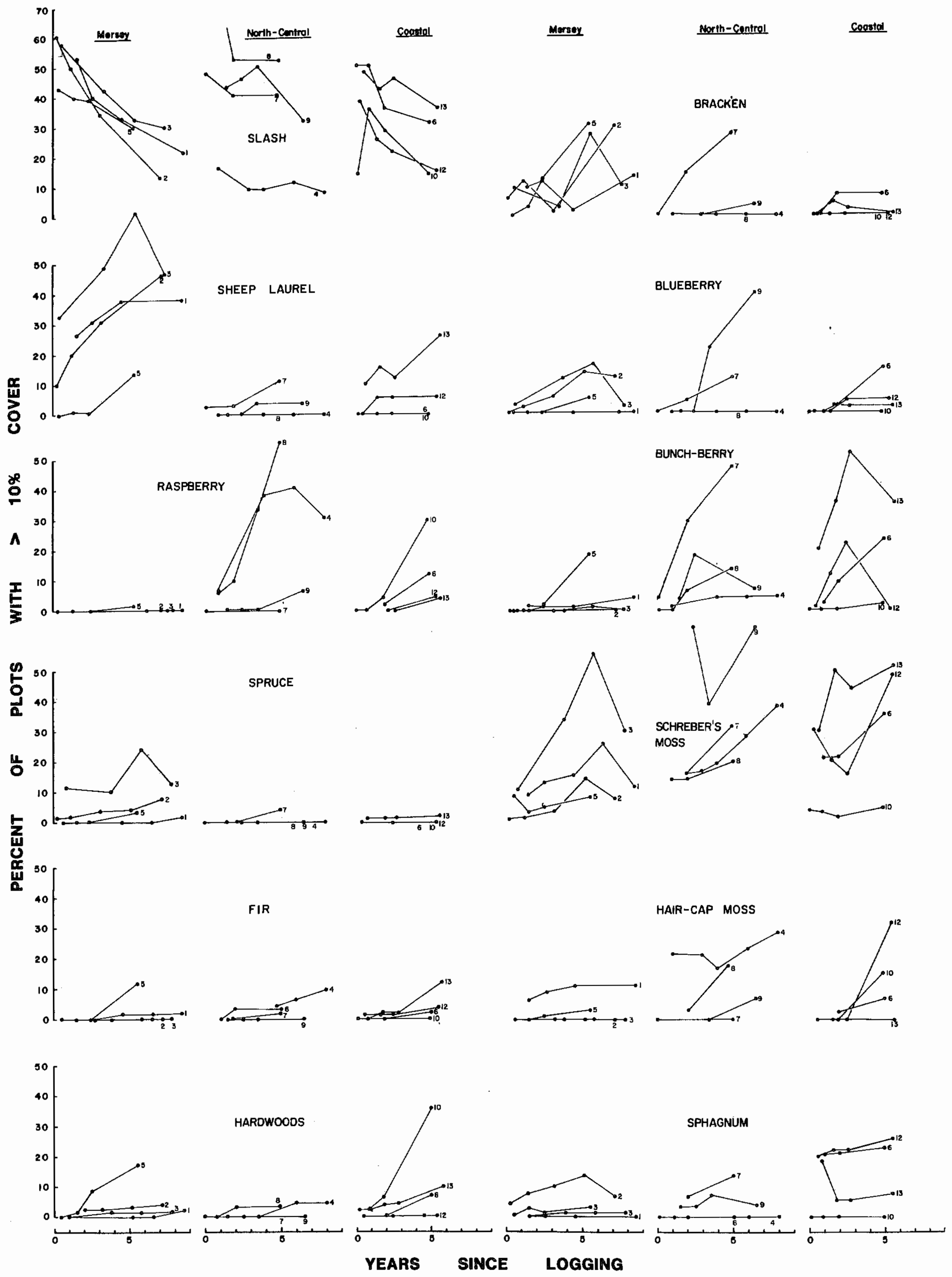

Fig. 3. Changes in major cover components on the study area in the Mersey forest district (locations 1,2,3, and 5), the north-central part of Nova Scotia (locations 4,7,8, and 9) and in coastal areas (locations 6,10,12, and 13).

