VEGETATION AND ENVIRONMENT IN THE CENTRAL RESEARCH FOREST, OTTAWA GREENBELT

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ABSTRACT

The geology and geomorphology for the area are reviewed and terrain units, based on soils and geology, are proposed. A reconstruction is made of early vegetational history, influence of Indians, clearing and abandonment by European settlers, and other human influences--pasturing, ditching, fires, power line clearance, soil strip mining and sugar bush operations. The results of a vegetational survey and analysis of the forested, central plateau (Dolman Ridge) are presented. Principal component ordination, agglomerative classification, environmental models and gradient analyses are used to elucidate vegetation-environment relationships. Vegetational variation is judged to be influenced mainly by the several man-induced disturbances, and the open-pioneer forest/longtime-forested gradient is the most apparent variational trend in vegetation. The complex of disturbance factors is the main causative agent underlying the light gradient. The other most important direct factor is moisture regime, which is indirectly determined by topographic position and soil texture. Species distribution patterns are shown in relation to principal components of variation, to classifications of shrub-herb types and species groups, and to gradients of moisture (depth to groundwater) and light (canopy cover). Maps of terrain units, land use classes, and forest cover types are also presented.

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INTRODUCTION

The Central Research Forest (CRF) is a 950-acre[3] tract of open farmland, brushland and forest located in the Ottawa Greenbelt (Fig. 1). The area is being developed by the Forest Management Institute of the Canadian Forestry Service for such uses as forestry research, teaching and demonstration, and interpretive nature study (Salm unpublished)[4]. An important element of this development is the interpretation of the ecology of the native forests which occupy approximately one fifth of the total area. This report presents basic information and examines vegetation-environment relationships for the CRF.

Ecological surveys are often disadvantaged by their lack of environmental data and background information. The present study was not limited in this way because studies of the soils, geology, and hydrology preceded the vegetational work, and a considerable amount of information was available on the history of the area. The objectives of this report are (1) to describe and document the physical environment, history of occupation and abandonment, and forested vegetation at the CRF, and (2) to examine in some depth the relationships between the forested vegetation and selected physical factors of the environment.

GEOLOGY AND TERRAIN UNITS

Geological background

The CRF is located on the floor of the late Pleistocene and early Holocene basin of the Champlain Sea. Subsequent to the disappearance of the Wisconsin ice cover, marine submergence took place in the isostatically depressed Ottawa area. To the extent that subglacial and proglacial relief and attendant deposits disappeared under the Champlain Sea, these were modified by marine erosion and covered by marine deposits. Sandy and gravelly littoral deposits are found in abundance along the periphery of the Champlain Sea Basin and on portions of the relief that protruded from the sea. In the deeper segment of this basin, however, the presence of the marine environment is attested to mainly by the occurrence of up to 200 ft of gray-blue marine clay.

The landforms and deposits that are associated with the post-glacial marine submergence form a wedge of younger, nonglacial physical

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[3] The measurements given in this report are in the units in which they were originally taken. The basic conversion factors are as follows: 1 acre = 0.405 hectares, 1 mile = 1.609 kilometers, 1 foot = 0.305 meters, 1 inch = 2.54 centimeters.

[4] Salm, J. (1969) Progress report on the development of the Central Research Forest. Can. For. Serv., Ottawa. Intern. Rep. FMR-15. 30 p.

Fig. 1. Location of the Central Research Forest, Ottawa Greenbelt.

environment driven into erosive-glacial and depositional-glacial landscapes of this part of eastern Canada. The parent materials of the soils and the geological characteristics of the substratum on which its vegetation developed are different from the adjoining glacial landscapes.

Within the Champlain Sea Basin, a further distinction needs to be made between the central and the peripheral portions (Bik unpublished)[5]. Upon withdrawal of the Champlain Sea, the peripheral portions of the basin emerged as a landform association of clay plains alternating with littoral forms and deposits. The central and lowest portions, however, being the last to emerge during postglacial uplift, provided the natural location for the trunk streams of the subaerially developing drainage system; associations of deltaic and fluvial landforms are characteristic of this part of the basin. The establishment of fluvial channels and attendant channel-floor gradients in the deepest portion of the Champlain Sea Basin induced a locally substantial measure of erosion of the marine clay and of the superimposed deposits.

Some of the channels that were cut into the basin floor during its postglacial emergence were abandoned shortly after they were formed; lacustrine conditions were present in these channels for some time after abandonment. Upon further withdrawal of the Champlain Sea in response to continued isostatic uplift, wet terrestrial conditions replaced the lacustrine environment and induced the growth of peat bogs. The largest accumulations of peat known to occur in the area once covered by the Champlain Sea, such as the Alfred and Mer Bleue Bogs, are located within and confined to the channels that were cut into the lowest portion of the floor of the marine basin.

The locale of the CRF is considered to be representative of the lowest central portion of the Champlain Sea Basin.

Probable age of the landforms and deposits

All terrain units of the CRF are younger than *ca.* 10,000 years. The highest dated occurrence of Champlain Sea shore deposits in the Ottawa-Hull area is at the southeastern end of Meach Lake at *ca.* 557 ft elevation. Marine shells in this deposit were found to be 11,600 ± 150 radiocarbon years old (GSC 842, Lowdon and Blake 1970). The lowest and youngest dated shoreline deposit of the Champlain Sea in the Ottawa area is located to the northwest of Uplands Airport;

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[5] Bik, M.J.J. (1971) Superficial deposits, geomorphogenesis and edaphic geology of the Central Research Forest, Ramsayville, Ontario. Geol. Surv. Can. 100 p.

a whale bone from an elevation of *ca.* 320 ft was dated at 10,420 ± 150 radiocarbon years (GSC 454, Dyck *et al.* 1966). This location is *ca.* 70 ft higher and *ca.* 7 miles WSW of the highest deposits of marine clay in the CRF. As the lowest portion of the Champlain Sea Basin took somewhat longer to emerge from the sea and increments of deltaic and aeolian deposits were added to the top of the marine clay, an age estimate of *ca.* 10,000 years for the oldest landforms and soils of the CRF appears reasonable. The base of the peat that was deposited in the channels of the basin floor was dated for the Mer Bleue area at 7,650 ± 210 radiocarbon years (GSC 681, Mott and Camfield 1969), and at 8,220 ± 150 radiocarbon years in a channel belonging to the same system which was sampled just west of Ottawa (GSC 547, Lowdon *et al.* 1967). It would appear, therefore, that none of the landforms or superficial deposits of the CRF is younger than *ca.* 7,500 years, except areas where organic sediments are accumulating at the present time, bluff-foot fans which may still be receiving minor increments of sediment, and areas adjoining the present-day drainage lines.

Terrain units

The surficial-geological study of the CRF area prompted the definition of over 70 mapping units which, within narrowly defined limits, could be considered to present uniform segments of terrain (Bik, unpublished)[5]. For the purpose of this report, however, these were grouped into morphogenetically defined terrain units which are portrayed on Map 1. (NOTE: All maps referred to in this report are found in the envelope attached to the inside back cover.)

Within the area of the CRF, the depositional surface of the gray-blue marine clay was covered by sandy deltaic deposits. The oldest deltaic deposit (Unit I, Map 1) occupies the northern and higher portion of Dolman Ridge. It comprises 2-14 ft of generally poorly sorted, dominantly fine sands that do not contain carbonates. Pockets of gray-blue marine sand, up to 2 ft thick, and containing up to 8% of carbonates, occur locally between the deltaic sand and the marine clay. Vertical drainage through the deltaic sands is generally poor owing to the presence of thin laminae of silty clay at irregularly spaced intervals in the sand sequence.

A second lobe of buff deltaic deposits (Unit II, Map 1) was laid down south of the first lobe after up to 15 ft of marine clay had been removed by erosion. On the average somewhat coarser than the older lobe, it is also of more even thickness, ranging from *ca.* 4 ft in the north to *ca.* 15 ft in the south. At its base one commonly finds gray-blue marine sands which locally contain shell fragments and up to 8% of carbonates; these sands can be up to 8 ft thick. This younger deltaic deposit is also free of carbonates and contains stringers of coarse sand in its deeper horizons and therefore has better drainage at depth when compared with the older deltaic lobe; the upper horizons consist of fine and very fine sands which contain drainage-impeding clay laminae.

Both lobes of deltaic deposits are covered by a 1-5 ft layer of silty, very-fine-to-fine sand, which appears to be of aeolian rather than aquatic origin. The active pedogenic horizons were developed partly or wholly in this layer, except for small areas where organic deposits are accumulating or streams are active. The layer is rather well sorted, commonly well drained, and generally shows a slight decrease in average grain size from bottom to top.

Each deltaic lobe has its own distinctive topographic detail. The older, northern lobe owes its larger local relief to dissection which took place prior to the deposition of the second lobe; hummocks, up to 15 ft high and aligned along an easterly trend, dominate the local topography (Fig. 2). The younger, southern lobe is generally more level, its local relief does not exceed 5 ft, the surface relief has a NNE trend and consists of alternating rises and swales, and its surficial drainage lines are directed towards a central, longitudinal abandoned channel which separates the older from the younger deltaic lobe (Unit III, Map 1).

Generally speaking, both lobes are poorly drained; however, the hummocks and low ridges together with elongate areas adjoining the northern and southern bluffs of Dolman Ridge are well drained.

Borthwick Valley, adjoining Dolman Ridge to the south, and Black Creek Valley to its north, resulted from up to 50 ft of erosion into the marine clay. Bluffs, up to 30 ft high, consisting of marine clay and covered by a thin veneer of colluviated sand, separate the deltaic lobes from the valley floors (Unit IV, Map 1). The bluff faces, with slope angles of 17°-30°, provide the only excessively drained environment in the CRF.

Each valley contains a thin, discontinuous mantle of coarser-textured deposits which overlie the eroded marine clay. This mantle is thinnest in Black Creek Valley, where in *ca.* 90% of the area the pedogenic horizons were partly if not wholly developed in marine clay; in *ca.* 80% of the portion of the CRF located in Borthwick Valley, the pedogenic horizons were developed entirely in the mantle deposits.

The mantle deposits can be subdivided into three units; each represents a phase in the development of the valley floor during which erosion of older deposits was followed by deposition. The relevant units of Map 1 comprise areas in which presumably uneroded deposits are to be found.

Within the boundaries of the CRF the oldest phase of the mantle deposits occurs only in Borthwick Creek (Unit V, Map 1), where it is represented by a poorly preserved terracette located at the foot of the southern bluff of Dolman Ridge; its surface has an elevation of *ca.* 225 ft. The deposits of this phase consist mainly of silty and clayey

Fig. 2. Open sand knoll. On the crest (foreground) is *Rubus strigosus*, and open sand near woodchuck burrows which are common on these crests. Below crest is an open grass zone with *Danthonia spicata* and *Poa* (*nemoralis* or *pratensis*). At the bottom of the grass zone are scattered *Solidago graminifolia*, followed by a low shrub zone of *Spiraea alba*. In the background wooded area are speckled alder and trembling aspen. Line FF, East Block, CRF. 16/9/70.

fine sand, commonly less than one meter thick, resting on marine clay; drainage is poor.

The surface of the second phase of the mantle deposits attains *ca.* 218-220 ft elevation in Borthwick Valley and *ca.* 220-222 ft in Black Creek Valley (Unit VI, Map 1). This phase was deposited after channel floor erosion had removed part of the older deposit and the channel floor itself had also been lowered. It is widely distributed in Borthwick Valley, where it is locally up to 7 ft thick. In the part of the CRF located in the valley of Black Creek it is rather rare and is commonly less than 2 ft thick. The average grain size of this deposit varies with the location; it is dominantly sandy, has a sandy clay at the base, clayey fine sand constitutes the main component and it shows a gradual change from coarse to fine textures from bottom to top, the near-surface horizons usually consisting of silty or fine sandy loam. The deposits do not contain carbonates.

The third and youngest phase of the mantle deposits is found only at elevations below *ca.* 216 ft (Unit VII, Map 1). It consists of a sheet of up to 1 ft of mainly silty clay which overlies the eroded surface of the marine clay: it was probably deposited from standing rather than flowing water. Lenses of sand, clayey sand or sandy loam were found locally between the sheet of silty clay and the marine clay.

Drainage conditions are generally poor in terrain units V, VI and VII (Map 1). Notable exceptions, however, are found in areas where thicker accumulations of mantle deposits form convex relief elements; the deposits are then as well drained as in the better-drained areas of Dolman Ridge. The footslopes below the northern bluffs of Dolman Ridge and Borthwick Ridge also provide a better-drained environment; this results from the general asymmetry of the valley floors, the main drainage line in each valley being located close to the bluffs bordering the southern sides of the valleys. The southern portion of the valley floors is therefore more steeply inclined and has better surface drainage than the northern portion of the valley floors, irrespective of the thickness of the mantle deposits.

Up to 8 ft of organic deposits occur below the lowest portions of the CRF (Unit VIII, Map 1). They consist mainly of organic channel fill, detrital peat, leaf litter accumulations and gyttja, with small amounts of *Typha* and *Carex* peat. *Sphagnum* peat is rare; it was found only in two small areas where the convex surface of the topography indicated that bog development had reached the oligotrophic stage (Unit IX, Map 1). The peripheries of these oligotrophic *Sphagnum* peat accumulations have, however, become covered with 16 inches of marsh and swamp peat and silty overwash due to eutrophication which resulted from rising groundwater levels. The CRF is located at the western eutrophic periphery of the Mer Bleue peat bog--a valley-damming, convex *Sphagnum* bog; its organic deposits fill channels that were cut into the marine clay of the valley floor of the CRF after the deposition of the final phase of the mantle deposits. These channels are up to 400 ft wide; their bottoms extend as much as 9 ft below the surface of the adjoining mantle deposits. Water-logged conditions are normal in this terrain unit.

Fans occur at the mouths of gullies that were incised into Dolman Ridge (Unit X, Map 1). They consist mainly of up to 9 ft of somewhat clayey fine sand which is poorly sorted. A clay-rich horizon found in two fans in Borthwick Valley represents the youngest phase of the mantle deposits; the upper, sandy horizons of the fan deposits are thus younger than the mantle deposits and some sediment is being added to some of the fans at the present time. This terrain unit is relatively poorly drained because the occurrence of drainage-impeding horizons and laminae of clay-rich sediment inhibit the subsurface flow of water supplied by the sand cover of Dolman Ridge.

VEGETATIONAL HISTORY AND LAND USE

A reconstruction of the history of the area was accomplished in several ways. The postglacial development of the vegetation was interpreted from Camfield's (1969) pollen analysis from the Mer Bleue bog (Fig. 3). The impact of man was reconstructed from ethnological data on the presence of Indians in the area (G.M. Day, personal communication), municipal files of settlement and assessment of local properties, texts of the general history (Belden 1897, Hughson and Bond 1964, Walker and Walker 1968), interviews with longtime residents of the area, air photos with coverage back to 1945, and old tree stumps in the CRF. Finally, land use classes were developed for the central plateau of the forest (Dolman Ridge) and these are presented in Map 2.

