Papers

PHYTOECOLOGICAL STUDY OF SYLVOTUNDRA AT SMALL TREE LAKE, N.W.T.[1]

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ABSTRACT. Characteristics of terrain and the associated microenvironmental conditions determine various vegetation types in the study area. Lakeshores and hill-bottoms support closed canopy *Picea mariana* forest, but the exposed slopes are treeless. A *Picea glauca* parkland forms a transition between forests and treeless slopes. The large size of trees in the parkland, absence of krumholz zone, and abrupt timber-line due to topography indicate a delicate balance between the vegetation types at the sylvotundra investigated. The present forest-tundra boundaries at Small Tree Lake appear semi-permanent.

Vegetation analysis by stratification showed that the cover by each stratum decreased as the level above ground increased. Along a gradient from forests to treeless slopes, the percentage of boreal plants decreased and that of arctic plants increased.

RÉSUMÉ. *Étude phytoécologique de la toundra forestière à Small Tree Lake, T. du N.-O.* Dans l'aire d'étude, les caractères du terrain et les conditions de micro-environnement qui en découlent déterminent divers types de végétation. Les rives du lac et le pied des collines supportent une forêt de *Picea mariana* à voûte fermée, mais les pentes exposées sont dépourvues d'arbres. Une savane boisée de *Picea glauca* forme la transition entre les forêts et les pentes. La grande dimension des arbres de la savane, l'absence d'une zone de krumholz et une abrupte limite des arbres liée à la topographie indiquent que l'équilibre entre les types de végétation de cette toundra forestière est délicat. Les frontières actuelles entre la forêt et la toundra à Small Tree Lake semblent semi-permanentes.

L'analyse de la stratification a démontré que, pour chaque strate, la couverture diminuait selon l'éloignement au-dessus du sol. Le pourcentage des plantes boréales diminuait et celui des plantes arctiques augmentait selon un gradient entre les forêts et les pentes.

АБСТРАКТ. ФИТО-ЭКОЛОГИЧЕСКОЕ ИЗУЧЕНИЕ ЛЕСОТУНДРЫ У ОЗЕРА СМОЛЛ ТРИ, Северо-Западные территории. Канада. Особенности почвы и связанные с ними микрорайонные условия определяют различие растительных типов в изучаемой местности. Берега озера и подножья холмов покрыты сплошным лесом **Picea mariana** в то время, как открытые склоны безлесны. Редколесье из **Picea glauca** образует переход от леса к безлесным склонам. Значительный размер деревьев редколесья, отсутствие криволесья и отчетливость границы древесной растительности, обусловленная топографией, свидетельствуют о тонком балансировании типов растительности в исследуемой лесотундре. Теперешняя граница лесотундры у озера Смолл Три представляется полу-постоянной.

Стратификационный анализ растительности показывает, что растительный покров уменьшается по мере подъема местности, и что с переходом от леса к безлесным склонам процент бореальных растений уменьшается, в то время как процент арктических растений увеличивается.

Introduction

THE ECOTONE between the treeless tundra and the circumpolar coniferous forest zone (taiga) is known as sylvotundra (Tikhomirov 1960), lyesotundra or wooded tundra (Hoffmann 1958). This transition zone, which in North America stretches sinuously from northern Alaska across northern Canada past the Mackenzie delta and on to the Atlantic, is characterized by a mosaic of forest patches and treeless areas. In spite of the theoretical and practical importance of sylvo-

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tundra ecology, the number of studies and information available in North America is scanty, and even the exact geographical extent of this zone is not well delineated. The purpose of this study in the central portion of the North American sylvotundra was to make a quantitative evaluation of representative plant communities in relation to physiographic features.

In the eastern part of the ecotone, Hustich and Patterson (1945) studied the east coast of Newfoundland and Labrador and have classified the periphery of the forest region, and Marr (1948) conducted a tree-ring analysis on the east coast of Hudson Bay. A general physiognomic and floristic description of the forest-tundra zone in northern Manitoba has been reported by Ritchie (1960). The relationship between plant communities comprising this ecotone and climate at the Ennadai Lake area has been described by Larson (1965). At the north shore of McTavish Arm, located on the northeastern shore of the Great Bear Lake, Lindsey (1952) studied tree density and ground cover by employing photographic methods of sampling. Drew and Shanks (1965) analysed the soils and associated vegetation in the forest-tundra ecotone at Upper Firth River Valley located 70 miles south of the Arctic Ocean. Considerable information regarding recent extension of timberline into tundra is available from the work of Griggs (1934) conducted in the western extremity of the transition zone. In addition to the various forementioned ecological studies, Raup (1947) delineated the natural floristic areas of boreal North America by analysing the distribution patterns of 283 vascular species collected at Brintnell Lake, N.W.T. The range maps of these species show a significant phytogeographic transition zone at the arctic timber line.

The investigation reported here was conducted during the fourth week of July, 1961 and comprised determination of structure as well as composition of various vegetation types and their relationships with landscape on an unnamed island. The study area is located at 60°1'N., 105°1'W. in Small Tree Lake, Northwest Territories (Fig. 1). Smooth, gentle slopes extending into the forest at their lowest edge, and absence of recent biotic and pyric interference (during the life of the dominant trees) made this island particularly suited for the study.

Study area

GEOLOGY AND SOILS

Small Tree Lake is located in an area of paragneisses, gneissic granite, massive granite and granodiorite of the Canadian Shield (Taylor 1959). These pre-Cambrian rocks are in part covered by drift. According to Kupsch (personal communication), the island is composed entirely of drift, mainly poorly stratified sand and gravel. Air photo study (Fig. 2) reveals the presence of irregular ridges surrounding depressions forming a pattern similar to that interpreted elsewhere as resulting from crevasse deposits (MacKay 1960). The depressions were formed by blocks of dead ice, which stagnated in outwash sand and gravels. The ridges represent material that either sloughed off the blocks into the crevasse between them, or was pressed up into crevasses from underneath by the weight of the blocks of ice adjacent to the crevasses. Well developed strandlines on the north side of the island attest to the fact that a relative drop in water has taken place in post-glacial times.

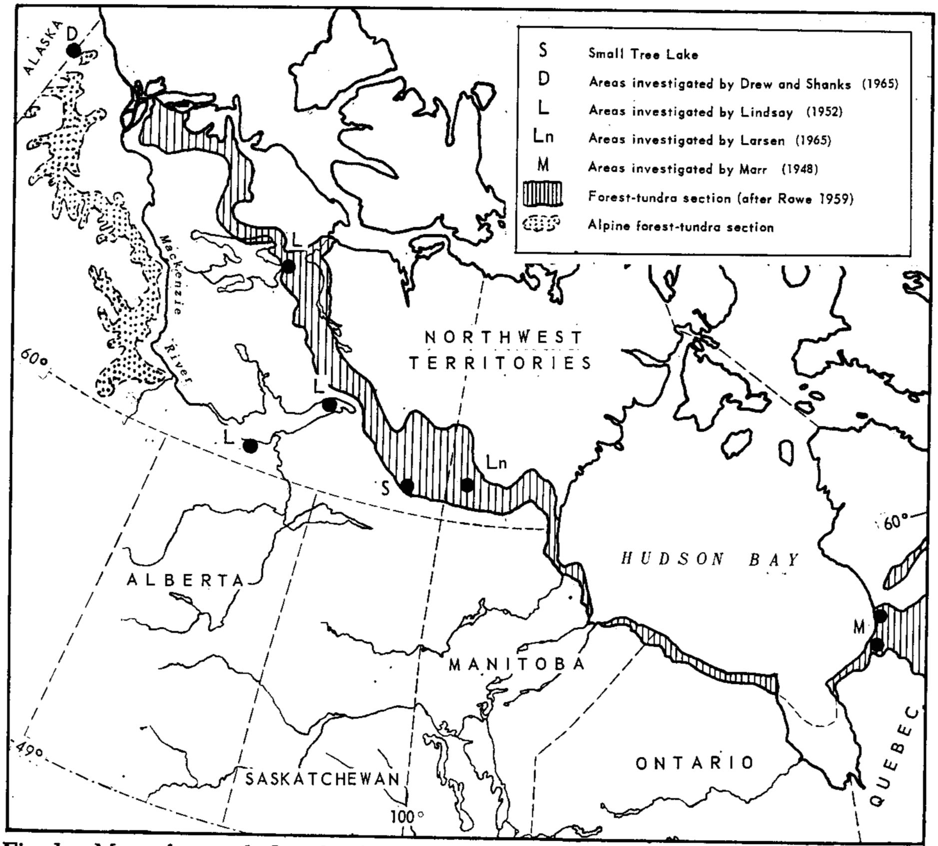


Fig. 1. Map of central Canada showing Small Tree Lake and other areas investigated.