Table 5. Stocking levels of tree regeneration on the study areas

Location	Years after logging	Percent of 4-m^2 plots stocked								
		Spruce	Fir	Other conifers	Total conifers	Red maple	Birch	Other hardwoods	All hardwoods	Total tree species
1. Ten Mile Lake	4	71	56		89	20	11	13	31	89
	6	69	53		87	24	7	7	36	84
2. Six Mile Bog	3	49	36	11	63	41	19	6	52	79
	5	60	32	13	69	38	39	7	58	83
3. Four Mile Road	3	73	7		74	20	1		21	79
	5	76	3		77	31			31	83
4. McLellan's Mountain	4	12	31		38	10	5	2	17	43
	6	12	33		38	19	2	5	26	50
5. Milton	1	48	53	27	65	47	8	3	52	83
	2	42	48	30	68	67	7	7	72	90
	5	25	30	2	57	33	2	5	40	83
6. St. Esprit	0	12	57		62					62
	1	10	45		43		2		2	48
	2	21	57	2	57		29		29	64
	5	31	74	7	76	2	45	2	45	83
7. Governor's Lake	0	55	20	7	59	18	2		20	64
	2	36	11	2	43	18	6		23	53
	5	57	23	11	71	30	52		66	89
8. Upper Musquodoboit	0	20	53		60	27	17		43	60
	1	10	40		40	33	13		40	53
	2	7	37		37	37	30		53	63
	5	17	53		60	40	60		73	90
9. Caledonia	1	14	43		50	50	7		57	75
	2	7	29		29	54			54	68
	3	11	36	4	43	50	11		54	68
10. Chignecto	0	18	12		22		22		22	38
	1	20	10		24	14	34		42	56
	2	22	8		24	12	66		74	80
	5	12	2		16	2	86		86	88
12. Framboise Intervale	0	26	28	4	46		6		6	52
	1	26	62	6	74	4	34		34	78
	2	28	62	10	70		42		42	74
	5	38	66	12	82		68		68	98
13. Sherbrooke	1	22	78		78	16	4		20	80
	2	26	84		86	44	24		56	92
	3	32	88		90	46	36		70	98
	6	28	84		88	50	52		84	98

Table 6. Species incidence in the study areas

Species*	Maximum incidence %											
	Location											
	1	2	3	4	5	6	7	8	9	10	12	13
Bryophytes												
Liverwort, *Bazzania trilobata*	16	27	13		47	2	7	10		6	2	26
Sphagnum mosses		22	6		5	29	19		7		36	22
Schreber's moss, *Pleurozium schreberi*	40	33	76	55	27	51	59	47	82	14	52	66
Feather mosses, *Hypnum imponens*	11	11	9	5	25					4	2	4
Hypnum crista-castrensis	2	1										
Hylocomium splendens	4	3				19		20	7		8	18
Dicranum spp.	47	41	46	12	47	26	25	13	11	28	44	24
Hair-cap moss, *Polytrichum commune*	36	16	4	38	10	12		30	21	30	44	2
Club mosses - *Lycopodium* spp.				2				3				
Ferns												
Interrupted fern, *Osmunda claytoniana*		1				2		3				2
Cinnamon fern, *Osmunda cinnamomea*	2	10	11		17	14	2	3			8	
Bracken fern, *Pteridium aquilinum*	69	42	77		45	12	66		7	2	8	42
Wood ferns, *Dryopteris* spp.	2	2	1	7		7	5	7		16		2
Hay-scented fern, *Dennstaedtia punctilobula*		1		24		24		73		16	2	
Conifers												
Balsam fir, *Abies balsamea*	20	7	6	19	23	48	12	33	21	8	30	58
Black spruce, *Picea mariana*	18	22	60			2			11		12	18
White spruce, *Picea glauca*				2								
Red spruce, *Picea rubens*					32		24	7		12		
Larch, *Larix laricina*		1									6	
White pine, *Pinus strobus*		2	3		12		5					
Hemlock, *Tsuga canadensis*					2							
Dicotyledons												
Willows, *Salix* spp.				2				3				
Aspens, *Populus tremuloides*		1			7							
P. grandidentata	2		1									
Bayberry, *Myrica pensylvancia*		3	3		5							
Sweet gale, *Myrica gale*												
Sweet fern, *Comptonia peregrina*	2											
Yellow birch, *Betula alleghaniensis*						10	5	3	4	42		
White birch, *Betula papyrifera*	11	11	1		3	14	18	10	7	16	46	38
Gray birch, *Betula populifolia*		1		2								
Speckled alder, *Alnus rugosa*		6	4	7								
Red oak, *Quercus borealis*	7	1										
Sheep sorrel, *Rumex acetosella*				45				7				