Early vegetational history

Vegetational colonization of the region around the CRF began approximately 7,500 years ago when the Champlain Sea receded. Subsequent freshwater flooding created marsh and swamp conditions in the low-lying areas, including the depression in which the Mer Bleue bog has developed. The climatological changes are interpretable from the pollen diagram of the Mer Bleue (Fig. 3). An initial dominance by jack pine[6] was followed by white pine dominance, then white pine accompanied by birches and oaks. This was followed by decline of the pines and an increase of hemlock, beech, birches, alder, ironwood, hornbeam, elm, hickory, maple, ash and walnut. This species sequence suggests that the climate was warming up. Several of these species are now missing from the local vegetation, or at least are more abundant south of the Mer Bleue, which suggests a cooling of the climate in the most recent period.

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[6] Scientific names for tree species are given in Appendix A.

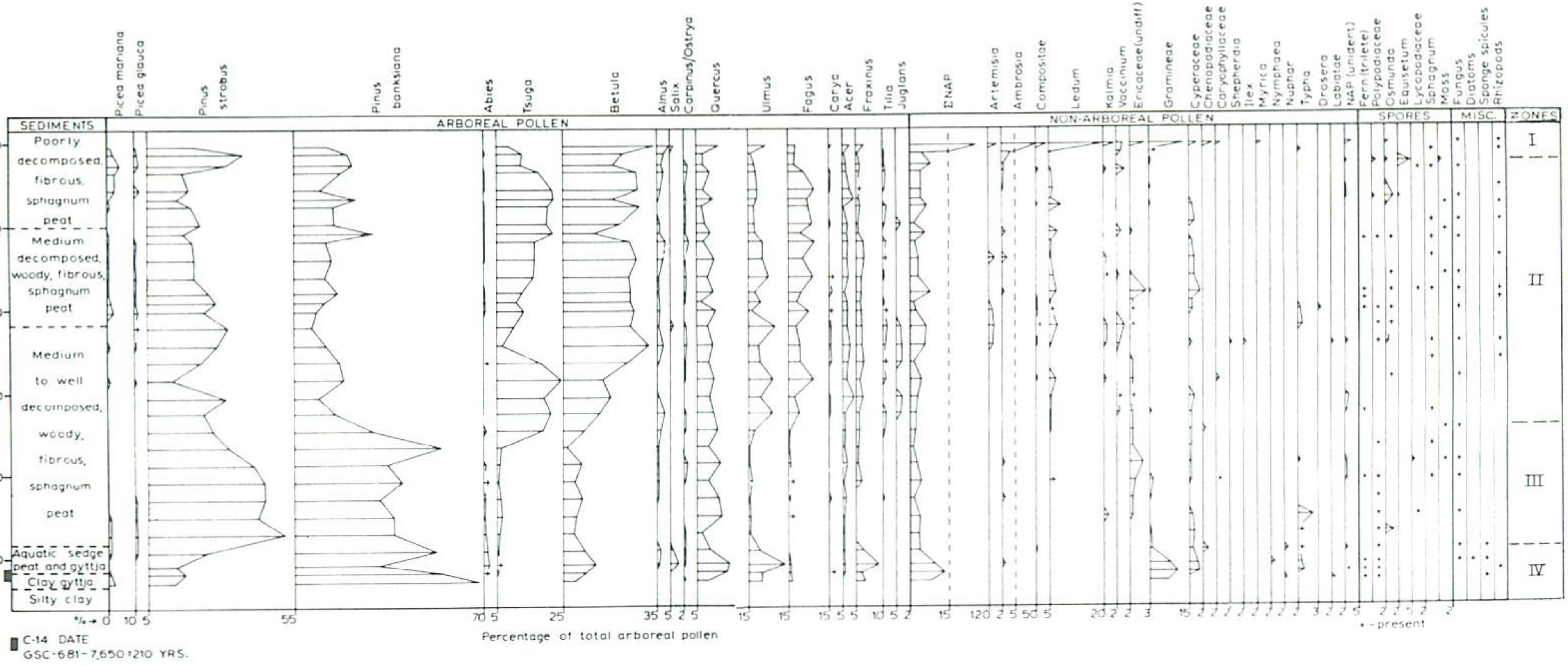

Fig. 3 Pollen record at the Mer Bleue (Camfield 1969, courtesy of the Canadian Field-Naturalist).

Indian influence

Indians must have been present during the last two periods. The Algonquins occupied most of the Ottawa Valley. They were not agriculturally inclined like their rivals, the Iroquois of the St. Lawrence Valley, but were hunters and fishermen, and consequently did not leave noticeable marks in the Mer Bleue and surrounding vegetation. Even if the abundance of blueberries attracted pickers in the summer and some beaver or muskrat trapping was carried on, it is not likely that more than single family groups would stay in temporary encampments on the ridges to harvest these products.

Pioneer settlement

The expression of human influence in the vegetation is not visible in the pollen record (Fig. 3) until approximately 150 years ago, when there was a drastic reduction in pine pollen marking the clearing of land and logging by white settlers. The simultaneous increase of birch pollen indicates an increase by that species on some of the cleared land. The other indicators of cleared land are the weed and grass pollens, in particular that of ragweed.

For the higher ridges and area surrounding the bog, the peak of wood harvesting was in the mid-19th century. Pines and spruces of considerable size were logged off during the winters and driven down Green's Creek in spring to be picked up in the Ottawa River for further transport. The high graded forest land was readily picked up by settlers who could gradually clear everything and start farming.

The earliest survey records are dated 1820, and come from north of Mer Bleue close to Montreal Road. The CRF area must have been surveyed soon afterward. Gloucester Township was organized in 1832. Regulations for fencing quality from those days would indicate the need to keep boundaries well defined (5 ft high; 10 inches between the horizontal stretch poles, which had to be of reasonable size).

James Forsythe, the first settler of the district, bought land in 1840 two miles west of Carlsbad Springs, just south of the CRF. The first settler on the southern ridge was Thomas Borthwick, whose name was later given to the entire ridge and to the creeks running through the valley north of the ridge. Borthwick operated a mineral spring at the foot of the ridge and supplied ailing Ottawa customers for many years. These salt springs are still a feature of the area.

Names of other settlers of the mid-valley having their homesteads on the Borthwick Ridge were Gray, Ramsay, White, Alexander and Mackey. All these names can still be found in the region, and one was even used to name the local village--Ramsayville.

Wood use

After 1850 there was a building boom in Bytown (Ottawa) and the demand for wood was great.

In later years much hardwood was cut for the furnaces of the parliament buildings. Fuelwood suppliers soon obtained new customers among the railway companies. In 1882 the Canadian-Atlantic railway pioneered the line to Carlsbad south of the CRF. The engines would stop locally to take in water from the creeks and ponds and to restock fuelwood.

With the railways ready to haul logs to the mills, logging for pines could be done farther away from the rivers.

Before the turn of the century there was a good demand for "ships' knees", the stump-root joints of white and red pine, full of resin and therefore impervious to saltwater. They were roughly fashioned at the Carlsbad mills and formed to ribs for the construction of the fishing fleet in Nova Scotia.

All this indicates that land clearing was a paying proposition. The Brennans, farming on the Dolman [sic] Ridge where the Geomagnetic Laboratory is now situated[7], had a large stump puller. George Doleman still recalls their stump-clearing operations at the turn of the century. His father, John Doleman, was a pioneer market gardener on the first lot east of Anderson Road extending across the ridge which now carries his family name.

The North Valley

The Canadian Pacific Railway track, forming the north boundary of the CRF, was built in 1898 and the Blackburn station was just across Anderson Road north of the tracks. The local children used to sell blueberries, a ready-made Mer Bleue cash crop, at this station.

The CPR line cuts a few acres out of the middle of each of the lots through which it passes. Homesteads were located along the road which followed the southwest banks of Blackburn Creek, now forming part of Anderson Road and Renaud Road. Anderson Road itself remained until very recently a gravel wagon trail connecting Cyrville Road with the old Russel Road at the crossing of the sixth concession line.

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[7] The Geomagnetic Laboratory is located on the Dolman Ridge between the East and West Blocks and south of the Dolman Ridge Road (Map 2).

The earliest settler in the north valley was Woodburn, who bought a lot west of the CRF in 1844, followed by Hopkins who took the CRF's neighbouring lot. The most westerly property within the CRF was settled by William O'Donnell in 1860. Two of his sons served with the Ottawa Company of Sharpshooters in the Riel rebellion and remained to farm in Saskatchewan. A third son and the grandchildren kept the property in the family for over 100 years. The grandchildren still live in the old farmhouse at Cyrville Road. Their land stretched over part of the Dolman Ridge, including the old growth farm woodlot at the west boundary of the CRF and the adjacent municipal dump (Map 2).

Fire

Charcoal was commonly found on top of the mineral soil profiles in the soil survey, indicating that much of the CRF has been burned at some time in the past. Although fire is partly a natural phenomenon it was used extensively during the landclearing by the pioneer settlers. Mr. O'Donnell mentioned that his grandfather used fire to clear a thin peat cover off the clay lands of their property.

Sparks from engines of the passing trains and human carelessness have caused a number of peat fires, some as recently as 15 years ago, but the largest on record is from the beginning of World War I when practically the entire Mer Bleue was afire. Only a few western pockets escaped it. People had to protect themselves at night against the acrid peat smoke by covering their screens with wet cloths. The fires lasted the entire summer season and extended into autumn.

Spring firing of pasture fields was a regular practice in the region but in the CRF the evidence of past fire is not generally noticeable in the woody vegetation. However, in the older forested section west of Anderson Road at the southern descent of Dolman Ridge (Map 2) red maple has aggregated trunks which arose as sucker sprouts, and this, plus the presence of aspen, suggests that the stand originated after fire.

Land use

Land use classes in Map 2 were derived mainly to reflect clearing and abandonment. Time elapsed since pasturing has been superimposed as number-letter symbols over the basic clearing-abandonment classes. Other influences, such as power line clearance, sugar bush areas, and topsoil mining, are also shown. Major drainage ditches are shown in Map 2, including ditches which were cut from low, wet areas in the central parts of Dolman Ridge through the higher shoulders bordering the bluffs.

The areas with the least disturbance are the classes of 'longtime wooded' and 'longtime marsh and swamp' (Map 2). The woodlot on the west boundary of Dolman Ridge and a similar pocket at the east boundary of the CRF form the only level ridge parts that apparently were never cleared. However, they were grazed at some time in the past, as were all other parts of the CRF. Other sites that were not cleared include: (1) some wet shrub areas, (2) the minor creek valleys and erosion gulleys which cut deeply into the embankments, (3) some areas on the north and south embankments of Dolman Ridge, and (4) a few scattered groups of shade trees. Areas in the longtime wooded classes are dominated mainly by red maple and to a lesser degree by white cedar and hemlock (compare maps 2 and 3).

A large portion of the presently wooded area was at some time in the past cleared and cultivated, or cleared or partially cleared for pasturing. The most recently abandoned cultivated areas ('wooded, no cultivation for 20 years', Map 2) are dominated mostly by pioneer species--speckled alder, trembling aspen and grey birch (compare maps 2 and 3). The wooded classes with no cultivation for 30 and 40 years are dominated by a mixture of these pioneers and the species mentioned for the longtime wooded classes. A complication is that scattered throughout the wooded area are large, old trees, often surrounded by much younger forest of a different species (e.g., the west half of the lot bordering the Anderson Road (west block), where large white pines occur). Other trees with an open-grown habit are also found throughout the CRF--elm, hemlock, red maple and sugar maple--and these may in some cases have been seedlings or young trees which were missed at the time of clearing.

The most disturbed situation in the CRF is present in the central area of the west block (Map 2). The north end of this area still features part of a former sugarbush operation, where old windfall remnants and the remains of an old farmhouse are found. Topsoil was stripped off this central area around the farmhouse and adjacent to the south embankment at the time of the Queensway construction. This disturbed area was bulldozed to restore landscape fluency and no longer shows the original vegetation pattern.

Another man-made feature is the 300-ft-wide easement for the hydroelectric power line which crosses the west block (Map 2). The southern line was installed in 1932, the northern line followed in 1948 and both areas were kept brushfree with herbicides up to 1965. This cut line and the southern zone of the most westerly lot on the ridge served as open pasture. The latter area, dry and underlain by sand, was intermittently cultivated, but it is doubtful that cropping was profitable.

Pasturing uses are more difficult to map since precise records were rarely kept and there is less imprint by pasturing on the land and vegetation. Nonetheless, it is possible to indicate general areas for periods when pasturing was last done in various parts of Dolman Ridge. The far western portion of the west block represents the area with the most recent pasturing (up to 1970) whereas the eastern part of the west block and all of the east block have not been pastured for at least 20 years.

From the foregoing summary it can be concluded that much of the forest has been influenced by a variety of man-caused disturbances from which the forest is in varying stages of recovery. This large amount of disturbance will mask or interfere with the determination of ecological relationships of the vegetation with abiotic factors of the environment.

FOREST ECOLOGY

METHODS

Physical environment

Intensive study of the geomorphology, soil profiles, and groundwater properties at the CRF (Bik 1969, 1971[5]; Bik *et al.* 1971) was based on parallel, north-south lines positioned 250 ft apart, and groundwater wells located every 30 m along these lines. At each well, depths, colors and textures of soil horizons were described, and weekly measurements of groundwater depths were taken from June 1 to December 13, 1970, and from April 20 to May 31, 1971. Depths to groundwater were expressed as averages for the total year and as averages for the following periods: all of June; all of July and August 3; August 9 to September 20; September 27 to October 23; November 1 to December 13; and April 20 to May 31. The choice of these periods was made by inspecting trends in groundwater data and distinguishing periods when levels were predominantly high or low, or typified by rising or falling levels.

Other groundwater parameters determined for each well were: highest and lowest groundwater level for the year; greatest depth of groundwater below the sand-marine clay interface; number of times the groundwater level was below the marine clay horizon; and average depth of groundwater below the sand-marine clay interface when it was below this level.

Vegetation sampling

The ecological survey was limited to the forests on the east and west blocks (84 and 224 acres, respectively) of the central plateau (Dolman Ridge, maps 1 and 2). Since the north-south lines had been cleared to facilitate the placement of wells, the centers of the circular plots used in sampling were offset to the west by 8 m in the west block and 10 m in the east block where cut lines are wider. A small amount of cut line disturbance was included on the perimeters of the 0.1-acre plots to insure that the groundwater and soil profile data would be included in and representative of the plots.