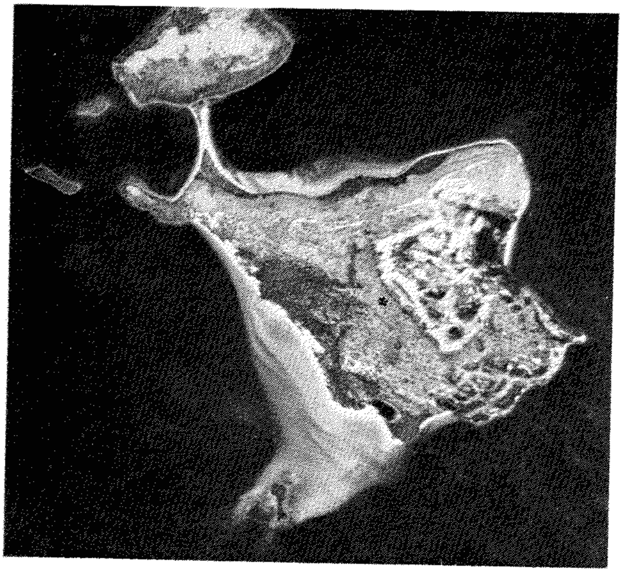


Fig. 2. Aerial photograph of the island investigated at Small Tree Lake. Scale: 1 in. = 650 ft. (R.C.A.F. Photograph).

Coarse-textured upland forest soils of the island, derived from poorly stratified sand and gravel, are podsolized. The F-H horizon is about 1 to 2 in. thick and is underlain by a podsolized A_2 horizon usually about 2 in. thick. The B horizon varies from 2 to 6 in. in thickness. In low-lying wet areas bordering the lake shore, frozen soil underlying peat is encountered at a depth of 16 in. On exposed slopes, thin vegetation cover provides little protection against strong arctic winds. Consequently, soil erosion is taking place at several localities. On soil at present covered by vegetation, the presence of exposed but intact thick lateral roots of *Picea glauca* (see list of species, page 242) indicates loss of 4 to 5 in. of superficial soil sometime during the life of the trees. It is very likely that high velocity winds originated centres of erosion by tearing loose pieces of lichens and mosses or by causing basal branches of trees and *Betula glandulosa* to rub on the ground.

Owing to the porous nature of these coarse soils, little moisture is held in the upper layers therefore, neither water gullies nor well-known cryopedological features of arctic or alpine soils are generally prominent. Only at the bottom of the north-facing slopes, faint unsorted polygons about 5 ft. in diameter were observed. However, on better drained slopes some polygonal bare areas occur as 'islands' in the soil otherwise well covered with a carpet of cryptogamic vegetation. On these bare areas, resembling frost scars, degenerated remains of preexisting vegetation cover and organic matter can be recognized (Fig. 3).

CLIMATE

Although areas unpopulated by humans provide an excellent opportunity to study vegetation in a relatively undisturbed state, climatic data are either unavailable or are meagre and incomplete. The climatic information presented here has been extrapolated from the Climatic Atlas of Canada (Thomas 1953). The study area lies in the region of permafrost, where winters are long and severe and summers short and cool. The mean daily temperature for January, April, and July is, respectively, about —21°, 15° and 57°F. In October, the mean daily temperature is about 25°F. and during the day the temperatures possibly rise above freezing. In ecotones, where some taxa reach their limit and others make their appearance, the extremes rather than mean climatic data are of significance.

Fig. 3. A polygonal bare area resembling a frost scar. Length of the scale is 3 ft.

The peripheral areas of distribution of taxa are mobile migration fronts, and extremes in the climatic conditions often play an important role in limiting their extension into new territory. The extremes of temperature in the area under study are about —65°F. and 94°F. January temperatures as low as —40°F., and July daily highs of 73°F. are not infrequent. Summer rainfall of about 8.5 in. comprises the major portion of annual precipitation which totals about 12 in.

Wind direction during summer is variable but during winter, the prevailing winds are from NW, W, and S. Mean wind speed during the year does not appear to vary and is about 10 mph., however, maximum gust speeds throughout the year range from 80 to 104 mph.

Great fluctuation in day-length occurs in the study area. In January, April, July, and October the mean hours of sunshine amount to 50, 200, 275, and 75, respectively, and the mean annual hours of bright sunshine total about 1700.

VEGETATION

Variations in environmental conditions due to characteristics of the terrain and slope of the study area are reflected by vegetation patterns. In this island located in the Forest-Tundra Section of Rowe (1959), mesic habitats comprising lower portions of hillside and lake shore were covered by closed-canopy stands of *Picea mariana* forest (Forest: "a plant community predominantly of trees and other woody vegetation usually with *closed* canopy": Empire Forestry Association, 1953) with an occasional individual of *Larix laricina* and *Betula papyrifera*. Exposed slopes were generally treeless but had abundant shrub thickets of *Betula glandulosa* (Fig. 4). Between the forest stands and the exposed slopes was a

Fig. 4. Looking westward from a ridge-top. Near lake shore is closed canopy *Picea mariana* forest. In the foreground is *Picea glauca* parkland with *Betula glandulosa* thickets and *Empetrum*. Light coloured ground is due to *Cetraria, Stereocaulon* and *Cladonia*.

Fig. 5. *Picea glauca* parkland with *Betula glandulosa* thickets, *Picea glauca* seedlings, *Empetrum nigrum* and lichens.

community dominated by widely spaced *Picea glauca* trees (resulting in an open stand) with a few large mature dead trees on the ground. In this report, this community is referred to as *Picea glauca* parkland (Figs. 4 and 5). Occasional small depressions in the parkland supported clumps of 6 to 10 dwarf and deformed individuals of *Picea mariana* (Fig. 5). The regeneration of *Picea mariana* was predominantly by vegetative means, i.e. layering, while *Picea glauca* reproduced by seeds.

The gradient and aspect of a slope usually influence the vegetation on it. Although *Betula glandulosa* was an important component of the vegetation on most slopes as well as on the ridge-top, it was conspicuously absent on the north-facing slope (Fig. 6). Occasional trees of *Picea glauca* were present on southerly slopes and on the bottom of westerly slopes. However, on the flat ridge-top, *Picea glauca* occurred only in the form of a few seedlings while north- and east-facing slopes were devoid of arboreal species (Figs. 6 and 7).

Methods

A reconnaissance of the island suggested that the environmental gradient available for colonization by plants could be represented by 9 selected sites which were subsequently sampled in detail. Three of these sites supported closed *Picea mariana* forest, 1 an open *Picea glauca* parkland, the remaining 5, although occasionally supporting isolated trees, were occupied by non-forest vegetation

Fig. 6. Treeless north-facing slope with small shrubs, lichens and mosses. Plant forming dark patches is *Empetrum*.

and were represented by north-, south-, east- and west-facing slopes and a ridge top; one site representing each of the above nine conditions was sampled.

The moisture-physiographic gradient present on the island was divided into 5 units: dry, dry-mesic, mesic, wet-mesic, and wet. In each of the sampled stands, a subjective estimate was made in the field as to which of these units best described the site and the stand was assigned to that unit.

Unfortunately, the wide range in physiognomic characteristics exhibited by the 9 stands necessitated the implementations of a complex, and admittedly cumbersome, sampling regime. The geometrical organization of vegetation was studied by assigning the various components of vegetation of all stands to 4 strata and the quantitative sampling implemented within this framework. Coverage of each species was recorded as a percentage of shading of a particular stratum to which the species was assigned. Therefore, the maximum total per cent cover of all species in a stratum could be 100. The criteria established for the segregation of the vegetation into strata and their subdivisions, along with the sampling procedures employed, are catalogued below.

Stratum I. Cryptogams.

Definition: Includes all lichens, mosses and liverworts occurring as ground vegetation. For convenience, this stratum is divided into: A. Lichens; B. Mosses and Liverworts.

Sampling technique: Frequency and estimated per cent cover readings were made in each stand by employing at least 20 quadrats 1 m. (3.3 ft.) square. The quadrats were equidistant, usually 50 ft. apart and located along a compass line.

Stratum II. Low herbs and decumbent shrubs.

Definition: Includes all vascular species which have an average mature height of 4 in. or less above Stratum I.

Sampling technique: same as Stratum I.

Stratum III. Tall herbs, small and tall shrubs, and arboreal seedlings.

Definition: Includes ground vegetation having average mature heights 4 to 36 in. above Stratum I. For convenience the stratum has been divided into:

III-A. Tall herbs and small shrubs having mature heights 4 to 18 in. above Stratum I.

Sampling technique: same as Stratum I.

III-B. Arboreal seedlings with height up to 36 in. above Stratum I.

Sampling technique: same as Stratum I.

III-C. Tall shrubs, which have an average mature height greater than 18 in.