Table 6. Species incidence in the study areas

Species*	Maximum incidence %											
	Location											
	1	2	3	4	5	6	7	8	9	10	12	13
Dicotyledons												
Knotweed, *Polygonum cilinode*				7				23				
Creeping buttercup, *Ranunculus repens*				10								
Goldthread, *Coptis groenlandica*		2	1		17	12	2	7	11	2	38	6
Skunk currant, *Ribes glandulosum*				2		5		3	4			
Witch hazel, *Hamamelis virginiana*	18	1	4		2							
Meadow sweet, *Spirea latifolia*				2								
Mountain ash, *Sorbus americana*				5		2	2	3				2
Shadbush, *Amelanchier* spp.	2	1	3				2				2	
Strawberry, *Fragaria* spp.		1		31		17						
Cinquefoil, *Potentilla* spp.				33					7			
Raspberry, *Rubus strigosus*		4		71	18	64		90	21	58	42	26
Blackberry, *Rubus hispidus*		10			5							
Dewberry, *Rubus pubescens*		2		7		17		3				
Pincherry, *Prunus pensylvanica*	4			2	2	14		10			2	6
Wood sorrel, *Oxalis montana*				7				13		44		2
False holly, *Nemopanthus mucronata*			4		7		16				12	
Red maple, *Acer rubrum*	9	24	29	12	33		10	17	25	2	2	28
Touch-me-not, *Impatiens* sp.				12								
Violets, *Viola* spp.		1	1	19		10		17			2	
Wild sarsaparilla, *Aralia nudicaulis*		1		2	2		4	50				4
Bristly aralia, *Aralia hispida*				7	2			13	21	44		10
Bunchberry, *Cornus canadensis*	42	23	31	36	32	55	84	37	61	6	78	76
Labrador tea, *Ledum groenlandicum*											10	2
Rhodora, *Rhododendron canadense*			6		2							
Sheep laurel, *Kalmia angustifolia*	78	74	94		30	10	48		53	2	54	56
Mayflower, *Epigaea repens*	7	1	1		5	2		3			10	
Teaberry, *Gaultheria procumbens*	22	18	21		2				4		10	2
Snowberry, *Gaultheria hispidula*		8	1		10	10	2	10	25		14	30
Huckleberry, *Gaylussacia baccata*	13	26	43		2		9					
Blueberry, *Vaccinium* spp.	36	56	73	2	13	36	59	3	86		58	26
Starflower, *Trientalis borealis*	27	22	7		25	7	5	3	7	2	6	8
Holly, *Ilex verticillata*		1	4									
Bearberry, *Arctostaphylos uva-ursi*											4	
Bedstraw, *Galium* spp.				4								
Partridge berry, *Mitchella repens*	7	1										
Witherod, *Viburnum cassinioides*	4	8	4			12	5				8	4
Elder, *Sambucus canadensis*				7						12		
Twin flower, *Linnaea borealis*				2	13	14		23	18		2	22
Aster, *Aster* spp.		1		19		41		7	4	4	2	2
Goldenrod, *Solidago* spp.				19		14		3	4		2	
Ox-eye daisy, *Chrysanthemum leucanthemum*				7								

Table 6. Species incidence in the study areas

Species*	Maximum incidence %											
	Location											
	1	2	3	4	5	6	7	8	9	10	12	13
Dicotyledons												
Yarrow, *Achillea millefolium*				5								
Pearly everlasting, *Anaphalis margaritacea*				2		5						
Hawkweeds, *Hieracium* spp.				17								
Monocotyledons												
Blue-grass, *Poa trivialis*				2								
Poverty-grass, *Danthonia spicata*				52		5		3	4			
Tickle-grass, *Agrostis* spp.				17								
Hairy panic-grass, *Panicum lanuginosum*				29					4			
Various grasses	2	9	1	41	5	7		7	18	2	4	
Sedges, *Carex* spp. and others	4	8		24	28	14	2	30	7	10	32	2
Rushes, *Juncus* spp., *Luzula* spp.				7	2							
Clintonia, *Clintonia borealis*	2					2	5				8	
Wild lily-of-the-valley, *Maianthemum canadense*	2	3		17	15	17	5	27	11	2	24	10
Indian cucumber root, *Medeola virginiana*	4											
Total plant species tallied	34	49	34	49	38	40	27	40	30	25	38	33