Trees, saplings and seedlings were sampled in 489 plots in the east and west blocks (excluding all of the area north of Dolman Ridge Road). Dbh was recorded for individuals equaling or exceeding 3.5 inches in the 0.1-acre circular plots. Clumps of speckled alder and willow species were counted in these plots, but no dbh data were taken. Tree species of sapling size (1-3.4 in. dbh) were counted in circular plots with 4-m radii located at each point. Tree species of seedling size, here regarded as individuals 1 ft in height to 0.9 inch dbh, were counted in circular plots with 2-m radii located at each point. "Tree species" were regarded for survey purposes as those listed as trees (*i.e.*, exceeding 15 ft when mature) by Hosie (1969).

To sample shrubs and herbs, 67 relatively uniform (not occurring on vegetational transitions) plots were selected (predominantly from forested sites, but three open plots were sampled at the end of the study to include some representation of this condition). Selection was such that the proportions of leading dominants in the plots were similar to their proportions in all forested plots (see Appendix A), and distribution of plots among five subjective classes of moisture (described below) was relatively uniform.

For all vascular species, canopy cover estimates were given according to the following classes: p -- 0-1%; + -- 2-5%; 1 -- 6-25%; 2 -- 26-50%; 3 -- 51-75%; 4 -- 76-100%. Bryophytes were collected at random, except for *Polytrichum* species which were consistently sampled in the 67 stands. Nomenclature for trees is according to Hosie (1969), for shrubs and herbs to Gleason and Cronquist (1963) and for bryophytes to Crum *et al.* (1965). In species identification Gillett's Checklist of Plants of The Ottawa District (1958) was very useful. A complete list of tree species observed at the CRF is found in Appendix A; a list of all other species is found in Appendix B. Vouchers for shrubs, herbs and bryophytes are lodged in the CRF herbarium.

Some additional habitat measures were collected. Canopy cover for leafy cover exceeding head height was estimated for the 67 plots using the scale given above, with the additional recognition of a low class 4 (76-87%) and a high class 4 (88-100%). A second team later rated canopy cover for all 489 plots. Both sets of ratings were carried out in late summer when there was complete canopy closure. Moisture classes were estimated for the 67 plots on the basis of the following topographically defined categories: (1) flats and drainageways,

(2) lower slopes, (3) upper slopes, (4) wooded knoll[8] crests and wooded upper slopes adjacent to open knoll crests, and (5) open knoll crests (Fig. 2). Finally, for all 0.1-acre plots the maximum relief difference and the difference in elevation of the ground surfaces at the groundwater well and the center of the plot were estimated.

Forest types

The leading dominant of a forested plot was taken as the species attaining the greatest sum of dbh for its tree-sized individuals. Numbers of stands dominated by each of the leading dominants are given in Appendix A. The forest cover type map was based on recognition on color infrared aerial photographs (scale *ca.* 1:4,100) of uniform areas of leading dominants and secondary dominants (Map 3). The latter were included to characterize a map unit when their total dbh from the ground survey was at least 25% of that for the leading dominant.

Shrub-herb types

An agglomerative classification (program developed by J.W. Sheard, University of Saskatchewan, using the method of Orloci, 1967) was applied with 49 species of shrubs and herbs, those which had values in 11 or more of the 67 stands. Values used for species were the midpoints of the cover scale ratings they had obtained: p -- 1%; + -- 3%; 1 -- 15%; 2 -- 38%; 3 -- 63%; and 4 -- 88%. The values were not transformed or adjusted because we wished the classification to be based on the magnitudes (covers) of shrub and herb species rather than on simple presence or absence. Classifications of both plots and species were derived using the agglomerative technique. The plot types and species groups were chosen by inspecting the classification dendrograms and the actual cover values in the synthesis tables (Table 1), and drawing lines between what seemed to be natural groupings of plots or species.

Principal component analysis (P.C.A.)

The P.C.A. employed here utilized a variance-covariance matrix and R-type analysis. It was the same as that used by Jeglum *et al.* (1971) in which the analysis was based on vegetational variation alone. The original measures for species as well as for various habitat measures are correlated with plot scores on each of the extracted components.

A P.C.A. for trees and saplings was based on the 11 species in the tree size class and seven species in the sapling size class which

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[8] The knolls referred to here, although highly variable in size, are on the order of 5 m in height and 20-50 m across (Fig. 2). They may have been formed by the action of wind or water.

Table 1. Agglomerative classification: shrub-herb stand types and species groups. (ACru=*Acer rubrum*, ACsa=*Acer saccharum*, ALru=*Alnus rugosa*, BEpa=*Betula papyrifera*, BEpo=*Betula populifolia*, PIst=*Pinus strobus*, POgr=*Populus grandidentata*, POtr=*Populus tremuloides*, THoc=*Thuja occidentalis*, TSca=*Tsuga canadensis*, ULam=*Ulmus americana*). Note: The letter-number designations are lines and plots in the CRF.

SHRUB-HERB STAND TYPES

			I										II											III											IV												V							VI															
	Species groups	Dominant stand	BEpo H 1320	ACru O 1650	ALru E 1290	ALru K 1320	BEpa C 1200	THoc EE1350	THoc FF1260	BEpo BB1920	BEpo CC2010	PIst M 1170	POtr L 1140	BEpo EE1550	POtr CC1770	BEpo BB2070	BEpo FF2070	POtr EE2070	POtr FF1980	OPEN O 1740	OPEN B 1080	POgr D 1080	OPEN BB1740	TSca F 870	ACru N 1590	PIst L 1440	THoc M 1440	PIst L 1560	ULam G 990	ALru K 1110	ACru B 840	ACru E 1020	ACsa H 960	ACru D 1050	POtr B 1020	ACru H 1290	ACru O 1320	THoc M 1650	POgr D 1110	POtr K 1200	POtr K 1230	POtr I 1290	BEpo BB1350	BEpo BB1320	ALru K 1350	ALru DD1500	ULam B 810	BEpa N 1680	BEpa L 1290	ACru M 1410	BEpa N 1530	ACru M 1590	ACru B 960	POtr E 900	BEpo CC1500	ACru J 1260	BEpo CC1230	PIst N 1290	TSca EE1530	PIst L 1320	PIst M 1380	ACru D 1020	ACru FF1530	THoc EE1410	PIst O 1500	THoc EE1440	THoc EE1320	ACru FF1560	ACru J 1200
	Kalmia angustifolia		1		1			15	3	1	1						1																							1	1						1					1		3			1					1		3		
	Lycopodium complanatum							15	1																							1	1		3					1										1	1			1									1		1				1
I	*Aster umbellatus*		1	1				3	1				1				1				3		1										1			1			1			1		1										1		1												1
	Rubus hispidus		15	38	38	38	38	63	38	38	15	3	15	1	1	15	1		1			1									1					1	1		1	1	3	1	1	1	15			1	1	1	1		1	1	38	3	1	1	1	1	1		1		1			1	
	Osmunda regalis							38	63				3	15								1				1		3			1	1	1	1	3	1			1			1									1	1	1	15	1					1				1	1			3		1
	Prunus virginiana								1																							1	1	1	1	1		1		1												1		1				1								1	1					
	Athyrium filix-femina																								1	1	1	1	3			3	1	1				1		1								1	1			1	1								1		1	1	1		1			
	Danthonia spicata							1		1														1	1	1			1	1	1	1	1			1	1		1		1						1	1		1						1			1	1	1	1	1	1		1			
	Ranunculus acris																													1		1		1			1	1		1	1	1				1		1				1			1		1			1	1	1	1						1	1
	Thelypteris palustris							1	1																							1	1									1						1						1		1			1			1	1	1		1	1	1	1
VI	*Taraxacum officinale*						1		1																			1									1			1	1		3	1				1	1			1	1		1				1	1	1	1	1		1		1		1	1
	Equisetum arvense					1		1			1													1	1			1		1		1	1		1			15	1	1									1		1									1	1		1				1	1		
	Maianthemum canadense											1																				1	1	1		1				1							1						1											1	1					1	1
	Onoclea sensibilis		1			1		38	1	38	3	1												1	1	1	1	1		1	1			1		1	1	1	15	1		3					38			1	1	3		38	3	38	38	1	38	38	63	15	15	38	15	15	38	15	38	38
	Osmunda cinnamomea					1				3	1													1		1	1							1	1					3	3	1		1			1		1		1	1	38	15		38	38	38	38	1		3	3	1	1		
	Rhamnus frangula				1	1	1					1	1									1									1				1	1	1	1			1	1	1			1					3	1		1	1	1		3				15	1								3
	Carex brunnescens		1				1	1		1		1			1									1									1		1		1						1		1		1				1	1			1	1			1		1			1	1	1			
	Lycopus uniflorus			1	1		15	1	1	1	1	1					1			1		15		1	1	1	1	3	1	1	1	3	1	1	3	15	38	3	1	1	1	3		1	1	1	1	3	1	3		1	15	1		3		1	1	1	1	1	3	3	1	15	1	1	15
V	*Cornus alternifolia*			1			1	1				1	1							1						3					1	1	1		1	1			1						1	1	1	1		1	1				1	1			1							
	Fragaria virginiana		1	15				1	1		1						1											1	1	3			1	1											1	1			1		15	15	63	63	63	38	88	1	15			15							1			
	Solidago graminifolia		1	15		1	1	3	1	1	1	1	3	1		3	3				1	1						1	1	1				1		1	1		1	1	1	1	1		1	1		1	1					1	1	1		1				1	1	1	1			1
	Viola spp. stemless		38	38		1	15						1									1										1		1						1	3			1	1																	1						1		15
	Spiraea tomentosa			1			1	1							3	1		1			1																				1	1	1															1													1
	Viburnum cassinoides		1		1		1	1		1	1	1					1					1				1		1		1	1	1				1	1		1	3	38	3			1				1	1	1	1	1	1		15		1	1	1	1	1			1	1		1	15
	Calamagrostis canadensis		1				1	1	1			1		1																	1			1			1	1		15	38	3	1		1			1	1	1							15			1	1						1	1	1	1
	Nemopanthus mucronata								1																									1				1		1	3	1								1		1				38		1	1		1		1		1			15	3
	Polytrichum commune							1			1				1		3		1															1		1	1	1	1	3			1	1					1			1	1		1	15	38	1						1		1			
IV	*Salix petiolaris*		1	1				1					15	38	1	1	1	1										1																	1													3	1						1					1	
	Lycopodium obscurum									3	1					15		1				1				1					1								1	1			1	3	1	1	1											3			1	1						1	1	
	Carex arctata		1			1	1	1	1		1	1					1		1		1	3			1			1	1	1	1	1	1	1			1	1	1		1				1				1				1		1				1				1						1
	Pteridium aquilinum						1		1	1	1	1					1					1				1		1			1	1	1						1				1		1		1	1			1						1	1		1				1			
	Trientalis borealis					1	1				1	1	1									1								1	1	1						1	1	1		1	1	1			1	1				1			1						1		1	1	1		1
	Muhlenbergia mexicana		1	15	15	1	1	1	1	3	15	1					38						1	1	1	1	3	1	3	1		1			1	15		3	1		38	63	15	38	38	1	1	1		1	1	1	1	3	15	1	1	1	3	1	1			1	3		1	1
	Carex debilis														1	1			1		1	1	1																					1		1																				1					1	1
	Pyrola elliptica						1					1	1		1		1			1	1	1						1										1						1																										
	Rubus pubescens						1						1		1				1		1	1							1									1						1		1																							
	Achillea millefolium		1			1	1	1	1		1	1	1		1	1	1		1		1		1							1				1				1				1				1						1														
	Solidago rugosa								1			1	1		1	1		1		1	1	1						1	1				1									1			1								1													
	Dryopteris austriaca		1		1	1		1	1		1	1			1		1	3	1	1					1	1		1	1					1		1					1	1	3	1	1	1		1					1		1	1		1	1	1				1			
	Mediola virginiana			1		1	1			1		1	1			1													1						1									1	1																									
II	*Carex scoparia*								38		1		1	3		1		38	63	15		3														3			1	1								1									3		1												
	Rubus strigosus					1			1	38	15	3	38	15		1	1											1		1					1				1	1				1		1							1		1	1														
	Vaccinium myrtilloides								1	1			15				1					1				1	1		1	1						1	1			1					1					1						3	3						1		1	1				1
	Rubus spp.			1	1		1			3	1						38													1	1		1							1	1	1			1	1			1					1			1									1			
	Agrostis stolonifera								1					1		1	15	1	1	1	1	1		1																																3														
	Spiraea alba		3	38	1	1	1	3	1	1	1	1	38	15	38	63	38	1	3	15	1	1	15					1		1					1			1	3	1	3	1	1	1			1				1	1	1	38	3	1	1							1		1		1
	Equisetum sylvaticum		1	1	1	1	1		1	1	1		1	1	1	15	1		1	1	63	38	15					1	1	1		1				1				1	1	1			1	1		1	1					1		1													
	Solidago canadense					1	1	1	1				1	1		1	1	1	1		15		1			1										1																					1										1			
	Aster simplex			1							1		1		1			1	1		38	1	38	1								1						1			1	1		1	1											1														

had values in six or more of the 67 plots. The 11 species of trees were represented by two sets of values, density and mean dbh. Saplings were represented by density. Hence, there were 29 attributes in the tree and sapling P.C.A. for the 67 plots. No transformations or adjustments of the raw data were performed prior to the analysis.

Another P.C.A. based on the same 49 species that were used for the agglomerative classification was carried out for shrubs and herbs. Again, no transformations or adjustments of data were performed prior to analysis.

In each of the P.C.A.'s all available habitat measures were correlated with the plot scores for the first three components. Several of the measures for depth to groundwater were adjusted for the difference in ground surfaces between the groundwater wells and the centers of the 0.1-acre plots; if the center point was higher than the well the difference was added, if lower it was subtracted.

To judge the relative importance of each measure in relation to vegetational variation we required an index combining the proportions of vegetational variation and habitat measure variation accounted for on the first three (the most important) components. The index we used for this was $\sum^{3} (r^2 \times \%V)$ (*cf.* Jeglum 1974), which is the sum for the first three components of the values of r^2 (coefficient of determination, the variance in a habitat measure accounted for in its correlation with stand scores on a component) multiplied by the percentage of the total vegetational variance (%V) accounted for (see tables 2 and 3).

With the above index it was possible to select a few measures from the many that were available to represent moisture regime. The unmodified groundwater depths yielded slightly higher values for $\sum^{3} (r^2 \times \%V)$ than those for adjusted depths. This suggests that the groundwater is more or less parallel to the groundsurface rather than horizontal as is assumed for adjusted values, and that unmodified groundwater depths are the best indicators of moisture regime for the plots. Consequently, adjusted values were not considered any further.

The unmodified depth to groundwater averages for the various time periods showed very similar correlations for the first three components, and the values of $\sum^{3} (r^2 \times \%V)$ were similar. Hence, we used only one groundwater level average, that for the whole year. To represent moisture regime, we also used moisture class and number of times the groundwater was below the sand-marine clay interface. The latter measure may indicate restricted availability of water to plant roots, which are probably limited in their degree of penetration into the unaerated and compacted marine clay horizon.