Sampling technique: In each forest stand, per cent cover was estimated from at least 20 plots having a radius of 10 ft. The location of plots was the same as

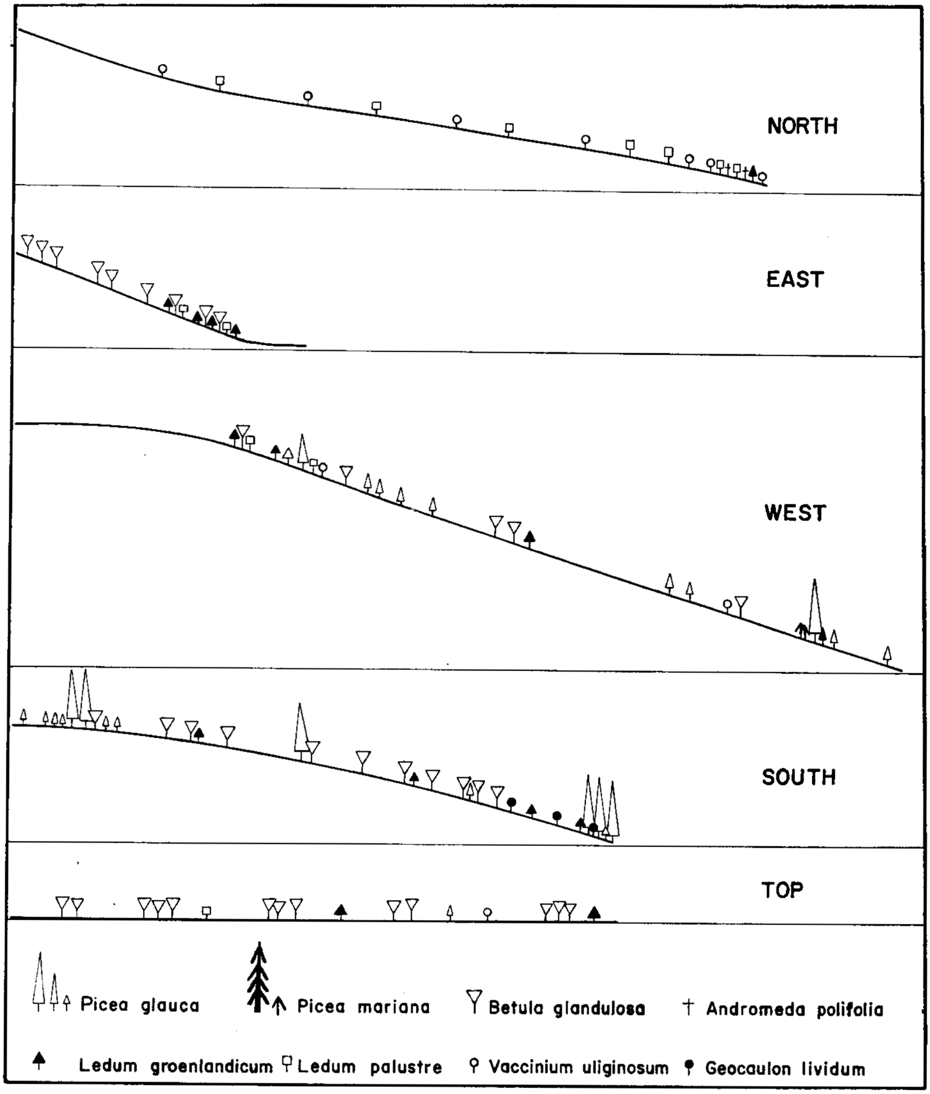


Fig. 7. Profile of vegetation on the slopes and the ridge-top. Angle of slopes and location and extent of important species are shown exactly as recorded in the field.

the quadrats for Stratum I. In parkland and other non-forest stands, tall shrubs were measured in terms of estimated per cent cover by the line intercept method. These lines, each 0.5 in. wide and 100 ft. long and running perpendicular to the slope contours, were established in parallel series in each stand.

Stratum IV. Trees (including their regeneration).

Definition: Includes all species capable of obtaining stem diameters of 3 in. at breast height. The individuals within this category were further segregated into the following size-classes:

Trees:	Individuals with a dbh of 3 in. or more.
Saplings:	Individuals with a dbh of 2.0 to 2.9 in.
Juveniles:	Individuals with a dbh of 1.0 to 1.9 in.
Seedlings:	Individuals with a dbh below 0.9 in.

Sampling technique:

Trees. In the three forest stands, the point-centred quarter method (Cottam and Curtis 1956) was employed. The location of points was the same as the quadrats for Stratum I. Since these stands have but a single dominant tree, 20 points per stand were considered an adequate sample. In the open parkland, the wide spacing of the trees made the point-centred quarter method impractical. Therefore, 20 equidistant circular plots, each 1/25 of an acre and located along compass lines were used to sample the trees. In stands on the slopes and the ridge-top, trees were counted in three or more 50 x 100 ft. plots located along a line perpendicular to the slope contour.

Saplings, Juveniles and Seedlings. In the forest stands and the parkland, the numbers of individuals in each of these categories were counted in at least 20 ten-foot radius plots per stand. The location of plots was the same as the quadrats for Stratum I. In the remaining non-forest stands, similar counts were made in 20 x 100 ft. contiguous plots.

In this study every rooted shoot was counted as an individual. In the case of *Picea mariana*, which predominantly reproduced by vegetative means, the count of 'seedlings' included individuals developed from seeds and individual vertical rooted stems that developed from layered branches. The role of arboreal regeneration was studied from two points of view: (1) their number, in order to evaluate community dynamics and (2) their coverage in Stratum III to determine their spatial relationships with other ground vegetation.

The stratification of vegetation was based on growth-forms and on heights of individuals above the ground. Predominant life-form in Strata I and II was chamaephytes, in Stratum III nanophanerophytes and in Stratum IV meso-, micro-, and nanophanerophytes. These strata, although composed *predominantly* of one life-form are not equivalent to synusiae. According to Dansereau (1957) a synusia is "a horizontal layer of definite depth in a stand of vegetation, including *only* plants of the *same* life-form . . ." (present author's italics).

In spite of the complex sampling procedures necessary in this study, it was possible in most cases to render the analytical data directly comparable within the established strata. Data from Strata I, II, III-A, and III-B are presented separately as estimated per cent foliage cover of each stratum. From the 3 forest stands data on Stratum III-C (comprising tall shrubs) are presented as estimated per cent crown cover from circular plots having a radius of 10 ft. In the parkland and other non-forest stands, however, data for Stratum III-C are given as per cent crown cover as determined from line intercept readings. Because of the application of different methods, Stratum III-C data from the forest stands are not directly comparable with similar data from the parkland and other non-forest stands. This situation is not critical, however, since tall shrubs were of minor importance in the forest stands. In Stratum IV, all data are presented in terms of number of individuals per acre.

The growth characteristics of trees were analysed in 3 stands. Measurements were made of the height, dbh and age of 10 to 13 randomly located trees in 2 forest stands and in the parkland. Tree heights were obtained by triangulation; basal areas were measured directly and ages were determined from cores obtained with an increment borer.

At each stand, slopes were determined with an Abney level, soils were hand textured in the field and exposures were determined with a hand compass.

Results

Picea mariana was the most important tree species in the mesic forests (Table 1). *Larix laricina*, although present in the wet and the wet-mesic stands, was absent in relatively drier areas. *Betula papyrifera* was of minor significance, and recorded only in the wet-mesic stand. In the well-drained, dry-mesic parkland, *Picea glauca* was the most important species while *Picea mariana* was an insignificant component of the tree layer.

The ages of the oldest trees sampled in *Picea mariana* stands (#121 and #120)

Table 1. Composition of arboreal species in terms of numbers per acre, in *Picea mariana* forests and *Picea glauca* parkland at Small Tree Lake. Trees were sampled by point-centred quarter method (20 points) and saplings, juveniles, and seedlings by a total of 20 10-ft. radius circular plots. P = present in the stand but not recorded in the sampling.

		FORESTS			PARKLAND
STAND NOS. PHYSIOGRAPHIC POSITION		126 Wet	121 Wet-Mesic	120 Mesic	124 Dry-Mesic
Trees (dbh 3.0 in. or more)	*Betula papyrifera*	0	7	0	0
	Larix laricina	2	11	0	0
	Picea glauca	0	0	0	47
	Picea mariana	170	263	275	1
	Total	172	281	275	48
Saplings (dbh 2.0 — 2.9 in.)	*Betula papyrifera*	0	0	0	0
	Larix laricina	0	0	0	0
	Picea glauca	0	0	0	7
	Picea mariana	277	360	291	0
	Total	277	360	291	7
Juveniles (dbh 1.0 — 1.9 in.)	*Betula papyrifera*	0	14	0	0
	Larix laricina	0	0	0	0
	Picea glauca	0	0	0	0
	Picea mariana	471	977	381	0
	Total	471	991	381	0
Seedlings (dbh below 0.9 in.)	*Betula papyrifera*	0	208	0	0
	Larix laricina	0	131	0	0
	Picea glauca	0	P	0	298
	Picea mariana	1372	7983	4290	14
	Total	1372	8322	4290	312
Total regeneration all size classes		2120	9673	4962	319

and *Picea glauca* parkland (#124) were 193, 189, and 193 years, respectively. Although no evidence of recent fire on the island was observed, similar age of forest stands on wet-mesic, mesic, and dry-mesic sites suggests contemporary initiation of the forest stands, possibly following a destruction of the previous vegetation by fire.