* Common names according to Roland, A.E., The Flora of Nova Scotia, 1945.

Fig. 4 Photographic records of changes in ground cover vegetation over time. A-D. A spot at the Ten Mile Lake Cutover (location 1) showing ingress of sheep laurel and bracken from 1972 (A), 1973 (B), 1974 (C) to 1976 (D); E,F. A spot at the St. Esprit cutover in 1974, shortly after logging (E) and in 1976 (F); G,H. Another spot at St. Esprit in 1974 and 1976, respectively.

The only available measure of initial stand productivity was the average basal area (based on stump diameter) divided by average stand age. Using this rough index, raspberry cover was positively correlated with original productivity (r = 0.67) while blueberry was negatively correlated (r = -0.61). No other correlations, including tree regeneration, were significant. It should be noted here that this index of productivity was more closely related to stump diameter than to stand density.

Effects of Residual Tree Cover

Several plots were established in adjacent uncut forest in locations 1, 2 and 3 in the Mersey River district. In other areas, residual tree cover was scattered or non-existent. Since the Mersey study areas were close together and had similar vegetation, data were combined and are presented in Fig. 5 for the dominant species, sheep laurel. There was a marked increase in sheep laurel cover in cleared areas but little increase under residual forest cover. Other colonizing species followed similar trends.

Effects of Slash Cover

The uneven slash cover in most study areas facilitated a measure of this factor on succession. Ingress of species onto and under slash piles was surprisingly rapid and after 5 years, the density of some of the dominant cover types was as great as in open areas (Table 7).

Care was taken not to disturb the slash piles during examination, and thereby providing new openings for light. Much of the early colonization occurred beneath slash piles wherever light penetrated but after compaction of the slash the surface also become quickly colonized.

In three of five study areas where sheep laurel was listed in Table 7, its cover was as great or greater under slash piles as in relatively slash-free areas. Dense raspberry cover became more frequent on slash piles than in slash-free areas at St. Esprit and Upper Musquodoboit. However, none of the recorded differences in Table 7 are statistically significant. Bunchberry, blueberry, bracken, and hay-scented fern also colonized slash piles. Tree regeneration was found in small openings and at the edges of slash piles but did not grow through heavy slash. Again no differences in regeneration could be found between plots in the vicinity of slash piles and in slash-free areas that could not be attributed to chance alone.

Effects of Surface Characteristics

Plots not dominated by residual trees and not covered with slash were classified according to predominant surface characteristics after logging. Four categories were used, i.e., litter, feather mosses, (Schreber's moss, *Dicranum* mosses, *Hylocomium* spp.), *Sphagnum*, and exposed mineral soil or humus (Table 8). Because comparison of disturbed and undisturbed surfaces was of special importance, only study areas with comparable numbers of plots in each category were included.

Hair-cap moss was the only species consistently associated with disturbed surfaces but it also invaded *Sphagnum* plots at the Framboise site (Table 8). Bracken, bunchberry, and blueberry could not be associated consistently with any surface feature. Sheep laurel invaded all types of plots but showed a slight preference for *Sphagnum* surfaces. Spruce and fir showed a distinct association with undisturbed (i.e., litter, feather moss, or sphagnum) surfaces indicating a preponderance of advance regeneration among surviving seedlings.

Effects of Sheep Laurel on Regeneration

The effects of ericaceous vegetation on regeneration is of considerable interest. Analyses of numbers of young conifers in the vicinity of dense sheep laurel plots compared to relatively weed-free plots showed no significant differences. However, when the nearest regeneration within the 1-m^2 plot area was considered (Table 9), regeneration of spruce was not only more abundant on the ericaceous sites but also taller: spruce regeneration was still taller when the larger trees (consisting mainly of advance regeneration), were excluded.