Table 2 P.C.A. for trees and saplings for the 67 stands having shrub and herb data. Included are the percentages of the total variance accounted for by each of the three component axes, and the correlation coefficients between raw values for environment and species and the stand scores on each of the components

Component axis	1	2	3	
Percentage of total variance accounted for (% V)	24.5	16.9	8.9	Σ = 50.3
Correlations for environmental measures (r)				
Moisture-related measures				Σ(r^2X %V)
Moisture class	-0.14	0.18	0.16	.013
Depth to groundwater (yr avg)	-0.15	0.01	0.14	.007
No. times groundwater below marine clay	-0.20	-0.01	-0.25	.015
				Σ= .035
				Σ/3= .012
Light-related measures				
Cover class (first rating)	0.43**	-0.10	-0.06	.047
Cover class (second rating)	0.31*	-0.12	-0.04	.026
				Σ= .073
				Σ/2= .037
Edaphic-relief-related measures				
Depth to marine clay	0.04	0.09	0.34**	.012
Depth of organic-rich layer	-0.06	-0.28*	0.13	.016
Depth of sand (marine clay-organic)	0.05	0.04	0.35**	.011
Relief in plot	0.19	0.02	-0.02	.009
				Σ= .048
				Σ/4= .012

(continued)

Table 2 P.C.A. for trees and saplings for the 67 stands having shrub and herb data. Included are the percentages of the total variance accounted for by each of the three component axes, and the correlation coefficients between raw values for environment and species and the stand scores on each of the components (concluded)

Component axis	1	2	3
Correlations for tree and sapling data			
Tree density data			
Aspen, largetooth	0.02	-0.13	-0.14
Aspen, trembling	-0.04	-0.09	0.31**
Birch, grey	-0.35**	0.11	0.00
Birch, white	0.19	-0.13	0.39**
Birch, yellow	0.29*	-0.06	0.24*
Cedar, white	0.54**	0.84**	-0.01
Cherry, pin	0.08	0.04	0.34**
Elm, American	0.23	0.03	-0.03
Hemlock, eastern	0.07	-0.05	-0.34**
Maple, red	0.83**	-0.45**	-0.16
Pine, white	0.17	-0.16	0.64**
Tree diameter data			
Aspen, largetooth	0.07	-0.18	0.04
Aspen, trembling	0.10	-0.14	0.48**
Birch, grey	-0.07	0.25*	0.11
Birch, white	0.30*	-0.03	0.37**
Birch, yellow	0.51**	0.09	-0.33**
Cedar, white	0.54**	0.39**	0.24*
Cherry, pin	0.21	0.19	0.23
Elm, American	0.34**	0.08	-0.21
Hemlock, eastern	0.33**	-0.15	-0.51**
Maple, red	0.62**	-0.15	-0.17
Pine, white	0.40**	-0.11	0.74**
Sapling density data			
Alder, speckled	-0.39**	0.10	-0.27*
Aspen, trembling	-0.23	0.00	0.10
Birch, grey	-0.38**	0.07	-0.04
Birch, white	0.00	-0.07	0.21
Cedar, white	0.40**	0.78**	-0.06
Cherry, pin	-0.05	0.01	0.30*
Maple, red	0.48**	-0.15	0.11

Table 3 P.C.A. for shrubs and herbs for the 67 stands. Included are the percentages of the total variance accounted for by each of the first three component axes, and the correlation coefficients between raw values for habitat and species measures and the stand scores on each of the components

Component axis	1	2	3	
Percentage of total variance accounted for (% V)	18.4	17.1	13.6	Σ = 49.1
Correlations for environmental measures (r)				$\Sigma(r^2 X\ \%V)$
Moisture-related measures				
Moisture class	-0.06	-0.20	0.43**	.033
Depth to groundwater (yr avg)	-0.15	-0.26*	0.16	.019
No. times groundwater below marine clay	-0.26*	-0.09	-0.08	.015
				Σ = .067
				Σ/3 = .022
Light-related measures				
Cover class (first rating)	0.21	-0.29*	-0.22	.019
Cover class (second rating)	0.22	-0.18	-0.26*	.024
				Σ = .043
				Σ/2 = .022
Edaphic-relief-related measures				
Depth to marine clay	0.13	-0.17	0.12	.010
Depth of organic-rich layer	0.06	0.23	-0.13	.012
Depth of sand (marine clay-organic)	0.12	-0.20	0.14	.012
Relief in plot	-0.05	-0.10	-0.03	.002
				Σ = .036
				Σ/4 = .009

(continued)

Table 3 P.C.A. for shrubs and herbs for the 67 stands. Included are the percentages of the total variance accounted for by each of the first three component axes, and the correlation coefficients between raw values for habitat and species measures and the stand scores on each of the components (continued)

Component axis	1	2	3	
Correlations for shrub and herb data				
SHRUBS				%V
Cornus alternifolia[a]	0.11	-0.27*	0.13	0.0
Kalmia angustifolia	0.13	0.33**	0.41**	0.2
Nemopanthus mucronata	0.21	0.23	-0.19	1.4
Prunus virginiana	0.07	-0.09	0.02	0.0
Rhamnus frangula	0.36**	0.21	-0.19	0.2
Rubus hispidus	0.04	0.45**	0.79**	10.6
Rubus spp.[b]	-0.14	0.06	0.31**	1.2
Rubus idaeus var. *aculeatissimus*[c]	-0.04	0.20	0.27*	2.7
Salix petiolaris	-0.13	0.02	0.14	1.4
Spiraea alba	-0.21	0.15	0.57**	8.7
Spiraea tomentosa	0.02	0.30*	0.32**	0.0
Vaccinium myrtilloides	-0.06	0.13	0.21	0.2
Viburnum cassinoides	0.06	0.07	-0.15	1.5
HERBS				
Achillea millefolium	-0.29*	0.14	0.44**	0.0
Agrostis stolonifera	-0.17	0.09	0.37**	0.2
Aster simplex	-0.21	-0.09	-0.06	2.4
Aster umbellatus	-0.11	0.21	0.32**	0.0
Athyrium felix-femina	0.02	-0.15	-0.26*	0.0
Calamagrostis canadensis	0.00	0.07	-0.14	1.5
Carex arctata	-0.26*	-0.05	-0.03	0.0
Carex brunnescens	0.20	0.19	0.01	0.0
Carex debilis	-0.20	0.06	-0.04	0.0
Carex scoparia	-0.19	-0.01	0.17	5.7
Danthonia spicata	0.17	0.15	-0.30*	0.0
Dryopteris spinnulosa	-0.12	0.11	0.01	0.0
Equisetum arvense	0.03	0.03	-0.11	0.2
Equisetum sylvaticum	-0.24*	-0.08	-0.02	4.7
Fragaria virginiana	0.68**	-0.67**	0.28*	16.9
Lycopodium complanatum	0.15	0.25	0.33**	0.2
Lycopodium obscurum	-0.09	0.09	0.02	0.2
Lycopus uniflorus	0.12	-0.06	-0.11	2.0
Maianthemum canadense	0.31**	-0.16	-0.11	0.0

(continued)

Table 3 P.C.A. for shrubs and herbs for the 67 stands. Included are the percentages of the total variance accounted for by each of the first three component axes, and the correlation coefficients between raw values for habitat and species measures and the stand scores on each of the components (concluded)

Component axis	1	2	3	
HERBS (cont'd)				%V
Mediola virginiana	-0.22	0.12	0.37**	0.0
Muhlenbergia mexicana	-0.14	0.13	-0.04	7.9
Onoclea sensibilis	0.75**	0.60**	-0.17	14.1
Osmunda cinnamomea	0.49**	0.47**	-0.17	5.7
Osmunda regalis	0.10	0.15	0.48**	4.7
Pteridium aquilinum	-0.04	0.00	-0.03	0.0
Pyrola elliptica	-0.32**	-0.03	-0.08	0.0
Ranunculus acris	0.15	0.09	0.37**	0.0
Rubus pubescens	-0.27*	-0.04	0.11	0.0
Solidago canadense	-0.19	-0.03	0.04	0.2
Solidago graminifolia	-0.11	0.16	0.51**	0.2
Solidago rugosa	-0.31**	-0.03	0.10	0.0
Taraxacum officinale	0.15	0.02	-0.21	0.0
Thelyteris palustris	0.16	0.30*	-0.12	0.0
Trientalis borealis	-0.16	-0.02	-0.10	0.0
Viola pallens	-0.08	0.07	0.32**	2.7
MOSS				
Polytrichum commune	0.20	0.27*	-0.04	1.4

[a] Nomenclature of vascular species is according to Gleason and Cronquist (1963), that of the single moss species to Crum *et al.* (1965).

[b] *Rubus* spp. consist only of those specimens that were not positively identified.

[c] This identification follows Gray's Manual of Botany (Fernald 1950).

To judge the relative importance of main regimes or complex-gradients, selected factors were categorized as representing moisture, light or landform. The subjective moisture class was based mainly on position on slope, and hence could have been categorized as well beneath the edaphic-relief regime. To judge relative importance of the regimes, the average value of $\sum^{3} (r^2 \times \%V)$ for the measures representing each regime was calculated (see tables 2 and 3).

RESULTS

Species numbers

Forty-two species of "trees", *i.e.*, woody species attaining 15 ft at maturity (Hosie 1969), occur in the CRF (Appendix A). However, 12 of these do not regularly attain tree-sized trunks (3.5 inches dbh), including speckled alder, alder buckthorn, choke cherry, alternate-leaved dogwood, mountain maple, striped maple, nannyberry, one species of serviceberry (*Amelanchier canadensis*), staghorn sumac, bebb willow, pussy willow, and white willow[9]. Thirty-eight shrub and woody vine species, 279 herbs and 24 bryophytes were identified (Appendix B).

Forest composition and cover types

The number of stands in which trees occur is in Appendix A. The nine commonest species, in order of decreasing frequency, are red maple, trembling aspen, speckled alder, grey birch, white birch, white pine, American elm, yellow birch and white cedar. Fifteen of the tree species are leading dominants (Appendix B). Leading dominant within a plot was defined as the species which attains the greatest sum of dbh for all its tree-sized individuals. In the case of tall clumped shrubs we judged leading dominance by comparing the numbers of shrub clumps with numbers of tree-sized individuals for other species in the plot, and noting which species was judged to be dominant in the field classification of each plot. The six most frequent leading dominants, in order of decreasing frequency, are red maple, grey birch, trembling aspen, white pine, white cedar and speckled alder. The open plots, 122 in number, are the commonest cover type. If one adds to this the road plots, which are also predominantly open, the resulting 133 plots comprise 27% of the 489 plots.

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[9] White willow, a European adventive, can attain tree size but in the CRF plots where it was sampled it exists as a tall clumped shrub, similar to alder and the other willows.

Shrub-herb types

From the agglomerative classification six plot types are recognized (Table 1). Type I is established primarily on the basis of a sequence of high cover values for *Rubus hispidus* (Fig. 4), type II on *Spiraea alba*, type IV on *Muhlenbergia mexicana* (Fig. 5), type V on *Fragaria virginiana*, and type VI on both *Onoclea sensibilis* and *Osmunda cinnamomea* (Fig. 6). All of these species attain at least four cover values over 25% in the 67 plots. Plots comprising type III have no cover values over 3% for any species: hence this type is termed the "sparse-understory" type (Fig. 7). A number of plots comprising type IV have high values for *Calamagrostis canadensis*, and this type might also be termed the "wet grassy" type (Fig. 5).

From the agglomerative classification five species groups are recognized (Table 1). These species groups have high cover values and/or distributions of cover values which are similar to those for one of the main species characterizing the plot types. Hence, species associated with shrub-herb type I, characterized by *Rubus hispidus*, include *Kalmia angustifolia*, *Lycopodium complanatum*, *Aster umbellatus* and *Osmunda regalis*. This group of species is designated species group I because the species it contains characterize plot type I. In like manner the groupings of other species have been designated according to the plot type they best characterize. Five species groups are recognized (one less than the number of plot types). This difference occurs because the sparse-understory plot type III is not characterized by any particular grouping of species.

There are only general relationships between forest dominance types and understory plot types (Table 4). For example, red maple occurs mainly in plot types III through VI. The open plots are in type II, and grey birch and trembling aspen have a fair proportion of plots in types I and II. For each of the plot types two or three dominance types have high numbers of plots but usually a number of other dominance types are represented. The lack of strong relationships between dominance types and understory plot types is not surprising in view of the high degree of disturbance which has altered the forests. Shrub-herb communities may have corresponded better to dominance types in the past, and probably will in the future, with periods of no or little disturbance and subsequent succession towards more distinct community types controlled to a larger degree by the leading dominants (*cf.* Daubenmire 1966).

Tree and sapling P.C.A.

Results of the analysis are presented in Table 2 and Figure 8. The analysis was most strongly influenced by density values, since the sum of the percentages of total variance for tree density values is 55%, for tree diameter data is 27%, and for sapling density is 18%.

Fig. 4. Understory vegetation of type I, characterized by *Rubus hispidus* (upper right, prostrate shrub with three leaflets). Also present are *Rubus setosus* (lower half, shrub with arching stems, five leaflets) and *Rhamnus frangula* (upper left, shrub with obovate, short, acuminate leaves). Plot K1320, West Block, CRF.

Fig. 5. Understory vegetation of type IV, characterized by *Muhlenbergia mexicana*. The grass in the photograph is *Calamagrostis canadensis*, another grass associated with this type. Also present are *Dryopteris austriaca*, *D. cristata*, and *Solidago rugosa*. This plot was actually classified as type VI, since *Onoclea sensibilis* and *Osmunda cinnamomea* attained high cover values in the plot. This suggests that type IV and VI intergrade, and indeed these types are positioned close together in both the P.C.A. vegetational ordination (positive end of axis 2) and the environmental model (wetter locations, Fig. 9). Plot J1260, West block, CRF.

Fig. 6. Understory vegetation of type VI, characterized by *Onoclea sensibilis* (upper left) and *Osmunda cinnamomea* (not shown). Also present is *Osmunda regalis* (lower left). Plot L1320, West Block, CRF.

Fig. 7. Understory vegetation of type III, "sparsely understoried". *Maianthemum canadense* is present. Plot E900, West Block, CRF. June 1970.