Among the 3 forest stands and the parkland, the stands in extremely moist and dry-mesic conditions had a lower density than those in intermediate conditions (Fig. 8). The wet and dry-mesic stands had, respectively, 172 and 48 trees per acre, while in the wet-mesic and mesic stands the number was, respectively, 281 and 275. Although the average basal area per tree did not differ appreciably among the wet-, wet-mesic, and mesic stands, the trees were relatively much larger in the dry-mesic stand. Tree dominance (basal area per acre) in the forest stands and parkland has a trend similar to that of stand density (Fig. 8), i.e. more under the intermediate conditions than under those of extreme moisture.

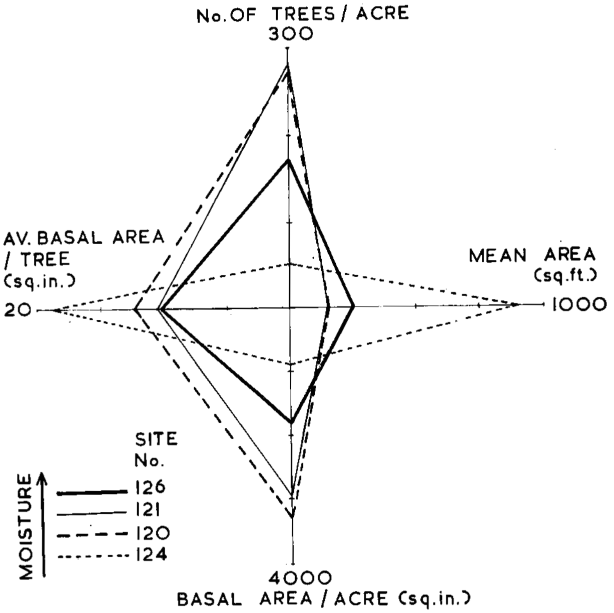


Fig. 8. Polygraph showing stand density and dominance, size and dispersion of trees in the three forest stands and the parkland.

Maximum height recorded in the wet-mesic, mesic, and dry-mesic habitats was 22.5, 35.0, and 37.0 ft., respectively, and maximum dbh was 5.7, 8.5, and 11.5 in., respectively (Fig. 9), indicating improved growth with better drainage and related topographic conditions. Age-height and age-dbh curves of *Picea mariana* tend to level earlier in the wet-mesic than in the mesic site (Fig. 9). However, deceleration in height- and girth-growth of *Picea glauca* on the dry-mesic site appears at a later age than in *Picea mariana* on the mesic site (Fig. 9). The growth of *Picea glauca* trees at this part of the ecotone is comparable to those growing in other parts, i.e. solifluction slopes (Drew and Shanks 1965), and on eskers at the south end as well as in ravine habitat at the north end of Ennadai Lake (Larsen 1965). *Picea mariana* trees in the wet stand were straggling and with deformed tops. The site is low-lying where a fair amount of snow possibly accumulates. In the wet site, the occurrence of slow growing, deformed trees with whipped tops was attributed to cold, desiccating winter winds and to the late melting of snow in the low-lying area and consequent shorter growing season. The size of *Picea mariana* trees attained in the study area is similar to that attained at the Ennadai Lake area (Larsen 1965). In general, *Picea glauca* grew much better than *Picea mariana* and the latter grew more vigorously in the mesic than in the wet-mesic and wet sites (Fig. 9).

Frequency distribution of trees in different dbh classes exhibits a significant feature (Table 2). In the stands dominated by *Picea mariana*, 77 to 90 per cent of the trees were in the 3 in. diameter class; the per cent frequency decreased sharply with an increase in size class and the maximum size was in the 6 in. class. However, in the *Picea glauca* parkland only about 50 per cent of the trees were in the 3 in. class and the frequency of trees decreased gradually with an increase in the diameter. An appreciable proportion of trees in the parkland were more

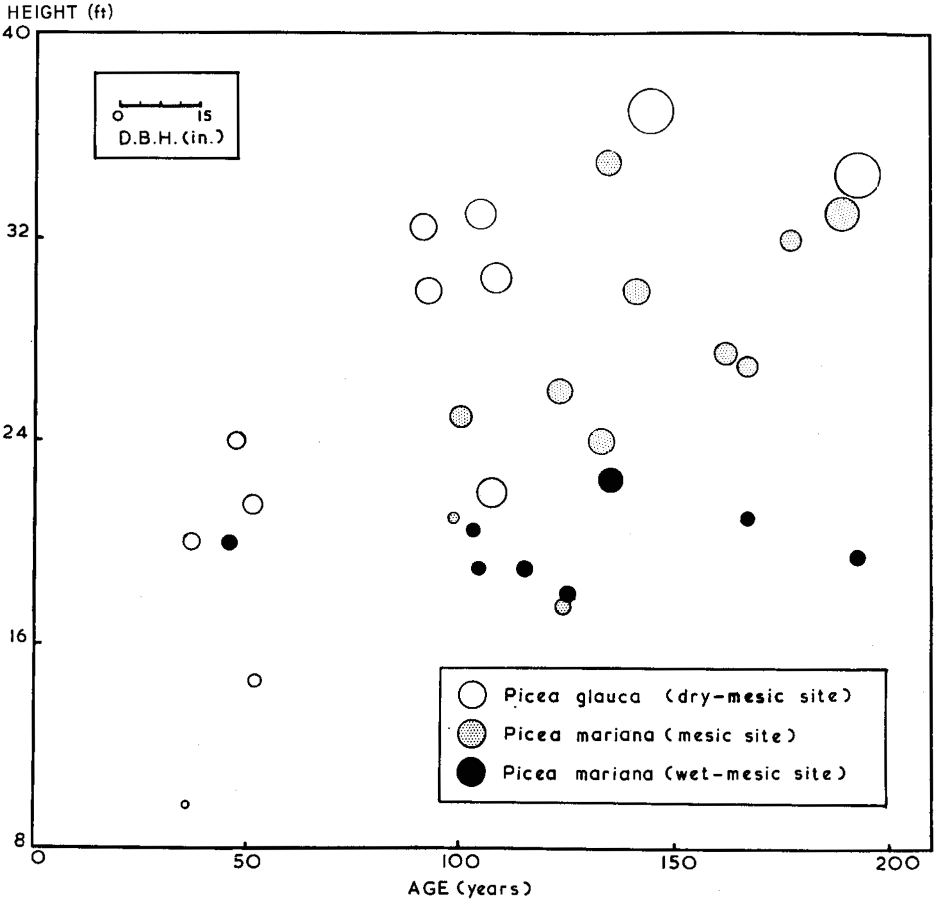


Fig. 9. Scatter diagram showing age-height-dbh relationships of the trees sampled in the forest stands and the parkland. Size of circles is proportional to the dbh.

Table 2. Relative per cent distribution of trees in different size-classes (dbh in.) in the three forest stands and the parkland.

SITE NO.	MOISTURE	DOMINANT TREE	DIAMETER AT BREAST HEIGHT (IN.) 3.0 — 3.9	4.0 — 4.9	5.0 — 5.9	6.0 — 6.9	12.0 — 12.9
126	Wet	*Picea mariana*	90	8	1	1	0
121	Wet-Mesic	*Picea mariana*	90	5	5	0	0
120	Mesic	*Picea mariana*	78	14	6	2	0
124	Dry-Mesic	*Picea glauca*	45	24	13	13	3

than 3 in. in diameter with a maximum in the 12 in. class. Differences in the pattern of the size-class distribution of trees in *Picea mariana* forests and in *Picea glauca* parkland (Table 2) could be due to differences in the microenvironment of forests and parkland or to the predominant mode of reproduction of the two species. Unfavourable conditions in these forests may limit tree growth and result in a stand which is even-size but not necessarily even-age, or the trees in the forests may have originated simultaneously by seedlings or layering after the original canopy was destroyed; evidence is more in the favour of environmental limitations (Fig. 9). The well-drained dry-mesic parkland is uneven-age (Fig. 9) and new individuals continue to establish whenever good seed years coincide with conditions favourable to seedling establishment.