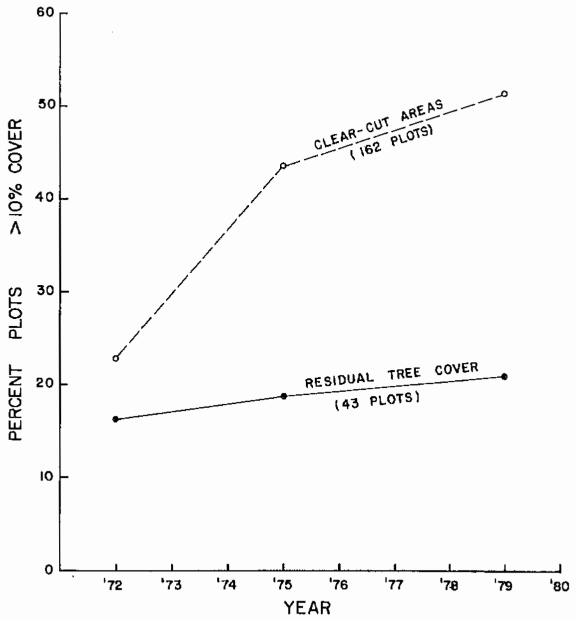

Fig. 5 Changes in sheep laurel cover in clearcut portions of study areas in locations 1, 2, and 3 and in adjacent uncut areas.

Table 7. Vegetative cover 5-6 years after logging in plots initially under heavy slash cover in comparison with relatively slash-free plots

Location and species	Percent plots >10% cover: Slash piles*	Little or no slash cover**
3. Four Mile Road		
Bracken	33	25
Black spruce	20	25
Sheep laurel	73	64
Huckleberry	6	15
Blueberry	27	13
5. Milton		
Bracken	25	31
Conifer regeneration	8	13
Hardwood regeneration	8	19
Bunchberry	25	17
Sheep laurel	8	15
6. St. Esprit		
Hay-scented fern	0	15
Raspberry	22	9
Bunchberry	11	27
7. Governor's Lake		
Bracken	33	26
Bunchberry	33	51
Sheep laurel	0	14
Blueberry	11	11
8. Upper Musquodoboit		
Hay-scented fern	35	54
Raspberry	65	46
Bunchberry	6	23
12. Framboise		
Sheep laurel	30	0
13. Sherbrooke		
Bunchberry	38	36
Sheep laurel	25	26

* Over 50% slash cover estimated in initial tally.
**50% or less slash cover estimated in initial tally.

DISCUSSION

Successional trends were followed from the time of logging until 5-8 years later on 12 clearcuts in the major pulpwood producing areas of mainland Nova Scotia and the south shore of Cape Breton Island. This represents a wide variety of forest types, each with a complex history of disturbance. Only the most consistent trends can be used to form general conclusions.

Although all vegetation was considered, regeneration of tree species is of primary interest in a study of this nature. Conifer densities of 1400 to 13 000/ha would, at first glance, appear adequate, but in terms of species composition and spacing, it is less than desirable. Over half the areas had predominantly balsam fir regeneration, which will probably detract from the ultimate quality of the stands (Davidson 1957; Davidson and Redmond 1957). Stocking levels are poor in some areas, indicating uneven spacing.

Analysis of all factors affecting regeneration is not possible without more data. However, it is evident that most of the regeneration is associated with undisturbed surfaces and it could not be demonstrated that slash or the most common weed, sheep laurel, had any detrimental effects on softwood regeneration.

Table 8. Ground cover and regeneration after five years of plots with different original surface conditions