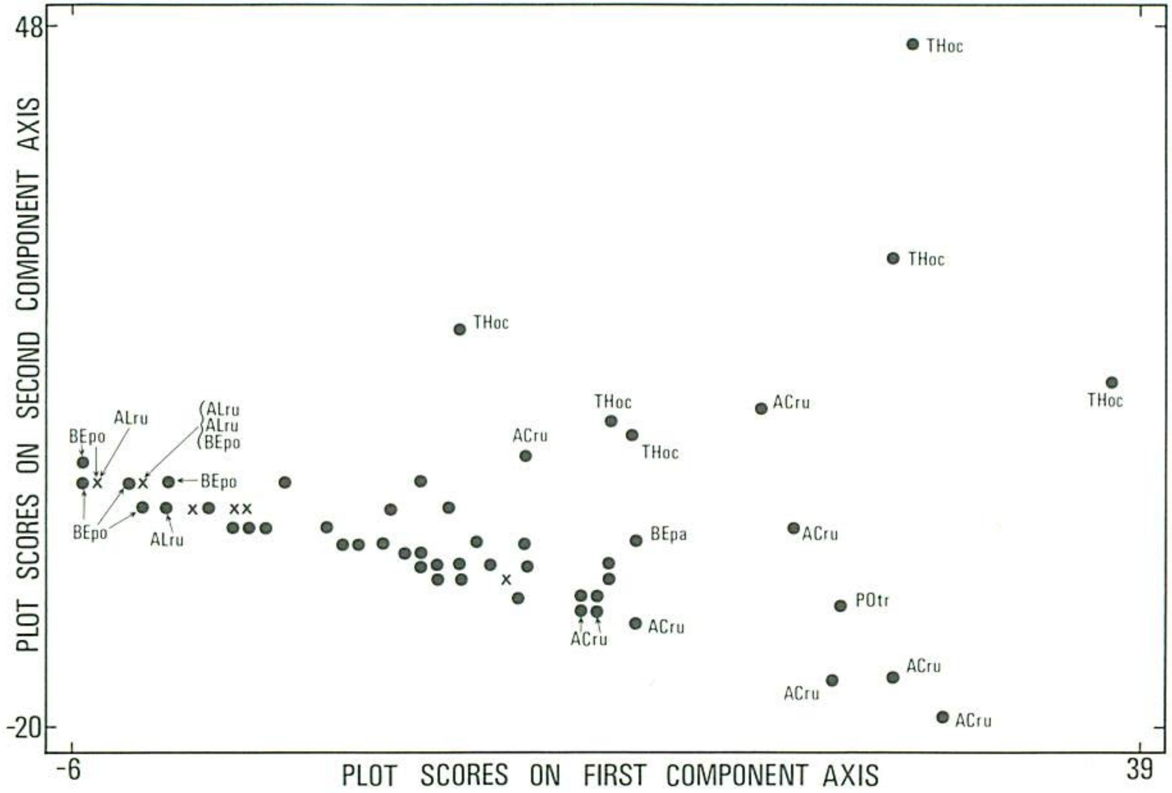

Fig. 8. P.C.A. vegetational ordination model based on density and mean diameter for 11 species of trees and on density for seven species of saplings in 67 stands. ACru = *Acer rubrum*, ALru = *Alnus rugosa*, BEpa = *Betula papyrifera*, BEpo = *B. populifolia*, POtr = *Populus tremuloides*, THoc = *Thuja occidentalis*. June 1970.

Table 4 Number of stands of 12 dominance types in the six shrub-herb types derived from the agglomerative classification for 67 stands. Shrub-herb type I is characterized by *Rubus hispidus*, II by *Spiraea alba*, III by a sparse understory of shrubs and herbs, IV by *Muhlenbergia mexicana*, V by *Fragaria virginiana* and VI by *Onoclea sensibilis* and *Osmunda cinnamomea*

Dominance type	Shrub-herb type					
	I	II	III	IV	V	VI
red maple	1		4	2	3	5
grey birch	3	3		2		2
trembling aspen		4		4		1
white cedar	2		1	1		3
white pine	1		2			4
speckled alder	2		1	2		
white birch	1				3	
open		3				
American elm			1		1	
largetooth aspen		1		1		
eastern hemlock		1				1
sugar maple		1				

Furthermore, the dominance types of most importance on components one and two were those having the highest percentages of variance for density values, *viz.*, red maple (17%), white cedar (16%), speckled alder (7%) and grey birch (5%).

The averages of the values of $\sum^{3} (r^2 \text{ X } \%V)$ for the three regimes (Table 2) suggest that light regime is most important (0.037), moisture and edaphic-relief much less so (0.012 for both). An analysis of components 1-3 follows, and the reader who does not wish any more detail may skip to the next section.

On the first component 25% of the total variance in the vegetational data is extracted (Table 2). Tree-sized species with significant positive correlations between stand scores and both density and mean dbh include yellow birch, white cedar and red maple. Saplings of the last two species also have significant positive correlations and these same two species dominate stands on the positive (right) side of Figure 8. Several other tree-sized species--white birch, American elm, hemlock and white pine--have significant positive correlations only for diameter data. These species are often found as a few large individuals per plot, in combination with more numerous individuals of the first-mentioned group. On the opposite, negative end of the component are stands with high densities of speckled alder clumps and tree- and sapling-sized grey birch (Fig. 8 left). The plots on the positive end of the component have more closed canopies than those on the negative end (correlations for canopy cover, Table 2). This is not surprising since one would expect plots with larger individuals (larger mean dbh's) such as are related to the positive end of the axis to have more closed canopies.

Component 2 accounts for 17% of the total variation (Table 2). Dense stands of red maple trees are at one end of the component (Fig. 8 bottom), whereas stands with large grey birch trees, numerous and large white cedar trees, and numerous white cedar saplings are at the other end (Fig. 8 top). The dense stands of red maple have deeper accumulations of litter and organic-rich soil layers than those of white cedar (see correlation, Table 2).

Component 3 extracts 9% of the variation. Tree density and diameter data for trembling aspen, white birch and white pine have significant positive correlations, and one or a few large trees of white cedar and pin cherry saplings are also at the positive end of the axis. At the negative end of the axis are numerous large trees of yellow birch and hemlock, and clumps of speckled alder. The first-mentioned group of species is associated with deeper sand depths, whereas the last-mentioned group is associated with more frequent occurrence of groundwater below the sand-marine clay interface (probably because the interface is closer to the surface).

Shrub and herb P.C.A.

Results of this analysis are in Table 3 and Figure 9. Species with the highest percentages of total variance in the data (*Fragaria virginiana* highest with 17%) were the same as those that determined the shrub-herb types in the agglomerative classification. In spite of the emphasis on these important species, other species with lower percentages of total variance still attain significant correlation on the components, indicating concomitant variation with leading species. The averages of the values of $\sum^{3} (r^2 \times \%V)$ for the three regimes suggest that moisture and light are equally important (0.022 for both), edaphic relief much less so (0.009). An analysis of components 1-3 follows, and the reader who does not wish any more detail may skip to the next section.

Component 1 accounts for 18% of the total variation in the vegetational data. Species significant at the positive end of this axis are those characterizing types V and VI of the agglomerative classification; species significant at the negative end are those characterizing type II (Fig. 9; tables 3 and 4). The former group of species is associated with somewhat wetter conditions than is the latter (number of times groundwater was below marine clay, Table 3).

Component 2 extracts 17% of the total variation. Significant positive correlations are attained by a mix of species characterizing types I, IV and VI; significant negative correlations are attained by species in group V (Fig. 9; tables 3 and 4). The former groups are associated with wetter and lighter conditions than the latter (see habitat correlations, Table 3).

Component 3 draws out 14% of the variation in the data. Species related to this axis are those characterizing mainly types I and II on one end and type VI on the other. The former groups are associated with drier and lighter conditions than the latter (habitat correlations, Table 3).

Environmental models

Depth to groundwater (yr avg) and canopy cover ratings achieve relatively high indices of importance in one or both P.C.A. runs. Because of this, and because they are easily grasped, single measures for moisture and light, the main tree dominants and the understory types are plotted in terms of averages for these measures in Figure 10.

The model for tree dominants includes the six best-sampled dominance types plotted in terms of the habitat means for the sample of 67 plots and for all uniform plots of the same types from the total sample (Fig. 10a). For canopy cover the means from 67 plots yield the greatest differences. The dominants with the most open canopies are trembling aspen and grey birch (e.g., see Fig. 11); canopies for other dominants

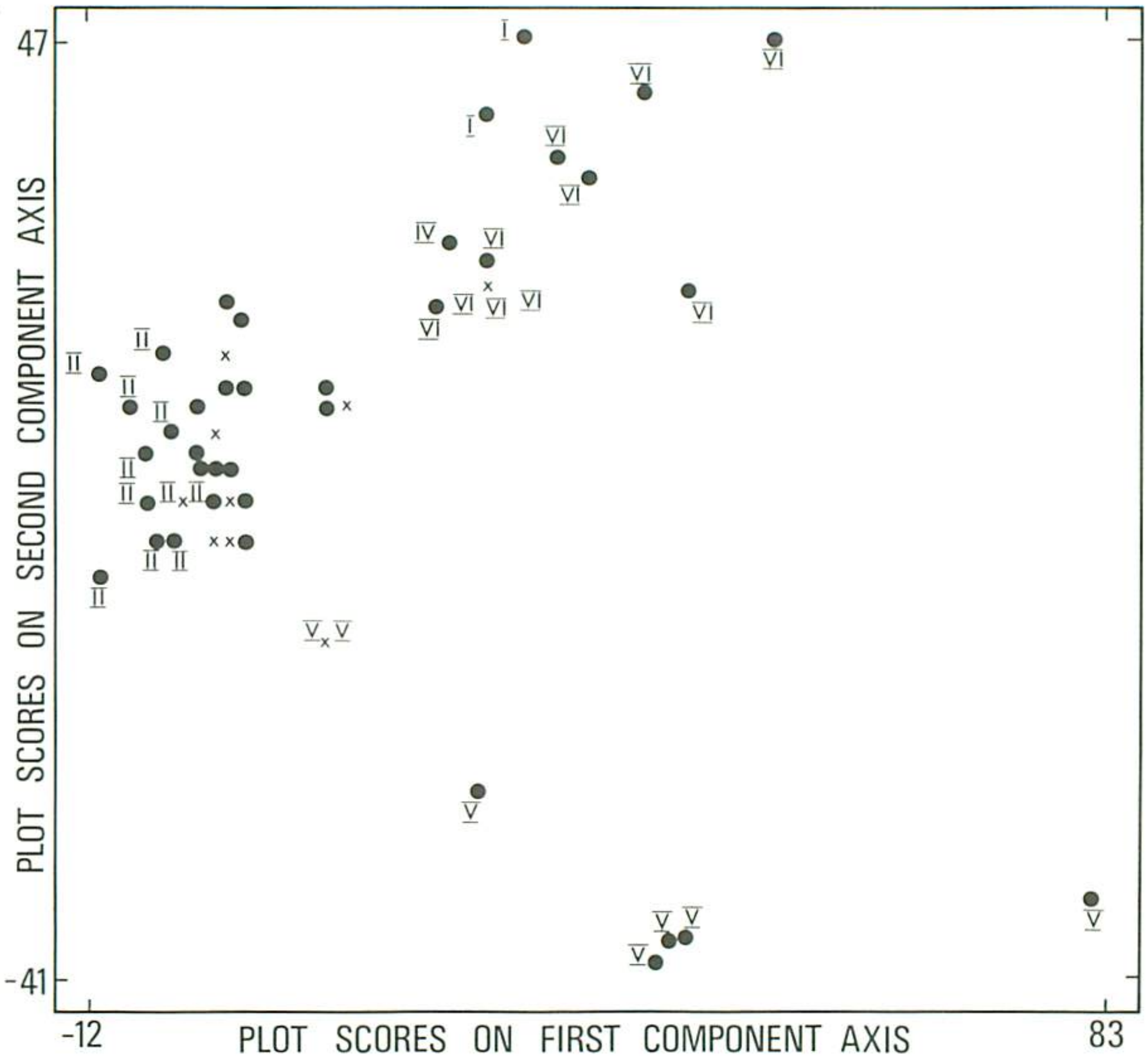

Fig. 9. P.C.A. vegetational ordination model based on cover values for 49 shrub and herb species in 67 stands. June 1970.

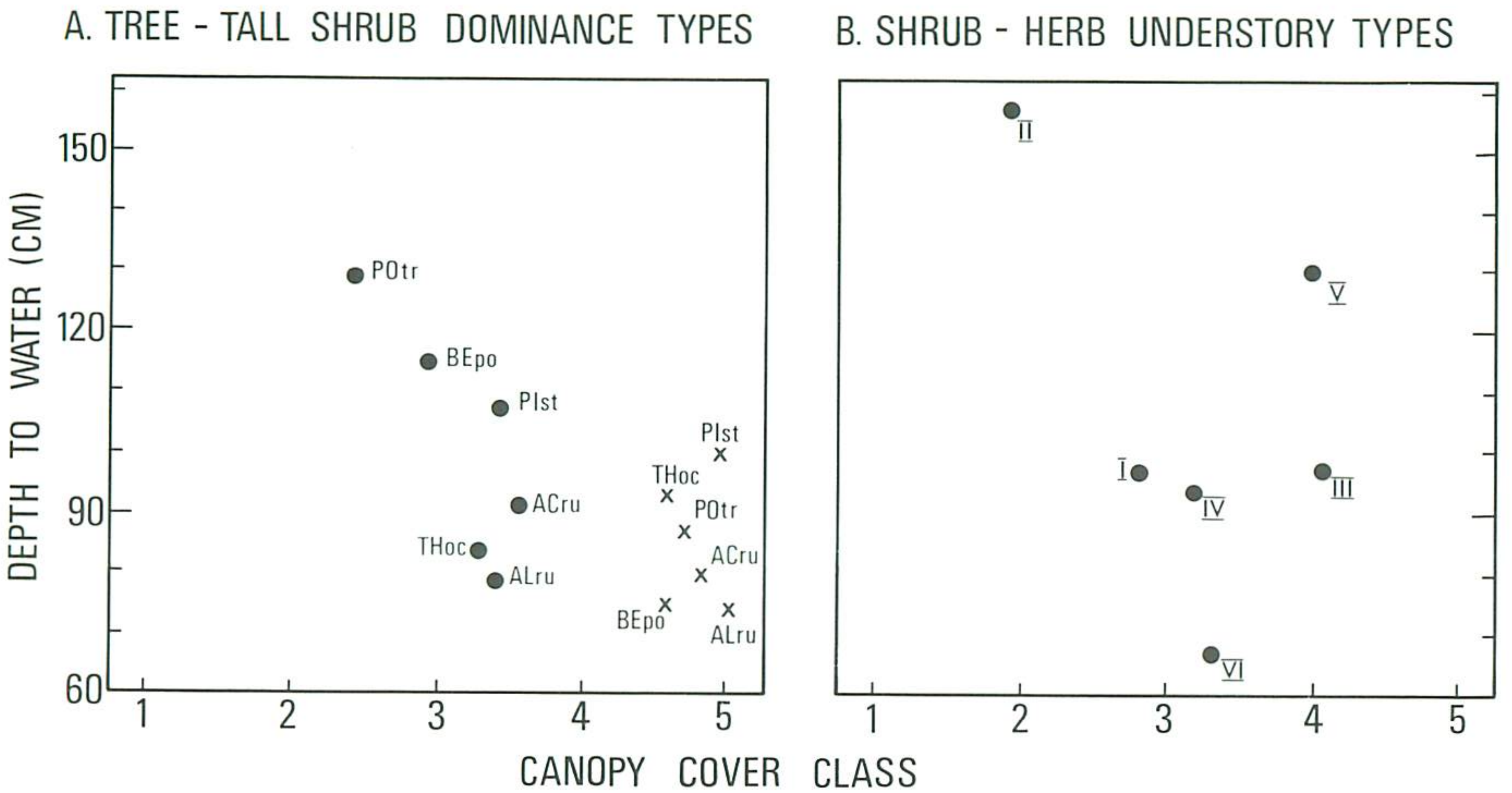

Fig. 10. Environmental ordination models based on means for depth to groundwater (yr avg) and canopy cover class. Fig. 10a, six major dominance types, based on leading dominance (greatest sum dbh); 0--means for the 67 stands sampled for shrubs and herbs, using the first set of canopy cover ratings; x--means for all sampled stands of these dominance types at the CRF, using the second set of canopy cover ratings; Fig. 10b, six shrub-herb stand types, derived from agglomerative classification. ACru = *Acer rubrum*, ALru = *Alnus rugosa*, BEpo = *Betula populifolia*, PIst = *Pinus strobus*, POtr = *Populus tremuloides*, THoc - *Thuja occidentalis*. June 1970.