Trees were absent on the ridge top and tree density on the south-facing slope was about nine times that on the west-facing slope (Table 3). A few saplings were present on the westerly slope. On the west- as well as the south-facing slope, 87 tree seedlings per acre were recorded, while only a few seedlings occurred on the ridge top.

Best regeneration of the arboreal vegetation was recorded in the wet-mesic areas (Table 1). The total number of seedlings in the wet-mesic stand was six times that in the mesic stand and three times that in the wet stand. A few *Betula papyrifera* and *Larix laricina* seedlings were present in the wet-mesic forest only. Compared to the seedlings in the forest stands, the number in the dry-mesic parkland was considerably small and was comprised principally of *Picea glauca*. No juveniles were recorded in the parkland. However, in the wet, wet-mesic, and mesic stands, the number of juveniles per acre was 471, 991 and 381, respectively. Sapling density in the wet, wet-mesic, and mesic *Picea mariana* forests was, respectively, 277, 360, and 291 per acre, but in the parkland it was only 7 (Table 1).

Table 3. Density and dominance of arboreal species on non-forest sites based on samples employing 50 x 100 ft. plots for trees and 20 x 100 ft. plots for arboreal regeneration. (T: ridge-top; N,E,W, and S: North-, East-, West-, and South-facing slopes)

		SPECIES	S	W	T	E	N
No. of samples			4	3	26	3	3
Trees	No./acre	*Picea glauca*	26	3	0	0	0
	Basal area/acre (sq. in.)	*Picea glauca*	1054	29	0	0	0
	Av. basal area/tree (sq. in.)	*Picea glauca*	40	10	0	0	0
Saplings	No./acre	*Picea glauca*	0	7	0	0	0
Seedlings	No./acre	*Picea glauca*	87	65	9	0	0
		Picea mariana	0	22	0	0	0
		Total	87	87	0	0	0

Betula glandulosa was a more important component of the *Picea glauca* parkland than of the *Picea mariana* forests, occupying 28 per cent of the ground cover in Stratum III. In the wet, wet-mesic, and mesic forests, *Betula glandulosa* had, respectively, 7, 173, and 179 clumps per acre, an average of 2, 6, and 8 shoots per clump. *Alnus crispa*, the other tall shrub in forest stands, occurred only in the wet-mesic forests and had 28 clumps per acre, an average of 4 shoots per clump and 123 rooted shoots per acre. *Betula glandulosa* thickets were equally dense at different sites but were taller on the south-, west- and east-facing slopes than in the *Picea glauca* parkland and on the level ridge top (Table 4).

Other notable species in Stratum III included *Picea mariana* seedlings, especially in the wet-mesic stand where they contributed significantly to the crown cover of the Stratum (Table 5); as pointed out earlier, the density of *Picea mariana* seedlings was also highest in the wet-mesic areas (Table 1). The total foliage cover recorded in Stratum III-A (comprising tall herbs and small shrubs) was very small and contributed by a total of 15 species (Table 5). Of these only 2 species, *Ledum groenlandicum* and *Ledum decumbens*, were recorded in all the forest stands and the parkland. On the slopes and ridge-top both *Ledum groenlandicum* and *Calamagrostis* spp. occurred in all 5 stands and *Ledum decumbens and Poa glauca* were recorded in 4 stands. A deviation from the general pattern of low cover of Stratum III-A was recorded on the east-facing slope where *Ledum groenlandicum* contributed significantly to the high total cover; a large amount of *Ledum groenlandicum* thrived under *Betula glandulosa* thickets which also were relatively more predominant on the east-facing slope (Table 4).

Table 4. Per cent cover (line intercept), per cent canopy (foliage density), and average height of *Betula glandulosa* in *Picea glauca* parkland (PRK), ridge-top (T), north-, east-, west-, and south-facing slopes (N,E,W, and S.)

SITE	PRK.	S	W	T	E	N
Moisture	Dry - Mesic	Dry	Dry	Dry	Dry	Dry
Per cent slope	level	10 — 16	15 — 18	level	22	10 — 18
Number of 100 ft. x 0.5 in. lines employed in sampling	20	4	3	26	3	3
Per cent cover of *Betula glandulosa*	28.5	24.9	8.4	24.2	33.7	0
Per cent canopy of *Betula glandulosa* thickets	60.0	60.0	70.0	70.0	70.0	0
Average ht. (in.) of *Betula glandulosa* thickets	30.0	48.0	48.0	36.0	60.0	0

In Stratum II, that comprised only 5 species of low herbs and decumbent shrubs, *Empetrum nigrum* var. *hermaphroditum* and *Vaccinium vitis-idaea* var. *minus* were an important component of the forest stands as well as the parkland. Both *Empetrum* and *Vaccinium* tended to increase towards the drier part of the moisture gradient (Table 5), and were the main contributors to the ground vegetation on all slopes as well as on the ridge top. *Rubus chamaemorus* was more important in the moister areas and *Carex drummondiana*, contributing a small cover, occurred on 4 slopes.

Among the various strata of the ground vegetation of forest stands as well as parkland, the cryptogamic component comprising Stratum I had the highest ground cover, ranging from 58 to 68 per cent (Table 5). The cover of Stratum I

Table 5. Comparison of forest and non-forest stands on basis of per cent cover of components of various strata in ground vegetation as sampled by 1-m² quadrats (N, E, W and S: north-, east-, west- and south-facing slopes; T: ridge-top; L: level; W: wet; WM: wet-mesic; M: mesic; DM: dry-mesic; D: dry; P: present in the stand but not recorded in the sample).

				PER CENT COVER					
		FOREST STANDS				NON-FOREST STANDS			
Site No.	126	121	120	124	125	127	123	128	122
Per cent slope	0–3	0–3	0–3	0–3	10–16	15–18	0–3	22	10–18
Exposure	L	L	L	L	S	W	LT	E	N
Moisture class	W	WM	M	DM	D	D	D	D	D
No. of quadrats	20	20	20	20	26	40	30	45	30
Stratum I (Cryptogamic)									
A. Lichens:									
Cladonia spp.	8.0	7.7	23.4	19.6	10.2	7.9	17.5	2.9	10.8
Cetraria islandica	1.5	0	0.6	0.7	0.4	0.7	1.5	0.1	1.5
Stereocaulon spp.	P	0	24.9	22.4	15.0	3.5	12.8	13.9	3.4
Crustose lichens covering rocks	0.1	0	0.2	0.8	0	4.6	0.1	0	0
Cladonia amauroeraea	0.4	0	0	0	0	0.4	0.1	0.5	1.2
Cladonia chlorophaea	1.1	0	0	0	0	0	0	0	0
Icmadophila ericitorum	0.1	0	0	0	0	0	0	0	0
Peltigera aphthosa	0	1.6	P	0	0.2	0.1	P	0.4	0
Nephroma arcticum	0	P	0	0	0	0	0	0	0
Total	11.2	9.3	49.1	43.5	25.8	17.2	32.0	17.8	16.9
B. Musci and Liverworts									
Ptilidium ciliare	11.6	0.1	13.2	0.3	0.3	1.1	1.5	1.1	0.1
Polytrichum spp.	2.4	2.5	1.0	13.8	13.5	29.2	25.6	6.3	8.6
Pleurozium schreberi	14.9	53.5	1.9	2.5	4.9	P	0	P	0
Rhytidium rugosum	0.1	0.2	0	0	1.8	0.3	0.3	4.3	0
Dicranum spp.	1.2	0	0	0.1	1.3	0.2	0.1	0.6	0
Sphagnum recurvum	0.4	1.5	0	0	0	0	0	0	0
Sphagnum fuscum	15.3	0	0	0	0	0	0	0	0
Mnium andrewsianum	0.7	0	0	0	0	0	0	0	0
Pohilia nutans	0	0	0	0	P	0	0.3	0	0
Hypnum crista-castrensis	0	0	0	0	0.2	P	0	0	0
Rhacomitrium canescens	0	0	0	0	0	0	0	0.1	0.1
Unknown moss	0	0.5	0	0	0	0	0	0	P
Total	46.6	58.3	16.1	16.7	22.0	30.8	27.8	12.4	8.8
Total Strata IA and IB	57.8	67.6	65.2	60.2	47.8	48.0	59.8	30.2	25.7
Stratum II (av. ht. of plants 4 in. above Stratum I; low herbs and procumbent shrubs).									
Empetrum nigrum var. *hermaphroditum*	0.3	1.0	1.8	12.2	16.7	19.3	5.4	13.3	10.4
Vaccinium vitis-idaea var. *minus*	4.5	7.9	13.1	7.7	12.9	11.9	5.8	18.7	9.9
Rubus chamaemorus	4.7	1.4	P	0	0	0	0	0	0.1
Oxycoccus microcarpus	0.3	0.1	0	0	0	0	0	0	0
Lycopodium annotinum	0	P	0	0	0	0	0	0	0
Carex drummondiana	0	0	0	0	0	0.3	P	1.0	0.1
Carex sp.	0	0	0	0	0	0	0.1	0	0.1
Saxifraga tricuspidata	0	0	0	0	0	0	0	0.2	0
Total Stratum II	9.8	10.4	14.9	19.9	29.6	31.5	11.3	33.2	20.6