Location and species	Litter surface	Feather moss surface	Sphagnum surface	Mineral soil or duff surface
5. Milton				
Hair-cap moss, % cover*	0a**	0a	-	4a
Bracken fern, %	5ab	1a	-	17b
Bunchberry, %	3a	1a	-	4a
Sheep laurel, %	1a	1a	-	1a
Blueberry, %	1a	0a	-	0a
Raspberry, %	0a	1a	-	1a
Conifer regeneration, %	0a	9b	-	0a
Hardwood regeneration, %	4ab	4b	-	0a
Spruce seedlings/m^2	0.14a	0.34b	-	0.20ab
Fir seedlings/m^2	0.14a	0.77b	-	0.15a
Red maple regeneration/m^2	0.53a	0.49a	-	0.18a
6. St. Esprit				
Hay-scented fern, %	1a	0a	7a	4a
Raspberry, %	1a	6a	3a	12a
Bunchberry, %	9b	13b	0a	6b
Sheep laurel, %	0a	0a	1a	0a
Blueberry, %	3b	4b	0a	4ab
Spruce seedlings/m^2	0.17a	0.46a	0.28a	0.00a
Fir seedlings/m^2	1.21a	2.29a	0.44a	0.44a
Birch seedlings/m^2	0.37a	1.38a	0.31a	0.94a
7. Governor's Lake				
Bracken, %	9ab	10b	1a	12b
Bunchberry, %	18a	15a	10a	14a
Sheep laurel, %	1a	3a	6a	3a
Spruce seedlings /m^2	0.68ab	0.43ab	1.11b	0.21a
10. Chignecto				
Raspberry, %	34b	2a	-	5a
Spruce seedlings/m^2	0.05a	0.22a	-	0.06a
Birch seedlings/m^2	2.16b	0.95a	-	2.33b
12. Framboise				
Hair-cap moss %	3ab	1a	18b	16b
Bunchberry, %	5a	4a	1a	2a
Sheep laurel, %	1ab	3b	4b	0a
Blueberry, %	3a	4a	1a	0a
Spruce seedlings/m^2	0.25a	0.13a	0.13a	0.22a
Fir seedlings/m^2	0.25a	0.98a	0.48a	0.22a
13. Sherbrooke				
Bracken, %	1a	3b	1a	0a
Raspberry, %	1a	0a	0a	2a
Bunchberry, %	8a	13a	12a	1a
Sheep laurel, %	5ab	1a	14b	1ab
Spruce, seedlings/m^2	0.00a	0.07a	0.80b	0.06a
Fir seedlings/m^2	1.18a	1.15a	1.48a	0.63a
Birch seedlings/m^2	0.34a	0.71a	0.78a	0.31a

* Figures converted from arcsin % transformation of values used in analyses.

** Numbers within a row followed by the same letter not significantly different at the 5% level of probability.

Table 9. Numbers and heights of nearest spruce seedlings within 0.6 m of plot centre, locations 1, 2, and 3, in 1977

	Ericaceous shrubs dominant in 1972*	Bracken - sheep laurel dominant in 1972*	Sparse cover in 1972*
Number of seedlings			
>1 m tall	1	1	0
0.6-1 m tall	9	2	0
0.1-0.5 m tall	9	4	11
<0.1 m tall	0	0	1
Total	19	7	12
Mean height (m)			
All seedlings	0.64b**	0.67b	0.21a
<1 m height	0.55b	0.53b	0.21a
<0.5 m height	0.34ab	0.45b	0.21a

* Plots dominated by slash or residual tree cover not included.
** Values within a row followed by the same letter not significantly different.

Thus, soil surface disturbance by logging equipment appears to be a more serious limiting factor than competing cover. Advance regeneration could have been destroyed by the logging operation. In some clearcuts, subsequent exposure of young seedlings on scarified microsites could have resulted in considerable mortality and seedling mortality was observed in exposed areas but was not followed quantitatively.

Studies of sheep laurel and other ericaceous vegetation have implied a detrimental effect on tree regeneration, either through direct suppression of tree seedlings, soil deterioration, allelopathy, or nutrient tie-up (Damman 1971; Peterson 1965; Strang[2]). There may be serious long-term effects of dominance by these shrubs as occurs in barrens (Strang[2]; Damman 1971) but in this study, no serious short-term effects could be found. The most dense shrub cover was about 30% on about one-third of the plots in the predominantly ericaceous sites in the Mersey forest district. In one of these areas, density of sheep laurel declined after 5 years and it is thought that the development of a forest cover will hasten this decline. Spruce regeneration on plots dominated by ericaceous shrubs or bracken and sheep laurel was taller than spruce on sparsely covered plots. Obviously, there is a need for more precise analyses of seedling development under different shrub covers.