Fig. 11. Tamarack in a grey birch-dominated forest. The site is poorly drained, on near-level terrain, with more than 40 cm of sand overlying clay. The groundwater was at or above the surface during spring, fall and winter, and fell to more than 60 cm below the surface during the dry summer. Near Plot Line BB1830, East Block, CRF. 4/11/70.

are somewhat denser. For moisture preferences the data from the total sample are better because they are based on more stands. Drier dominance types are trembling aspen, white cedar, and white pine; wetter types are speckled alder, grey birch, and red maple.

The understory types are more responsive to differences in moisture and light (Fig. 10b). Type II is the driest and type VI the wettest. The other types are intermediate, with V relatively drier and I, III and IV somewhat moister. Canopy cover averages indicate that type II is the most open type, followed by type I; types III and V are the most shaded types. The high shading in type III probably explains why it has a sparse understory. It is interesting that the P.C.A. extracted variation mainly from stands of types II, V and VI on the first two components (Fig. 9). These types are spatially separated by the greatest distances in the environmental model (Fig. 10b), and represent the three types that are environmentally most distinct. This correspondence of vegetationally and environmentally derived models suggests that the greater the environmental differences between types, the greater the differences in terms of vegetational variation between types. Finally, there is good correspondence between the interpretations of environmental relations of the types from the shrub and herb P.C.A. and the interpretations from the shrub and herb environmental model.

The moisture gradient

Species and habitat measures were summarized in terms of five groundwater classes (yr avg values) as follows: 1 -- $\leq$ 49 cm; 2 -- 50-75 cm; 3 -- 76-100 cm; 4 -- 104-125 cm; and 5 -- $\geq$ 125 cm[10]. Although both P.C.A.'s show that the subjective moisture classes have higher correlations with the components, we wish to show relationships of species to the less subjective depth-to-groundwater classes.

Means for subjective moisture class ratings among the five groundwater level classes show a direct relationship (Table 5). The subjective ratings do not distinguish between groundwater classes 3 and 4 as the same average, 2.8, was obtained for both. Organic horizons are considerably thicker in the wetter class 1. Depth to marine clay and depth of sand have greater values in drier classes 3-5. Deeper deposits of sand are associated with higher, drier sites. Canopy cover ratings show no clear relationships to groundwater classes.

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[10] These depths are from the ground surface to the groundwater level.

Table 5 Mean cover values, based on the number of stands in the class, and frequencies for shrubs and herb species in five depth-to-groundwater classes (yr avg). Species included are those 49 which were present in 11 or more of the 67 stands (the same species and stands as used in the agglomerative classification and the P.C.A. for shrubs and herbs)

Groundwater class	1		2		3		4		5	
Depth to groundwater (cm)	≤ 49		50-74		75-99		100-124		≥ 125	
No. of stands	10		15		13		11		18	
Selected habitat measures										
Cover class (first rating)	3.1		3.5		3.4		3.7		2.9	
Moisture class (subjective)	1.3		2.0		2.8		2.8		4.1	
Depth to groundwater (cm, yr avg)	40		60		89		109		181	
Depth to marine clay (cm)	108		115		192		183		260	
Depth of organic-rich layer (cm)	37		18		18		16		11	
Depth of sand (marine clay-organic) (cm)	83		104		176		167		250	
Shrubs	Avg cover	Fre-quency								
Cornus alternifolia[a]	0.0	0	0.3	27	0.2	15	0.6	55	0.7	56
Kalmia angustifolia	0.0	0	1.6	40	0.7	54	0.1	9	0.1	11
Nemopanthus mucronata	6.0	50	0.1	13	0.4	38	0.4	36	0.0	0
Prunus virginiana	0.0	0	0.2	20	0.2	15	0.4	36	0.2	22
Rhamnus frangula	0.8	40	1.3	33	0.4	38	0.5	27	0.4	39
Rubus hispidus	0.8	60	4.9	60	17.0	92	7.6	64	2.8	50
Rubus spp.[b]	0.4	40	0.1	7	0.5	38	0.5	45	2.2	17
Rubus idaeus var. *aculeatissimus*[c]	0.3	30	0.1	7	3.2	38	0.4	18	4.1	44
Salix petiolaris	0.4	40	2.6	13	0.3	15	0.2	18	1.1	28

(continued)

Table 5 Mean cover values, based on the number of stands in the class, and frequencies for shrubs and herb species in five depth-to-groundwater classes (yr avg). Species included are those 49 which were present in 11 or more of the 67 stands (the same species and stands as used in the agglomerative classification and the P.C.A. for shrubs and herbs) (continued)

Groundwater class	1		2		3		4		5	
Depth to groundwater (cm)	≤ 49		50-74		75-99		100-124		≥ 125	
No. of stands	10		15		13		11		18	
Shrubs (cont'd)	Avg cover	Fre-quency								
Spiraea alba	1.0	60	4.3	60	3.9	85	3.8	45	9.9	67
Spiraea tomentosa	0.5	30	0.3	20	0.0	0	0.2	18	0.3	22
Vaccinium myrtilloides	0.8	60	0.3	27	0.5	38	0.2	18	1.0	22
Viburnum cassinoides	3.7	70	3.1	53	0.7	69	0.5	45	0.4	44
Herbs										
Achillea millefolium	0.2	20	0.3	27	0.3	31	0.4	36	0.3	33
Agrostis stolonifera	0.1	10	0.1	13	0.3	15	0.0	0	1.1	33
Aster simplex	4.0	30	2.9	40	0.1	8	0.2	18	0.3	28
Aster umbellatus	0.4	20	0.5	40	0.2	23	0.3	27	0.1	11
Athryium filix-femina	0.1	10	0.5	40	0.1	8	0.6	64	0.3	22
Calamagrostis canadensis	5.7	60	0.7	60	0.2	15	1.8	54	0.1	11
Carex arctata	0.5	50	0.3	27	0.5	46	0.6	64	0.6	44
Carex brunnescens	0.5	30	0.1	13	0.1	8	0.3	27	0.1	6
Carex debilis	0.2	20	0.4	40	0.5	54	0.4	36	0.2	17
Carex scoparia	0.4	40	0.1	13	0.1	8	0.1	9	0.2	17
Danthonia spicata	0.0	0	0.1	7	3.2	15	0.1	9	7.2	61
Dryopteris austriaca	0.5	50	0.6	60	0.2	15	0.6	55	0.2	17
Equisetum arvense	0.4	40	0.7	53	0.7	69	0.3	27	0.6	44
Equisetum sylvaticum	0.4	40	0.5	47	0.2	15	1.6	36	0.2	17
Fragaria virginiana	6.7	50	1.2	27	0.5	54	0.5	45	3.4	61
Lycopodium complanatum	0.0	0	0.3	27	7.5	62	8.6	45	11.7	44
Lycopodium obscurum	0.1	10	1.1	13	0.3	31	0.3	27	0.2	11

(continued)

Table 5 Mean cover values, based on the number of stands in the class, and frequencies for shrubs and herb species in five depth-to-groundwater classes (yr avg). Species included are those 49 which were present in 11 or more of the 67 stands (the same species and stands as used in the agglomerative classification and the P.C.A. for shrubs and herbs) (concluded)

Groundwater class	1		2		3		4		5	
Depth to groundwater (cm)	≤ 49		50–74		75–99		100–124		≥ 125	
No. of stands	10		15		13		11		18	
	Avg cover	Fre-quency								
Herbs (cont'd)										
Lycopus uniflorus	0.9	70	1.7	60	0.2	8	0.0	0	0.1	11
Maianthemum canadense	2.4	80	5.4	80	0.7	69	2.8	100	2.7	72
Mediola virginiana	0.3	30	0.1	7	0.0	0	0.6	45	0.3	17
Muhlenbergia mexicana	0.1	10	0.1	7	0.2	23	0.3	27	0.2	17
Onoclea sensibilis	8.7	90	5.3	67	8.1	100	2.3	82	3.3	39
Osmunda cinnamomea	16.9	70	11.8	73	14.9	92	5.2	55	2.6	39
Osmunda regalis	5.7	40	3.3	53	9.9	77	0.3	27	0.2	17
Pteridium aquilinum	0.2	20	3.0	40	5.0	23	0.4	36	2.4	56
Pyrola elliptica	0.1	10	0.2	20	0.5	46	0.6	55	0.3	33
Ranunculus acris	0.2	20	0.1	13	0.1	8	0.3	27	0.2	17
Rubus pubescens	0.7	70	0.3	33	0.3	31	0.2	18	0.1	6
Solidago canadense	0.1	10	0.1	13	0.2	15	0.2	18	0.2	22
Solidago graminifolia	1.5	10	0.1	13	0.3	31	0.1	9	0.4	44
Solidago rugosa	0.8	80	0.7	53	0.7	69	1.9	64	0.8	44
Taraxacum officinale	0.4	40	0.1	13	0.1	8	0.2	18	0.3	33
Thelyteris palustris	0.6	60	0.5	33	0.4	38	0.3	27	0.3	17
Trientalis borealis	0.5	50	0.4	40	0.2	23	0.2	18	0.1	6
Viola pallens	0.5	50	0.4	40	0.4	38	0.6	55	0.2	17
Moss										
Polytrichum commune	1.6	20	0.3	20	3.4	38	4.9	27	0.2	17

[a] Nomenclature of vascular species is according to Gleason and Cronquist (1963), that of the single moss species to Crum *et al.* (1965).

[b] *Rubus* spp. consist only of those specimens that were not positively identified.

[c] This identification follows Gray's Manual of Botany (Fernald 1950).

Definite distribution patterns for shrubs and herbs among moisture classes can be seen in Table 5. Species peaking in the wettest classes (1-2) include the shrubs *Kalmia angustifolia*, *Nemopanthus mucronata*, *Rhamnus frangula*, *Salix petiolaris* and *Viburnum cassinoides*, and the herbs *Aster simplex*, *Calamagrostis canadensis* and *Solidago graminifolia*. Species in the dry classes 4-5 include the shrub *Spiraea alba*, and the herbs *Agrostis stolonifera*, *Danthonia spicata*, *Lycopodium complanatum* and *Solidago rugosa*.

Distribution patterns for the three size classes of tree species are given in Appendix C. Patterns are generally poorly defined. This corresponds with the results from the tree and sapling P.C.A. which show moisture measures to be only weakly related to vegetational variation. Nonetheless, some relationships can be observed. Species more frequent in the wetter classes 1-3 include speckled alder, American elm, red maple, pussy willow and white willow (*cf.* positioning of alder, grey birch and maple, Fig. 10a). Species in drier classes 4-5 include large-tooth aspen, trembling aspen, white birch, black cherry, pin cherry and white pine (*cf.* positioning of trembling aspen and pine, Fig. 10a). Other species show less definite trends or have too small a representation to reveal an association with a particular part of the gradient.

The light gradient

Species and habitat data are summarized in terms of five classes of canopy cover: 1 -- 0-25%; 2 -- 26-50%; 3 -- 51-75%; 4 -- 76-87%; and 5 -- 88-100%. For shrubs and herbs the cover ratings given by the first team are used because the distribution of the 67 stands among them was more uniform than among the second ratings. For tree, sapling, and seedling data the canopy cover ratings given by the second team are used because these are complete for 480 of the 489 stands.

The only clear relation of habitat measures to the five canopy cover values (the first ratings) are, as would be expected, the averages for the second canopy cover values (Table 6). The averages show that the second ratings were higher than the first.

Shrub and herb species demonstrate a wide variety of distributional patterns among the light classes (Table 6). To judge where species peak we use the value of frequency multiplied by average cover (based on number of values summed). Species demonstrating preferences for more open sites in classes 1-3 include shrubs such as *Rubus hispidus*, *R. strigosus* and *Spiraea alba*, and herbs such as *Aster simplex*, *Danthonia spicata*, *Fragaria virginiana*, *Pteridium aquilinum* and *Solidago graminifolia*. Species having preferences for closed forests with classes 4-5 include shrubs such as *Cornus alternifolia* and *Prunus virginiana*, and herbs such as *Athyrium filix-femina*, *Dryopteris austriaca* and *Lycopodium complanatum*.