Stratum III

A. (av. ht. of plants 4–18 in. above Stratum I; tall herbs and small shrubs).

Ledum groenlandicum	5.6	4.1	1.1	0.5	1.0	0.7	0.4	11.9	P
Ledum decumbens	0.1	0.4	0.1	0.1	0	0.3	0.1	0.5	0.9
Vaccinium uliginosum	0.5	1.6	0.1	0	0	0.2	0.1	0	1.7
Andromeda polifolia	0.5	0	0	0	0	0	0	0	0.5
Chamaedaphne calyculata	0.2	0	0	0	0	0	0	0	0
Kalmia polifolia var. *microphylla*	0.1	0	0	0	0	0	0	0	0
Calamagrostis canadense	0	P	0	P	P	0.2	0.1	0.2	0.1
Geocaulon lividum	0	P	P	0	0.3	0	0	0	0
Agrostis scabra	0	0.4	P	0	0	0	0	0	0
Equisetum sylvaticum	0	0.2	0	0	0	0	0	0	0
Epilobium angustifolium	0	P	0	0	0	0	0	0	0
Poa glauca	0	0	0	0	0	0.1	0.1	P	0.1
Luzula confusa	0	0	0	0	0	0	0.1	0	0.1
Carex sp.	0	0	0	0	0	0	0	0	P
Festuca sp.	0	0	0	0	0	0	0	0	P
Total	7.0	6.7	1.3	0.6	1.3	1.5	0.9	12.6	3.4

B. (av. ht. of plants 18–36 in. above Stratum I; tall shrubs and arboreal seedlings).

Picea mariana	0.3	9.7	4.1	0	0	0	0	0	0
Alnus crispa	0	0.3	0	0	0	0	0	0	0
Larix laricina	0	0.3	0	0	0	0	0	0	0
Betula glandulosa	0	0.2	0	0	0	0	0	0	0
Picea glauca	0	0	0	0.1	0.2	0.1	0	0	0
Total	0.3	10.5	4.1	0.1	0.2	0.1	0	0	0
Total Strata IIIA, and IIIB	7.3	17.2	5.4	0.7	1.5	1.6	0.9	12.6	3.4
Total Strata I, II, and III	74.9	95.2	85.5	80.8	78.9	81.1	72.0	76.0	49.7

was considerably more than that of Stratum II, the cover of which was more than that of Stratum III. The total cryptogam ground cover did not differ appreciably between the forests and the parkland. However, the importance of lichens, and of *Musci* and Liverworts differed in various segments of the environmental gradient. The ground cover by *Musci* and Liverworts in the wet forest stand was 47 per cent and in the wet-mesic 58 per cent; in the mesic and dry-mesic stands it was only 16 and 17 per cent, respectively. Nevertheless, the reverse was true in the case of lichens, that is, the wet, wet-mesic, mesic, and dry-mesic stands had a cover of 11, 9, 49, and 44 per cent, respectively. Of the *Musci* and Liverworts, *Polytrichum* spp., *Pleurozium schreberi,* and *Ptilidium ciliare* occurred in all 4 arboreal stands. In the wet areas, *Sphagnum* spp. were the principal cryptogamic species and other important moss-components were *Pleurozium schreberi* and *Ptilidium ciliare.* In the wet-mesic, mesic, and dry-mesic areas, *Pleurozium schreberi, Ptilidium ciliare,* and *Polytrichum* spp., respectively, were the most important mosses. Amongst lichens recorded in all the 4 arboreal stands, *Cladonia* spp. increased towards the drier part of the moisture gradient. Similarly *Stereocaulon* spp. also became more important in mesic and dry-mesic stands. On slopes and ridge-top, *Polytrichum* spp., *Ptilidium ciliare, Cladonia* spp., *Cetraria* spp., and *Stereocaulon* spp. were not only present on all the 5 sites, but also contributed significantly to the ground cover. *Pleurozium schreberi* and *Cladonia amaurocraea* were the other important components of the cryptogamic vegetation and occurred in 4 of the 5 stands sampled on the slopes and the ridge-top.

Relative importance of various strata on the slopes and the ridge-top had a pattern similar to that in arboreal stands, i.e. the cryptogamic (Stratum I) being the most important component of the ground vegetation and Stratum III the least (Table 5).

Numerous instances of *Empetrum nigrum* var. *hermaphroditum* extending on bare ground were observed on the exposed slopes. A polygonal shape of bare areas as well as of *Empetrum* patches suggests the colonization of these bare areas by this species (Figs. 3 and 10). However, existence of sharp boundaries between *Empetrum* and the surrounding cryptogamic vegetation indicates definite limitation to the extension of the former to the latter. The central parts of *Empetrum* patches die, presumably from old-age (or autotoxicity?), and this area is gradually colonized by cryptogamic vegetation and by a few individuals of *Vaccinium vitis-idaea* var. *minus* (Figs. 10 and 11). Occasionally, small stems of *Betula glandulosa* were also observed in the dead part of an *Empetrum* patch. Addition of organic matter and increase in moss-component of the microcommunity, both of which have a high water holding capacity, presumably results in an increase in the moisture content of the upper layer of soil. With insulation provided by the carpet of mosses, local lenses of frost are possibly formed during winter and persist during early summer. As snow cover is thin or absent on exposed slopes, cryopedogenic processes during severe winters appear to cause degeneration of vegetation and result in the formation of polygonal bare areas resembling a frost scar (Fig. 3). According to Larsen (1965) similar frost action apparently leads to repeated disturbance and destruction of tussock muskeg community at Ennadai. Possible cyclic changes of vegetation are shown in Fig. 12.

At an altitude of about 3,500 ft. on the Cairngorms in Scotland, Watt (1947) described a somewhat similar succession of vegetation, where spatial and temporal phases are characterized by extension of *Empetrum* towards the lee side, followed by *Vaccinium* spp., *Cladonia*, and *Rhacomitrium*, and finally by *Rhacomitrium* only. The *Rhacomitrium* phase is eventually eroded by wind and mineral soil once again laid bare for recolonization.

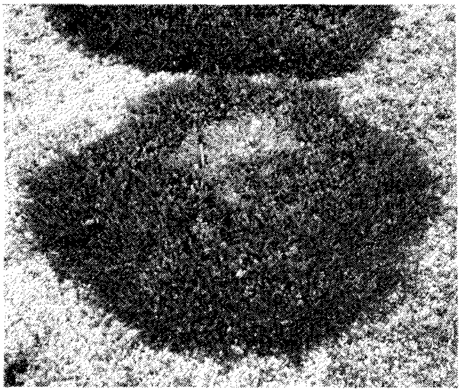
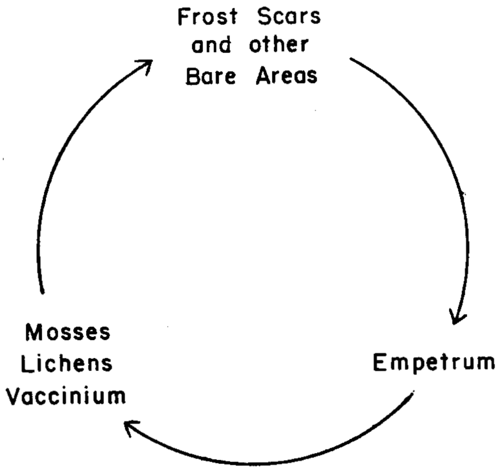


Fig. 10. Polygonal patches of *Empetrum nigrum* var. hermaphroditum. Lichens are appearing in the older portion of *Empetrum* which is dying.

Fig. 11. A closeup of *Empetrum* patch showing a large central portion now occupied by lichens and mosses.

Fig. 12. Diagrammatic scheme of possible cyclic changes of vegetation on exposed slopes of the study area.



Discussion

In the northern hemisphere, the transition from closed canopy forest zone to treeless tundra is generally attributed to a gradual transition in climate. In the forest-tundra ecotone, the pattern of distribution of arboreal and non-arboreal vegetation varies in different localities and may be determined by several factors including topography, edaphic condition, microclimate, and the ecological amplitude of species. In Newfoundland and Labrador, Hustich and Patterson (1945) classified the forest border on a physiognomic basis, while investigations by Marr (1948) on the east coast of Hudson Bay (Fig. 1) indicate that edaphic and not climatic conditions determine the distribution of trees. According to Ritchie (1960) physiography determines the vegetation patterns in the forest-tundra zone of northern Manitoba (Fig. 1); whereas some of the treeless heath is the result of felling and fire, in certain other areas tundra heath is a stable type. At Ennadai Lake area, N.W.T. (Fig. 1), where topography and geology are generally uniform, a gradient in the structure of plant communities reflects the known climatic gradients; within a span of less than 50 miles, black spruce forests lose ground to treeless vegetation (Larsen 1965). On the slope north of Hornby Bay, Great Bear Lake (Fig. 1), the timberline is determined by edaphic rather than climatic factors (Lindsey 1952). In the present study area the influence of various habitats on growth, density and regeneration of arboreal species as well as on the floristic composition and structure of associated vegetation was analysed.