Raspberry was found on mixed-wood cutovers which regenerated primarily to balsam fir and yellow birch. Raspberry and sheep laurel tended to be mutually exclusive. Raspberry attained significant cover on three sites (locations 4, 8, and 10) but on location 4 there was a decline in raspberry cover after 5 years. In none of the study areas was there evidence of a detrimental effect of raspberry on regeneration.

Where softwoods are a desired crop, hardwoods may be considered weed species. Significant hardwood cover developed on only one site (location 10). Close to the study area, red pine was planted following an attempt to control yellow birch regeneration. This could provide an opportunity to compare productivity of a plantation with that of natural regeneration of red spruce and fir on what is normally a very productive site.

A notable feature of the vegetation in all study areas is the absence of any legumes and the paucity of known nitrogen fixing species. Attempts to establish legumes on the ericaceous sites did not show promising results (Wall 1977). European black alder (Alnus glutinosa (L.) Gaertn.) planted near location 2, survived but did not grow well (Wall unpublished[4]). With no apparent input of nitrogen, release of this and other nutrients could be very important on a clearcut. Early cover by noncommercial species may thus be extremely important in nutrient retention on the site. Also, by forming a canopy over slash piles and thereby speeding slash breakdown by providing a more humid environment, cover is important in nutrient release. In this study, 'weed' species quickly colonized slash piles and slash cover decreased considerably in 5 years. Slash breakdown was notably slow on location 9, which was a dry, exposed site with

[4] Information on file at Maritimes Forest Research Centre, Fredericton, N.B.

little vegetation. Slash breakdown was especially rapid on location 8 where a dense raspberry cover developed.

This study indicates some associations among original stand type, ground vegetation after clearcutting, and type (but not adequacy) of regeneration. The more productive fir, mixedwood, red spruce, or old-field spruce stands regenerated mainly to fir or hardwoods and developed a ground cover dominated by raspberry. The supposedly less productive black spruce stands had a predominantly sheep laurel cover and sometimes regenerated poorly to spruce. However, the adequacy of regeneration cannot be predicted from invading ground cover. The old-field spruce site, for example, did not regenerate well. Several of the ericaceous sites had good regeneration after 5 years.

Poor regeneration of spruce and fir was associated mainly with heavy surface disturbance in the cutting operation and with open exposed microsites. When seed supply is uncertain, clearcuts which have been heavily scarified in the cutting operation are the ones that will most likely need planting and the ones least likely to need a second site preparation treatment if planted soon after harvesting. Most of the clearcuts observed in this study did not need planting unless conversion to different species was desired. In places where planting was carried out, e.g., near locations 1, 2, 4, 5, and 10, there is an opportunity to observe the relative performance and productivity of planted and natural stands.