Table 6 Mean cover values, based on number of stands in the class, and frequencies for shrubs and herb species in five canopy cover classes (first ratings). Species included are those 49 which were present in two or more of the 67 stands (the same species and stands as used in the agglomerative classification and the P.C.A. for shrubs and herbs)

Canopy cover classes	1		2		3		4		5	
Cover class range	0-25%		26-50%		51-75%		76-87%		88-100%	
No. of stands	5		10		28		17		7	
Selected habitat measures										
Cover class (second rating)	1.5		3.2		4.6		4.9		5.0	
Depth to groundwater (cm, yr avg)	98		148		97		86		109	
Depth to marine clay (cm)	93		226		166		169		177	
Depth of organic-rich layer (cm)	22		18		18		20		10	
Depth of sand (marine clay-organic) (cm)	72		208		147		149		166	
Shrubs	Avg cover	Fre-quency								
Cornus alternifolia[a]	0.2	20	0.4	40	0.3	21	0.5	47	0.4	43
Kalmia angustifolia	0.6	20	0.2	20	0.9	32	0.4	24	0.0	0
Nemopanthus mucronata	0.2	20	0.7	30	2.0	18	0.4	35	0.1	14
Prunus virginiana	0.2	20	0.2	20	0.1	14	0.2	24	0.3	29
Rhamnus frangula	0.0	0	0.7	50	0.9	36	0.5	41	0.3	29
Rubus hispidus	10.6	40	9.7	70	9.3	68	1.7	82	0.1	14
Rubus spp.[b]	7.6	20	0.2	20	0.4	32	0.3	29	0.1	14
Rubus idaeus var. *aculeatissimus*[c]	0.4	40	5.6	50	2.2	32	0.1	12	0.1	14
Salix petiolaris	0.2	20	2.1	50	1.6	29	0.1	6	0.0	0

(continued)

Table 6 Mean cover values, based on number of stands in the class, and frequencies for shrubs and herb species in five canopy cover classes (first ratings). Species included are those 49 which were present in two or more of the 67 stands (the same species and stands as used in the agglomerative classification and the P.C.A. for shrubs and herbs) (continued)

Canopy cover classes	1		2		3		4		5	
Cover class range	0-25%		26-50%		51-75%		76-87%		88-100%	
No. of stands	5		10		28		17		7	
Shrubs (cont'd)	Avg cover	Fre- quency								
Spiraea alba	19.0	100	13.8	90	3.5	64	0.7	53	0.3	29
Spiraea tomentosa	0.6	20	0.5	50	0.4	21	0.0	0	0.0	0
Vaccinium myrtilloides	0.2	20	2.1	50	0.4	29	0.3	29	0.3	29
Viburnum cassinoides	0.0	0	5.6	30	1.2	64	0.8	82	0.3	29
Herbs										
Achillea millefolium	0.8	80	0.4	40	0.3	29	0.2	18	0.1	14
Agrostis stolonifera	3.8	100	0.6	40	0.1	7	0.0	0	0.0	0
Aster simplex	15.2	40	0.6	60	0.1	14	0.2	24	0.1	14
Aster umbellatus	1.0	60	0.4	40	0.2	14	0.2	24	0.1	14
Athyrium filix-femina	0.0	0	0.0	0	0.4	29	0.5	35	0.7	71
Calamagrostis canadensis	0.2	20	4.3	40	1.4	43	0.4	35	0.3	29
Carex arctata	0.4	40	0.3	30	0.5	43	0.5	47	0.7	71
Carex brunnescens	0.0	0	0.0	0	0.2	14	0.3	29	0.1	14
Carex debilis	0.0	0	0.1	10	0.4	39	0.4	41	0.4	43
Carex scoparia	0.6	60	0.2	20	0.2	21	0.0	0	0.0	0
Danthonia spicata	10.8	60	11.1	60	0.2	14	0.1	6	0.1	14
Dryopteris austriaca	0.0	0	0.1	10	0.4	43	0.5	47	0.6	57
Equisetum arvense	0.4	40	0.6	40	0.6	57	0.6	47	0.3	29
Equisetum sylvaticum	0.0	0	0.2	20	0.9	39	0.3	29	0.3	29
Fragaria virginiana	19.0	100	0.7	70	1.8	50	0.3	29	0.1	14
Lycopodium complanatum	0.4	40	3.1	30	0.8	25	18.4	65	5.6	29
Lycopodium obscurum	0.2	20	0.1	10	0.7	14	0.4	35	0.0	0

(continued)

Table 6 Mean cover values, based on number of stands in the class, and frequencies for shrubs and herb species in five canopy cover classes (first ratings). Species included are those 49 which were present in two or more of the 67 stands (the same species and stands as used in the agglomerative classification and the P.C.A. for shrubs and herbs) (concluded)

Canopy cover classes	1		2		3		4		5	
Cover class range	0-25%		26-50%		51-75%		76-87%		88-100%	
No. of stands	5		10		28		17		7	
Herbs (cont'd)	Avg cover	Frequency								
Lycopus uniflorus	0.2	20	0.4	20	1.1	43	0.2	18	0.1	14
Maianthemum canadense	0.4	40	2.1	50	2.8	89	5.0	82	1.3	100
Mediola virginiana	0.0	0	0.2	20	0.3	18	0.4	24	0.1	14
Muhlenbergia mexicana	0.2	20	0.3	30	0.2	21	0.1	6	0.0	0
Onoclea sensibilis	0.2	20	2.0	40	10.1	79	2.5	88	1.1	86
Osmunda cinnamomea	0.2	20	7.7	30	15.2	71	7.9	82	0.7	71
Osmunda regalis	0.0	0	3.8	10	4.1	50	5.1	65	0.3	29
Pteridium aquilinum	12.6	20	2.2	40	1.9	39	1.2	41	0.3	29
Pyrola elliptica	0.2	20	0.0	0	0.5	46	0.4	41	0.1	14
Ranunculus acris	0.4	40	0.1	10	0.3	29	0.0	0	0.0	0
Rubus pubescens	0.0	0	0.3	30	0.3	29	0.4	41	0.1	14
Solidago canadense	0.4	40	0.1	10	0.2	21	0.1	6	0.1	14
Solidago graminifolia	3.6	80	0.6	60	0.2	18	0.1	6	0.0	0
Solidago rugosa	1.0	60	2.3	70	0.9	79	0.4	41	0.1	14
Taraxacum officinale	0.8	80	0.3	30	0.2	18	0.1	12	0.1	14
Thelyteris palustris	0.2	20	0.2	20	0.5	39	0.4	41	0.1	14
Trientalis borealis	0.2	20	0.2	20	0.4	36	0.2	24	0.0	0
Viola pallens	0.0	0	0.4	40	0.5	46	0.4	41	0.1	14
Moss										
Polytrichum commune	0.0	0	5.80	50	0.82	25	2.4	24	0.0	0

[a] Nomenclature of vascular species is according to Gleason and Cronquist (1963), that of the single moss species to Crum *et al.* (1965).

[b] *Rubus* spp. consist only of those specimens that were not positively identified.

[c] This identification follows Gray's Manual of Botany (Fernald 1950).

Distributional patterns for the three size classes of tree species are given in Appendix D. Tree-sized individuals of most species attain highest frequencies in the closed forest classes 4 and 5, but these same species are also found in the more open plots owing to the scattered openings and partial clearings which occur adjacent to all forest types. Species that attain highest frequencies in classes 1-4 include trembling aspen, grey birch, choke cherry, pin cherry, staghorn sumac, bebb willow, and white willow. These species are all common colonizers of open areas in forests. However, a number of the species attaining highest frequencies in classes 4 and 5, in particular speckled alder, white cedar and red maple, also colonize the open areas.

Generally, sapling and seedling distributions follow those of the tree-sized individuals (Appendix D). However, the relative magnitudes of frequencies across the classes give some indications of the future composition of the Dolman Ridge forests.

Red maple has the highest numbers of plots of saplings and seedlings (Appendix D). This species will undoubtedly maintain or increase its importance in the CRF. Of the other shade-tolerant species that might be expected to increase in importance, only yellow birch has enough regeneration to suggest that it might increase. Basswood, beech, red ash, and sugar maple have negligible numbers of plots of saplings and seedlings, usually corresponding to limited numbers of parent trees. That the same is true for balsam fir and white spruce is not surprising since these are species of upland boreal forest to the north. Although hemlock has small numbers of reproduction over all, it is reproducing strongly in two locations[11] for reasons not clearly understood.

The numerous openings and clearings, consisting of abandoned fields and pasture plus a hydroelectric powerline through the west block (Map 3), provide sites for tree colonization, mainly by pioneer, shade-intolerant species. From the data in Appendix D and field observations it can be seen that species most frequently invading these openings include speckled alder, trembling aspen, grey birch, white birch, black cherry, pin cherry, and white cedar. At present white pine is not regenerating well in the CRF, probably owing to competition from hardwoods. American elm is reproducing and will probably remain in the forest as seedlings, saplings and small trees in spite of the steady loss of larger individuals owing to Dutch elm disease (*cf.* McBride 1973).

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[11] Between lines J and L and plots 780 and 810, and between lines EE and FF and plots 1500 and 1530.

DISCUSSION

We have used a number of approaches in analyzing ecological relationships, and useful insights and conclusions are gained from each. Classifications for forest dominance types (leading dominant) and shrub-herb types (agglomerative classification) give units for description and orientation. Principal component analysis provides a means of judging relative influence of various factors and portraying vegetational relationships. Environmental models provide a means of portraying environmental relationships among the types. Species distributions plotted in terms of classes of depth to groundwater and canopy cover provide a summary of major species-environment relationships at the CRF.

A methodological problem pertaining both to P.C.A. and to agglomerative classification is that no transformations were applied to the data prior to the analysis. In this way the analysis is influenced by species with the largest quantitative values. This was done so that the more abundant species would play the greater role in the outcome of the analysis, mainly on the assumption that most people in the field identify more closely with quantitative abundance of species rather than simple presence.

Vegetational variation at the CRF is influenced mainly by light and moisture. The edaphic-relief measures used here are not as highly related, but it must be realized that these are related to the moisture regime, e.g., deep sand deposits and steep slopes on embankments are associated with relatively deep groundwaters, whereas shallow sands, drainageways, and low flat areas are associated with shallow groundwaters. Indeed, the subjective moisture class, which often showed significant correlation with principal components of vegetational variation, was derived mainly from positioning on slope.

Some general relationships between the terrain units and cover types can be discerned by comparing maps 1 and 3. The majority of species occur across a wide range of terrain units. For example, trembling aspen, grey birch, white cedar and red maple all are found as dominants on embankments, well-drained and poorly drained sites, and also sometimes in the distributary channels.

The well-drained deltaic lobes bordering the north and south embankments are predominantly open (nonforested). Openings in the adjacent forested parts of the well-drained deltaic lobes consist of elevated knolls and mounds (Fig. 2). These openings, owing to their being underlain with relatively deep deposits of well-drained sand, are only slowly recolonized by forest species. Before settlement these areas may have been natural openings of grass and shrubs. Such openings could be maintained by the rapid drainage of the deep sands underlying these knolls, or by the tendency for larger trees to be blown down owing to the unstable substrata. A final possibility is that some were created by Indians in the sites which then, as now, were the most favorable upland sites for resting or camping.

On the elevated, well-drained, younger deltaic lobe in the north-central part of the west block are found areas of large sugar maple, beech and hemlock. Part of the area is an open field with large maples left from previous sugar bush operations. On the embankment just north of this area hemlock is dominant. The embankment is well drained, and microclimatically cooler and moister owing to its north-facing aspect. A raised area in the east part of the east block also supports some large hemlocks.

The centrally located, poorly drained segments of the deltaic lobes are occupied by speckled alder, grey birch and red maple. White pine overlaps between poorly drained and well-drained segments in the west block. The abandoned distributary channels contain such dominants as speckled alder, American elm and willows (swamp species).

In the poorly drained portion of the east block an association between tamarack (in grey birch-dominated forest) and a particular set of site conditions was noted (Fig. 2). The site was characterized as poorly drained, near-level terrain, with more than 40 cm of sand overlying clay. The groundwater was at or above the surface during spring, fall and winter, and fell to more than 60 cm below the surface during the dry summer. It appeared to be a typical meadow soil.

The preponderance of red maple on the central plateau of the CRF may be explained by edaphic-relief factors--a high proportion of relatively level terrain underlain closely by marine clay acting together to create relatively poor drainage and wet substrates. Red maple is known to favor such wet locations, and two other common species, speckled alder and grey birch, act in a similar manner. It is surprising that white cedar does not occur in as wet locations as the above three species (Fig. 10a) but this may be because this species is associated with aerated groundwaters when it is on wet sites, and in the CRF the wetter sites are closer to the marine clays which do not provide adequate aeration.

Another reason for the predominance of red maple is that it has vigorous vegetative reproduction following cutting and/or burning. The red maple forest in the southeast corner of the west block has the form of fairy rings where suckers have developed from former trees. Other areas of young red maple also show these forms. Hence, the predominance of red maple is in large part explained by the wetness of the area, plus the disturbance which has probably increased the commonness of the species.

CONCLUSIONS

1. The natural vegetation at the CRF has been heavily disturbed by varying amounts of clearing for cultivation and pasturing. Other disturbances have been clearing for electric power lines, topsoil mining, sugar bush operations, ditching for drainage, and burning. Consequently, degree of forest disturbance varies from longtime wooded areas disturbed only by pasturing and some selective cutting, through varying stages of forest regrowth since land abandonment, to open areas with no forest. Large open-grown trees are found alone or as small pockets, and these were probably seedlings or young trees missed at the time of active clearing 150 years ago. The large amount of disturbance has masked the relationships of vegetation with abiotic factors of the environment.

2. Variation in forested vegetation at the CRF is influenced most directly by light and moisture regimes. The light gradient in large part results from the high amount of disturbance which has created a wide range of light conditions ranging from open through pioneer to closed forests. The edaphic-relief (landform) regime is not as influential as a direct factor, but it is nonetheless important in that it indirectly determines moisture regime via topographic positioning and soil texture.

3. The most frequent leading dominants, in order of decreasing frequency, are red maple, grey birch, trembling aspen, white pine, white cedar, and speckled alder. Grey birch and trembling aspen have more open canopies than the other dominance types. Red maple, grey birch and speckled alder are found, on the average, on soils having higher groundwater levels (wetter soils) than those for white pine, white cedar and trembling aspen.

4. Six shrub-herb types are recognized from an agglomerative classification emphasizing plant quantity (cover). The types and the species which characterize them are: I - *Rubus hispidus*, II - *Spiraea alba*, III - "sparsely understoried" (having no species with high cover values), IV - *Muhlenbergia mexicana* ("wet grassy type"), V - *Fragaria virginiana*, and VI - *Onoclea sensibilis* and *Osmunda cinnamomea*. (See Table 1 for other species characterizing these types.) Type II is associated with the driest and most open-canopied forest sites. Type V is the second driest, but is associated with the most closed canopied stands along with type III. Type VI is the wettest type. Types I and IV do not, on the average, have extreme moisture or light conditions (Fig. 10b). There are no strong relationships between shrub-herb types and

forest dominance types. This may be because of the high amount of disturbance which has altered the original forests.

5. The P.C.A. vegetational ordination of shrub-herb data extracts variation mainly from stands of types II, V and VI. These same types are separated by the greatest distances in the depth-to-groundwater canopy cover environmental model. This correspondence of vegetationally and environmentally derived models suggests that the greater the environmental differences between types, the greater the differences in terms of vegetational variation.

6. The majority of tree species occur across a wide range of terrain units. The elevated, well-drained, sand deltaic lobes bordering the north and south embankments are predominantly open but also support local small stands of sugar maple, beech and hemlock. Hemlock is also on the north-facing, well-drained, microclimatically cooler north embankment in the west block. Open, elevated, sand-underlain knolls in the forest may have originally been natural openings of grass and shrubs. The centrally located, poorly drained portions of Dolman Ridge are occupied principally by speckled alder, grey birch and red maple. Distributary channels contain speckled alder, American elm, and willows.

7. The predominance of red maple at the CRF is in large part explained by its association with the generally poorly drained, wet terrain, caused by the relatively flat land which is closely underlain by impervious marine clay deposits. Another factor may be the vigorous vegetative reproduction of red maple following the numerous disturbances in the area.