The stand density (expressed as number of trees per acre) varied along the moisture gradient, being considerably higher under intermediate than under extreme situations. The data show that *Picea mariana* dominated the more mesic and *Picea glauca* the drier habitat (Table 1). Both *Larix laricina* and *Betula papyrifera* were less significant constituents of the tree canopy, the former occurring in the wet and wet-mesic sites and the latter in the wet-mesic site only.

A comparison of tree canopy and regeneration (various size-classes) shows that the arboreal composition of the present forest communities and the parkland is stable. Lack of *Larix laricina* regeneration in the wet stand indicates uncertainty in the future status of the species. However, in the wet-mesic site, regeneration of both *Larix laricina* and *Betula papyrifera* appears sufficient to retain their present status. While *Larix laricina* reproduced by seeds, *Betula papyrifera* occurred in clumps that were possibly of vegetative origin. In the mesic site, lack of regeneration of any species other than *Picea mariana* indicates the stability of the pure *Picea mariana* stand in this habitat. In the *Picea glauca* parkland on the dry-mesic habitat, abundant regeneration of the same species shows that the arboreal component of the community is in equilibrium with present environment and that it is self-perpetuating. The spruce stands in the Upper Firth River Valley have also been reported to be in balance with the existing climate and are neither advancing nor retreating (Drew and Shanks 1965).

In all 4 arboreal stands, differences in the number of individuals in various regeneration size-classes decrease greatly with an increase in size (Table 1). The data also indicate that the wet-mesic conditions are most favourable for the regeneration of *Picea mariana* (Table 1). Profuse reproduction in *Picea mariana* stands was due to formation of layers; however, *Picea glauca* regenerated less abundantly by seeds. Under severe ecological conditions at the forest-tundra ecotone, some species perhaps survive owing to their ability to reproduce vegetatively.

Effect of microclimate and stand density on tree growth is evident from the age-height-dhb relationship of individuals sampled in 3 stands (Fig. 9). The scattergram indicates that *Picea glauca* grows most vigorously on the well drained dry-mesic site and *Picea mariana* on the mesic site. Although tree growth is poor in wet-mesic habitat, the best arboreal regeneration and high stand density was recorded under these conditions. Obviously factors favouring good regeneration do not appear to favour vigorous tree growth.

Distribution of arboreal vegetation on the slopes and the ridge top appears to be closely associated with insolation. The number of trees (*Picea glauca* only) on the warmer south-facing slope was higher than on the west-facing slope. Whereas trees on the west-facing slope were restricted to the bottom of the slope, individuals on the south-facing slope were observed near the top (Fig. 7). Arboreal regeneration was adequate on both west- and south-facing slopes. Presence of only a few *Picea glauca* seedlings and absence of juveniles and saplings on the ridge-top indicates favourable periods of climatic conditions enabling survival of seedlings. Trees were absent on the flat ridge top, and neither was there any evidence (dead logs and stumps) suggesting occurrence of trees in the past. Apparently, seedlings, when established, do not attain tree size and are possibly exterminated by strong winds and during unfavourable periods (cyclic?) of extreme climatic conditions. The distribution pattern of *Picea glauca* trees at Small Tree Lake is similar to that described by Drew and Shanks (1965) at the Upper Firth River Valley where the species extends about the lower two-thirds of the south-facing slope while the north-facing slope is treeless and occupied by upland tussock tundra.

Tall shrubs were insignificant components of the closed-canopy forests. However, the importance of *Betula glandulosa* increased in warmer and drier situations. In the *Picea glauca* parkland, slopes, and ridge-top, *Betula glandulosa* was a very important constituent of the woody vegetation (Fig. 5). Direction and inclination are two important factors affecting microclimate and thereby the vegetation on slopes in the northern latitudes. Among slopes of the same inclination but facing four cardinal directions, northerly and easterly slopes would be cooler than southerly and westerly slopes. Studies of Kaempfert (as cited in Geiger 1957) at 49°45′N. latitude suggest that with an increase in inclination, resultant reception of maximum amount of insolation on the east-facing slope is larger than on other slopes. High per cent cover of *Betula glandulosa* on the east-facing slope could be attributed to the steepness of the slope (Table 4 and Fig. 5). The quantity of *Betula glandulosa* in the *Picea glauca* parkland, on the ridge-top and on the south-facing slope, did not differ appreciably. On the cool north-facing slope, however, this shrub was notably absent. A similar observation has been recorded by Larsen (1965) in slope communities on the eskers at Ennadai area. While foliage density of *Betula glandulosa* thickets at different sites at Small Tree Lake did not vary appreciably, plants growing on the slopes were taller than those growing on the level terrain of ridge-top and the parkland.

Although a great diversity of habitats was sampled in the area under investigation, the data indicate that only a few species were restricted either to the forested or to the treeless areas (Table 5 and Fig. 13). A fairly large number of species exhibited a wide ecological amplitude and occurred in the forest stands as well as on the treeless slopes; these species include *Ptilidium ciliare*, *Polytrichum* spp., *Cetraria* spp., *Stereocaulon* spp., *Cladonia* spp., *Empetrum nigrum* var. *hermaphroditum*, *Vaccinium vitis-idaea*, var. *minus*, *Calamagrostis* spp., *Ledum groenlandicum*, *Ledum decumbens*, and *Vaccinium uliginosum*. Among species with narrow tolerance, *Sphagnum* spp., *Icmadophila ericetorum*, *Mnium andrewsianum*, *Lycopodium annotinum*, *Oxycoccus microcarpus*, *Equisetum sylvaticum*, *Kalmia polifolia* var. *microphylla*, and *Chamaedaphne calyculata* were restricted to forests and *Hypnum crista-castrensis*, *Rhacomitrium canescens*, *Carex drummondiana*, *Saxifraga tricuspidata*, *Poa glauca*, *Festuca* spp., and *Luzula confusa* were recorded only on the slopes. Cooler temperature conditions in the low-lying forests and northerly slopes provided equally favourable conditions for some widely distributed species including *Andromeda polifolia*, *Vaccinium uliginosum*, and *Rubus chamaemorus*. Both phytosociologically and physiognomically, *Picea glauca* parkland occupies a position between the closed-canopy forests and the non-forested sites.

Some of the species with broad tolerance were more important in the forests, while others were relatively more prominent on the slopes; still others attained their maximum importance in the intermediate situations (Fig. 13). Complex behaviour of some species indicates that their distribution was governed by some less obvious factors or interaction of several factors.

Floristic Affinities of Arboreal and Treeless Stands at Small Tree Lake

The plants sampled in various stands at the Small Tree Lake area were assigned to one of the four categories describing their principal areas of distribution (Table 6). These categories are similar to those described by Raup (1947) in his analysis of the flora at Brintnell Lake, N.W.T. Most vascular species were classified according to Raup (1947), lichens according to Hale (personal communication) and mosses according to Crum (personal communication). In each of the nine stands, the percentage of forest and arctic elements was calculated and stands ordinated along gradients of moisture (wet to dry) and vegetation (forests to treeless northerly slopes).