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APPENDIX I

Soils of the study areas

Study area	Horizon	Thickness (cm)	Color	Texture[1]	Consistence	Other features
1	LFH	5-8				Parent materials
(Mini ferric	Ae	1-2	gray	si fs	friable	basal till and
podzol to	Bf	25-30	yellow-brown	l s	friable	fine sandstone,
mini ferro-	BC	13-18	olive-brown	si s	friable	<5% slope,
humic podzol)	Cd		olive	s	firm	Good drainage,
						Rooting depth 40-45 cm.
2	LFH	7-20				Parent materials basal
(Ortho ferro	Ae	0-10	light brownish	si fs	friable	till and fine sandstone
humic podzol	Bf	0-18	strong brown	si fs	friable	<5% slope
to orthic	Bfh	0-25	dark red-brown	l s	friable	Poor drainage and gleying
gleysol)	BC	0-13	light olive brown	s	firm	in several places.
						Rooting depth 5-43 cm.
	C		olive-gray	fs	firm	
3	LFH	7-30				Parent materials basal
(Orthic	Ae	5-10	gray	si fs	friable	till and sandstone debris
ferro-humic	Bf	7-23	strong brown	l fs	friable	<5% slope
podzol to	Bfh	0-18	dark brown	l fs	friable to firm	Good to poor drainage
wet orthic	BC	12-15	yellow-brown	l s	friable to firm	Rooting depth 5-50 cm.
regosol)	C		olive-brown	l s	firm	
4	LFH	5-8				Parent materials shale.
(Orthic	Ap	3-14	dark brown	l	friable	quartzite, horneblende
podzol)	Ac	0-13	pinkish-gray	si fs	friable	sandstone
	Bf	10-40	dark brown	l	friable	1-12% slope
	BC	0-18	olive to yellow-brown	l	friable	Generally good drainage
						Rooting depth 25-50 cm.
	C		olive	l	friable	
5	LFH	10-15				Parent materials basal
(Mini	Ae	1-18	brown	si fs	friable to firm	till, sandstone + granite.
ferro-humic	Bf	0-15	reddish brown	s l	friable	1-10% slope
podzol to	Bfh	0-10	dark brown	s l	friable	Drainage good to poor
orthic	Bg	0-10	dark brown	l fs	firm	Gleying and mottling in
gleysol)	BC	0-10	olive brown	s l	friable to firm	several places.
	C		gray	si fs	firm to compacted	Rooting depth 5-33 cm.
6	LFH	10-15				Parent materials basal
(Weakly	Ae	7-25	light gray	si fs	friable	till, granite, quartzite,
gleyed	B	0-28	dark brown	s l	friable	and schists.
podzol	Bg	0-20	dark brown	s	mod. firm	2-12% slope
to orthic	BC	0-13	dark yellow-brown	l s	friable to firm	Drainage good to imperfect
podzol)						Gleying in spots.
	C		brown	s	firm	Rooting depth 20-35 cm.
7	LFH	8-10				
(Orthic	Ae	10-15	light brownish gray	s	friable	Very stony
podzol)						Parent material basal till,
	B	15-30	dark brown	l s	friable	granite, slates, schists,
	C		olive brown	s	friable to firm	gneiss.
						1-25 % slope
						Drainage generally good
						Rooting depth 25-35 cm.

Study area	Horizon	Thick-ness (cm)	Color	Texture[1]	Consistence	Other features
8 (Mini ferric to mini (humo-ferric podzol)	LFH	4-06				Parent material metamorphic rocks, basal till 5-15% slope Drainage good Rooting depth 30-43 cm.
	Ae	1-02	light brownish gray	si fs	friable	
	Bf	33-38	brown	l	friable	
	BC	5-17	dark grayish brown	l s	mod. firm	
	C		olive brown	l fs	firm	
9 (Well-drained mini podzol to orthic podzol)	LFH	4-06				Parent material basal till, quartzite, sandstone, and granite 3-15% south slope Good to imperfect drainage Rooting depth 40-42 cm.
	Ae	0-13	pinkish gray	si, fs	friable	
	Bf	17-38	strong brown	l	friable	
	BC	10-30	dark yellow-brown	l s	friable to firm	
	C		brown	s	firm	
10 (Orthic humo-ferric podzol)	LFH	3-10				Parent material sandstone and basal till <5% slope Drainage good Rooting depth 22-56 cm
	Ae	4-5	reddish-gray	l s	friable	
	Bfh	0-20	dark reddish brown	s l	friable	
	Aeb	0-15	reddish-gray	l s	friable	
	Bf	9-15	yellowish red	s l	friable	
	BC	10-14	dark reddish brown	l cs	firm	
	C		dark reddish brown	l cs	firm	
12 (Orthic podzol)	LFH	5-12				Parental material basal till, granite, quartzite, hematite, sandstone 1-8% slope Good to imperfect drainage Some iron staining Rooting depth 20-40 cm.
	Ae	5-13	pinkish gray	si fs	friable	
	Bfh	0-8	dark reddish brown	s l	friable	
	Bf	18-30	yellowish brown	s l	friable	
	BC	18-20	dark yellowish brown	l s	friable to firm	
	C		dark yellowish brown	s	firm	
13 (Not strongly developed mini podzol to orthic podzol)	LFH	5-13				Very stony Parent material shale, granite, sandstone 3-12% north slope Drainage good to imperfect Rooting depth 33-40 cm.
	Ae	1-13	light gray	fs	friable	
	Bfh	5-12	dark reddish brown	l	friable	
	Bf	7-20	dark brown	s l	friable	
	BC	0-10	yellowish brown	l s	friable	
	C		light olive brown	l s	friable to firm	

[1] si = silt, fs = fine sand, s = sand, cs = coarse sand, l = loam.