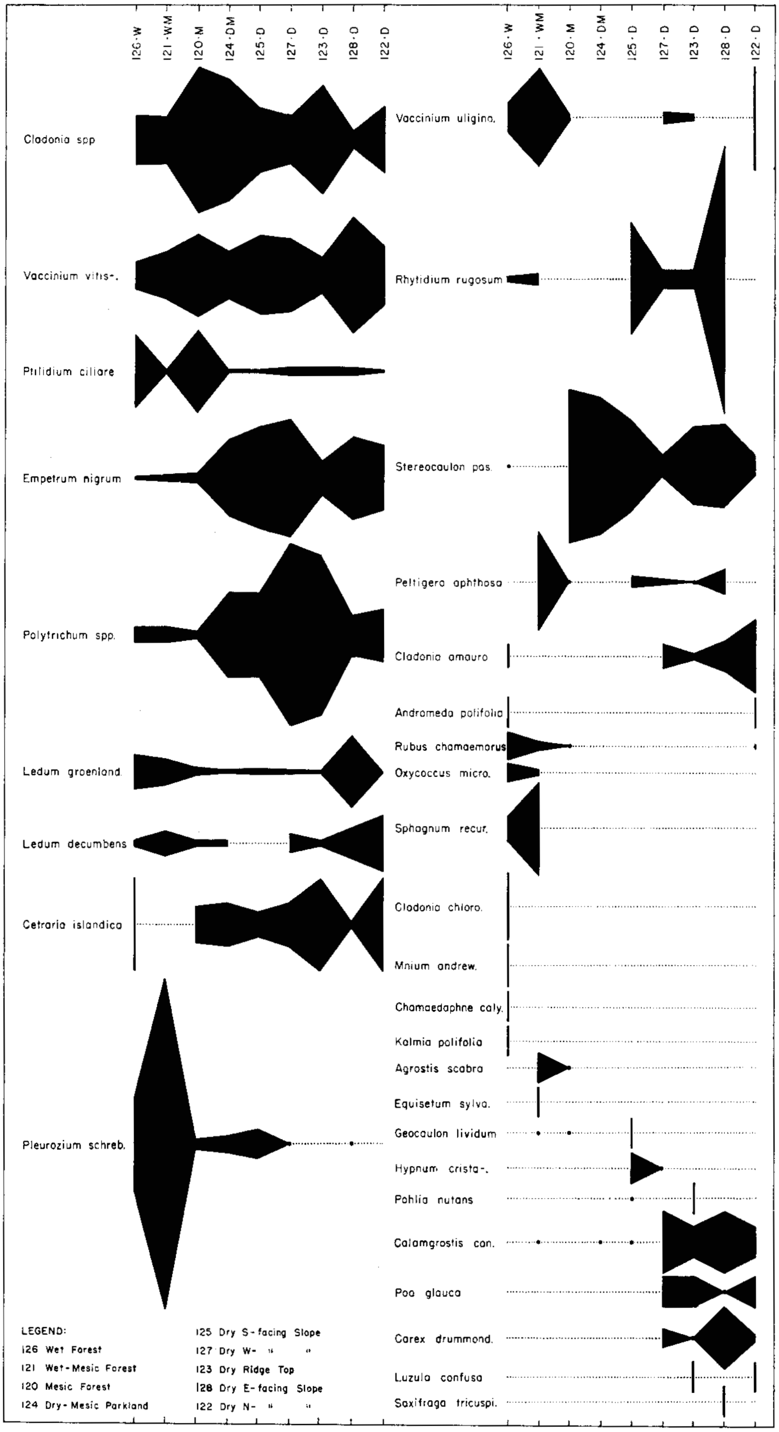


Fig. 13. Per cent cover of some recorded plants. Species contributing small cover have been drawn in an exaggerated scale.

Table 6. Floristic affinities of Small Tree Lake (STL) as determined by the percentage of forest and arctic plants that occur in various forests and treeless stands.

STAND NUMBER	126 Forest	121 Forest	120 Forest	124 Parkland	125 S-slope	127 W-slope	123 Ridge-top	128 E-slope	132 N-slope	STL
Moisture class	W	WM	M	DM	D	D	D	D	D	
Total number of species	22	23	15	10	14	17	16	16	16	71
	PER CENT OF TOTAL NUMBER OF SPECIES RECORDED									
1. Wide-ranging forest species which:										
a) extend north of timber-line	40.9	43.5	40.0	40.0	50.0	35.3	37.5	37.5	25.0	
b) whose northern limit is at or near timber-line	18.2	34.8	20.0	10.0	21.4	11.8	0	6.3	6.3	
c) unknown[1]	4.5	4.3	6.7	10.0	7.1	5.9	6.3	6.3	6.3	
Total	63.6	82.6	66.7	60.0	78.5	53.0	43.8	50.1	37.6	
2. Wide ranging arctic species which:										
a) extend far south of arctic timber-line	18.2	4.3	20.0	30.0	21.4	29.4	31.3	37.5	31.3	
b) whose southern limit is at or near timber-line	4.5	8.6	6.7	10.0	0	11.8	18.8	12.5	18.8	
Total	22.7	12.9	26.7	40.0	21.4	41.2	50.1	50.0	50.1	
3. Timber-line species	9.0	4.3	6.7	0	0	5.9	6.3	0	12.5	
4. Cosmopolitan species	4.5	0	0	0	0	0	0	0	0	0

[1]Wide-ranging forest species whose exact limits could not be ascertained.

The percentage of forest species decreased from arboreal to treeless stands and that of arctic species increased (Table 6). The maximum proportion of forest species (83 per cent) was recorded in the wet-mesic *Picea mariana* forest where the number of arctic plants was the minimum (13 per cent). The flora on the northerly slope contained the maximum amount of arctic species (50 per cent) and the least amount of forest species (38 per cent). The *Picea glauca* parkland occupied a somewhat intermediate position, having 60 per cent of forest and 40 per cent of arctic plants. All the 16 species recorded in the parkland were present in the *Picea mariana* forests as well as on the slopes and the ridge-top. The percentage of timber-line species was very small in all the stands. A relatively higher proportion of forest plants and a lower proportion of arctic plants in the Small Tree Lake flora is probably due to the location of the study area in the southern part of the forest-tundra ecotone.

Data and field observations show that the boundaries between forests and treeless stands at Small Tree Lake are semi-permanent and that the distribution of various vegetation types is determined by topography. Physiognomically as well as floristically, low-lying areas along the lake shore are predominated by forest vegetation while exposed northerly and easterly slopes are treeless with an appreciable proportion of arctic plants.

List of species recorded as present at Small Tree Lake, N.W.T.

LICHENS

Cetraria islandica (L.) Ach.
Cetraria nivalis (L.) Ach.
Cladonia alpestris (L.) Web.
Cladonia amaurocraea (Flk.) Schaer.
Cladonia cornuta (L.) Schaer.
Cladonia chlorophaea (Flk.) Spreng.
Cladonia rangiferina (L.) Web.
Icmadophila ericetorum (L.) Zahlbr.
Nephroma arcticum (L.) Torss.
Peltigera aphthosa (L.) Willd.
Stereocaulon paschale (L.) Hoffm.
Stereocaulon tomentosum Fr.

MUSCI

Cladopodiella fluitans (Nees) Joerg.
Dicranum bergeri Bland.
Dicranum elongatum Schleich.
Dicranum fuscescens Turn.
Dicranum rugosum Brid.
Dicranum scoparium Hedw.
Dicranum strictum Schleich.
Hypnum crista-castrensis Hedw.
Hypnum lindbergii Mitt.
Mnium andrewsianum Steere
Pleurozium schreberi (Brid.) Mitt.
Pohlia nutans (Hedw.) Lindb.
Polytrichum commune Hedw.
Polytrichum juniperinum Hedw. var. alpestre BSG
Polytrichum piliferum Hedw.
Rhacomitrium canescens (Hedw.) Brid.
Rhytidium rugosum (Hedw.) Kindb.
Sphagnum fuscum (Schimp.) H. Klinggr.
Sphagnum recuruum Beauv.

HEPATICAE

Ptilidium ciliare (L.) Nebs.

PTERIDOPHYTA

Equisetum sylvaticum L.
Lycopodium annotinum L.
Lycopodium complanatum L.

GYMNOSPERMAE

Larix laricina (Du Roi) K. Koch
Picea glauca (Moench) Voss
Picea mariana (Mill.) BSP

MONOCOTYLEDONEAE

Agrostis scabra Willd.
Calamagrostis canadensis var. macouniana (Vasey) Stebbins
Calamagrostis canadensis var. scabra (Presl.) Hitchc.
Carex aquatilis Wahlenb.
Carex bicolor Bellardi
Carex drummondiana Dewey
Carex interior Bailey
Carex media R. Br.
Eriophorum chamissonis C.A. Mey.
Juncus arcticus Willd.
Luzula confusa Lindebl.
Poa glauca Vahl

DICOTYLEDONEAE

Alnus crispa (Ait.) Pursh
Andromeda polifolia L.
Arctostaphylos uva-ursi (L.) Spreng.
Betula glandulosa Michx.
Betula papyrifera Marsh.
Chamaedaphne calyculata (L.) Moench
Empetrum nigrum var. hermaphroditum (Lange) Sorensen
Epilobium angustifolium L.
Geocaulon lividum (Richards.) Fern.
Kalmia polifolia Wang. var. microphylla (Hook.) Rehd.
Ledum groenlandicum Oeder

Ledum decumbens (Ait.) Lodd.
Loiseleuria procumbens (L.) Desv.
Oxycoccus microcarpus Turcz.
Potentilla palustris (L.) Scop.
Potentilla tridentata Ait.
Rubus chamaemorus L.
Salix planifolia Pursh
Saxifrage tricuspidata Rottb.
Vaccinium uliginosum L.
Vaccinium vitis-idaea L. var. minus Lodd.

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