8. Future development of the forest will see maintenance or increase in relative abundance of red maple, as indicated by its high numbers of seedlings and saplings. Other shade-tolerant species such as hemlock, yellow birch, and sugar maple will maintain themselves in the local areas where they already occur as large parent trees. White pine will not increase. The numerous openings and clearings will see colonization mainly by shade-intolerant, pioneer species, speckled alder, trembling aspen, grey birch, white birch, black cherry, pin cherry and white cedar. Although past disturbances will continue to leave their imprint in terms of dominant colonizers, open-grown trees, and a light gradient from forested to open conditions, vegetation will tend to develop into more clearly defined entities which are more closely related to abiotic factors of the environment.

LITERATURE CITED

Belden, H. 1879. The historical atlas of Carleton County.

Bik, M.J.J. 1969. Surficial deposits and geomorphology, Central Research Forest, Ontario. Rep. Act. Apr.-Oct. 1968, Geol. Surv. Can. Pap. 69-1, Part A: 187-188.

Bik, M.J.J., R. Herr and J. Salm. 1971. Saline groundwater, Central Research Forest, Ramsayville, Ontario. Rep. Act. Apr.-Oct. 1970, Geol. Surv. Can. Pap. 71-1, Part A: 149-154.

Camfield, M. 1969. Pollen record at the Mer Bleue. Can. Field Natur. 83: 7-13.

Crum, H., W.C. Steere and L.E. Anderson. 1965. A list of the mosses of North America. Bryologist 68: 377-432.

Daubenmire, R. 1966. Vegetation: identification of typal communities. Science 151: 291-298.

Dyck, W., J.A. Lowdon, J.G. Fyles, and W. Blake. 1966. Geological survey of Canada radiocarbon dates V. Geol. Surv. Can. Pap. 66-48: GSC#454.

Fernald, M.L. 1950. Gray's manual of botany 8th ed. Am. Book Co., New York. 1632 p.

Gillett, J.M. 1958. Checklist of plants of the Ottawa District. Can. Dep. Agric., Sci. Serv., Bot. Plant Path. Div., Ottawa. 89 p.

Gleason, H.A., and A. Cronquist. 1963. Manual of vascular plants of northeastern United States and adjacent Canada. D. van Nostrand, Princeton, N.J. 810 p.

Hosie, R.C. 1969. Native trees of Canada. 7th ed. Can. For. Serv., Ottawa. 380 p.

Hughson, J.W., and C.C.J. Bond. 1964. Hurling down the pine. Hist. Soc. Gatineau. 130 p.

Jeglum, J.K. 1974. Relative influence of moisture-aeration and nutrients on vegetation and black spruce growth in northern Ontario. Can. J. For. Res. (In press)

Jeglum, J.K., C.F. Wehrhahn and J.M.A. Swan. 1971. Comparisons of environmental ordinations with principal component vegetational ordinations for sets of data having different degrees of complexity. Can. J. For. Res. 1: 99-112.

Lowdon, J.A., J.G. Fyles, and W. Blake. 1967. Geological survey of Canada radiocarbon dates VI. Geol. Surv. Can. Pap. 67-2, Part B: GSC#547.

Lowdon, J.A., and W. Blake. 1970. Geological survey of Canada. Radiocarbon dates IX. Geol. Surv. Can. Pap. 70-2, Part B: GSC#842.

Marie-Victorin, F., and E. Rouleau. 1964. Flore Laurentienne, 2nd ed. Univ. Montréal Press. 925 p.

McBride, J. 1973. Natural replacement of disease-killed elms. Am. Midl. Natur. 90: 300-306.

Mott, R.J., and M. Camfield. 1969. Palynological studies in the Ottawa area. Geol. Surv. Can. Pap. 69-38: GSC#681.

Orloci. L. 1967. An agglomerative method for classification of plant communities. J. Ecol. 55: 193-205.

Walker, H., and O. Walker. 1968. The Carleton saga. Runge Press Ltd., Ottawa. 571 p.

APPENDICES

APPENDIX A

Numbers of stands in which trees (≥3.5 inches dbh) occur and in which they are dominant (greatest Σdbh) in the Central Research Forest. Species included are those listed by Hosie (1969) in Native Trees of Canada which also occur in the CRF.[a] Species are arranged in order of decreasing frequency of stands of occurrence of tree-size individuals (or as clumps as for speckled alder and the willows, indicated by enclosure in parentheses)

Species	Tree presence in 489 stands	Presence as leading dominants	
		489 stands	67 stands
red maple (*Acer rubrum*)[b,c]	220	129	15
trembling aspen (*Populus tremuloides*)	189	51	9
speckled alder (*Alnus rugosa*)	(143)	16	5
grey birch (*Betula populifolia*)	131	86	10
white birch (*B. papyrifera*)	113	9	4
white pine (*Pinus strobus*)	70	24	7
american elm (*Ulmus americana*)	64	7	2
yellow birch (*Betula allegheniensis*)	56		
white cedar (*Thuja occidentalis*)	54	16	7
bebb willow (*Salix bebbiana*)	(37)		
white willow (*S. alba*)	(35)		
eastern hemlock (*Tsuga canadensis*)	34	5	2
pin cherry (*Prunus pensylvanica*)	33	2	
large tooth aspen (*Populus grandidentata*)	24	4	2
pussy willow (*Salix discolor*)	(18)	1	
balsam fir (*Abies balsamea*)	15		1
white spruce (*Picea glauca*)	13	2	
red ash (*Fraxinus pensylvanica*)	10		
tamarack (*Larix laricina*)	9		
beech (*Fagus grandifolia*)	7		
black cherry (*Prunus serotina*)	6	1	
sugar maple (*Acer saccharum*)	6	2	1
balsam poplar (*Populus balsamifera*)	4		
serviceberry (*Amelanchier canadensis*)	3		
basswood (*Tilia americana*)	1		

(continued)

APPENDIX A

Numbers of stands in which trees ($\geq$3.5 inches dbh) occur and in which they are dominant (greatest Σdbh) in the Central Research Forest. Species included are those listed by Hosie (1969) in Native Trees of Canada which also occur in the CRF.[a] Species are arranged in order of decreasing frequency of occurrence of tree-sized individuals in stands (or as clumps as for speckled alder and the willows, indicated by enclosure in parentheses) (concluded)

Species	Tree presence in 489 stands	Presence as leading dominants	
		489 stands	67 stands
black ash (*Fraxinus nigra*)	1		
choke cherry (*Prunus virginiana*)	1		
alternate-leaved dogwood (*Cornus alternifolia*)[d]	0		
Manitoba maple (*Acer negundo*)	0		
striped maple (*Acer pensylvanicum*)	0		
staghorn sumac (*Rhus typhina*)	0		
open[e]		122	3
road[f]		11	

[a] Species not sampled in the 489 stands, but occurring in the CRF and classed as trees by Hosie (1969) include common apple (*Pyrus malus*), white ash (*Fraxinus americana*), alder buckthorn (*Rhamnus frangula*), cottonwood (*Populus deltoides*), ironwood (*Ostrya virginiana*), mountain maple (*Acer spicatum*), silver maple (*Acer saccharinum*), showy mountain ash (*Sorbus decora*), nannyberry (*Viburnum lentago*), white poplar (*Populus alba*), and black spruce (*Picea mariana*).

[b] Nomenclature of tree species is according to Hosie (1969).

[c] The two forms of red maple, *Acer rubrum* and *A. rubrum* var. *tridens*, are present. Sometimes the red maple approaches silver maple (*A. saccharinum*) in leaf characteristics, and there may be some introgressive hybridization of these two species in the CRF. However, because the silver maple form was so infrequent, and its identification uncertain, we combined all such individuals with red maple.

[d] Although Hosie (1969) lists this as a "tree", i.e., attaining 15 ft in height, in the CRF it does not attain this size, and in fact never achieves 1 inch dbh.

[e] "Open" represents stands appearing open during sampling in the field. Usually no tree or sapling-sized individuals are present.

[f] These stands have a road or lane passing through them.

APPENDIX B

A list of shrubs, herb and bryophyte species identified from the Central Research Forest.

Shrubs and woody vines

Amelanchier spicata
Aronia melanocarpa[a]
Celastrus scandens
Cornus stolonifera
Corylus cornuta
Diervilla lonicera
Gaylusaccia baccata
Ilex verticillata
Juniperus communis
Kalmia angustifolia
Ledum groenlandicum
Lonicera canadensis
Myrica asplenifolia
Nemopanthus mucronata
Parthenocissus quinquefolia
Parthenocissus vitacea
Prunus serotina
Ribes glandulosum
Ribes hirtellum
Rubus allegheniensis
Rubus hispidus
Rubus occidentalis
Rubus setosus (Incl. *R. vermontanus*[b])
Rubus spp.
Rubus strigosus (Incl. *R. idaeus* var. *aculeatissimus*[b])
Salix petiolaris
Sambucus canadensis
Sambucus pubens
Solanum dulcamara
Spiraea alba
Spiraea tomentosa
Taxus canadensis
Vaccinium angustifolium
Vaccinium myrtilloides
Vaccinium myrtilloides x angustifolium
Viburnum alnifolium
Viburnum cassinoides
Viburnum opulus var. *americana*
Viburnum rafinesquianum

Herbs

Acalypha rhomboidea
Achillea millefolium
Actaea rubra
Agrimonia gryposepala
Agropyron repens
Agrostis hyemalis (Incl. var. *tenuis*)
Agrostis perennans
Agrostis stolonifera (Incl. *A. gigantea*[b])
Alisma plantago-aquatica
Amaranthus retroflexus
Ambrosia artemisiifolia
Amphicarpa bracteata
Anaphalis margaritacea
Anemone cylindrica
Anemone quinquefolia
Anemone reparia
Antennaria neglecta
Apocynum androsaemifolium
Aralia nudicaulis
Arisaema triphyllum
Asclepias incarnata
Asclepias syriaca
Aster accuminatus
Aster cordifolius
Aster lateriflorus
Aster novae-angliae
Aster simplex
Aster umbellatus
Athyrium filix-femina
Bidens cernua
Bidens frondosa
Bidens vulgata
Boehmeria cylindrica
Botrychium dissectum
Botrychium matricariaefolium
Botrychium multifidum

(continued)

APPENDIX B

A list of shrubs, herb and bryophyte species identified from the Central Research Forest. (continued)

Herbs (cont'd)

Botrychium virginianum
Brachyelytrum erectum
Bromus inermis
Calamagrostis canadensis
Campanula aparinoides
Cardamine pensylvanica
Carex aenea
Carex arctata
Carex brunnescens
Carex canescens
Carex communis
Carex crawfordii
Carex crinita
Carex debilis
Carex deflexa
Carex deweyana
Carex gracillima
Carex intumescens
Carex leptonervia
Carex lupulina
Carex nigromarginata var. *muhlenbergii*
Carex novae-angliae
Carex pseudocyperus
Carex retrorsa
Carex scabrata
Carex scoparia
Carex stipata
Carex tenera
Carex vulpinoidea
Cerastium vulgatum
Chelone glabra
Chenopodium album
Chimaphila umbellata
Chrysanthemum leucanthemum
Chrysosplenium americanum
Cichorium intybus
Cinna latifolia
Circaea alpina
Circaea quadrisulcata
Claytonia caroliniana
Clematis virginiana
Clintonia borealis
Convolvulus sepium
Conyza canadensis
Coptis groenlandicum
Cornus canadensis
Cyperus esculentus
Dactylis glomerata
Danthonia spicata
Datura stramonium
Drosera rotundifolia
Dryopteris austriaca
Dryopteris cristata
Echinochloe muricata
Eleocharis obtusa
Eleocharis ovata
Epilobium angustifolium
Epilobium glandulosum
Epilobium palustre
Epipactis helleborine
Equisetum arvense
Equisetum hyemale
Equisetum palustre
Equisetum sylvaticum
Erigeron acris
Erigeron annuus
Erigeron strigosus
Eriophorum virginicum
Erysimum cheiranthoides
Erythronium americanum
Eupatorium rugosum
Euphorbia helioscopia
Euphorbia vermiculata
Fragaria virginiana
Galeopsis tetrahit
Galinsoga ciliata
Galium asprellum
Galium obtusum
Galium trifidum var. *tinctorium*
Galium triflorum
Gaultheria procumbens

(continued)

APPENDIX B

A list of shrubs, herb and bryophyte species identified from the Central Research Forest. (continued)

Herbs (cont'd)

Gerardia acuta
Geum allepicum
Geum macrophyllum
Glyceria canadensis
Glyceria striata
Gnaphalium uliginosum
Gymnocarpium dryopteris
Hedeoma hispida
Helianthus giganteus
Hieracium aurantiacum
Hieracium canadense
Hieracium floribundum
Hieracium pratense
Hieracium scabrum
Hierochloe odorata
Hypericum adpressum
Hypericum canadense
Hypericum majus
Hypericum perforatum
Impatiens biflora
Iris versicolor
Juncus compressus
Juncus dudleyi
Juncus effusus
Juncus tenuis
Juncus vaseyi
Lactuca canadensis var. *longifolia*
Laportea canadensis
Leersia oryzoides
Leersia virginica
Lepidium densiflorum
Linaria vulgaris
Linnaea borealis
Lobelia inflata
Lycopodium clavatum
Lycopodium complanatum
Lycopodium obscurum
Lycopus americana
Lycopus uniflorus
Lysimachia thyrsiflora
Lythrum salicaria
Maianthemum canadense
Malaxis uniflora
Matteuccia struthiopteris
Medeola virginiana
Mitchella repens
Mitella nuda
Monotropa uniflora
Muhlenbergia mexicana
Muhlenbergia racemosa
Nepeta cataria
Oenothera biennis
Oenothera perennans
Onoclea sensibilis
Osmunda cinnamomea
Osmunda claytonii
Osmunda regalis
Oxalis acetosella
Oxalis montanum
Oxalis stricta
Panax trifolium
Panicum capillare
Panicum lanuginosum
Penstemon digitalis
Phleum pratense
Phlox paniculata
Pilea pumila
Plantago major
Plantago rugelii
Poa nemoralis
Poa palustris
Poa pratensis
Polygala sanguinea
Polygonatum pubescens
Polygonum aviculare
Polygonum convolvulus
Polygonum cuspidatum
Polygonum pensylvanicum
Polygonum persicaria
Polygonum punctatum
Polygonum puritanorum

(continued)

APPENDIX B

A list of shrubs, herb and bryophyte species identified from the Central Research Forest. (continued)

Herbs (cont'd)

Polygonum sagittatum
Portulaca oleracea
Potentilla argentea
Potentilla canadensis
Potentilla norvegica
Potentilla recta
Prenanthes altissima
Prunella vulgaris
Pteridium aquilinum
Pyrola elliptica
Pyrola secunda
Ranunculus abortivus
Ranunculus acris
Ranunculus pensylvanicus
Rorippa islandica
Rubus odoratus
Rubus pubescens
Rudbeckia hirta
Rumex acetosella
Rumex mexicanus
Rumex occidentalis
Sagittaria latifolia
Saponaria officinalis
Scirpus atrovirens
Scirpus cyperinus
Scirpus validus
Scrophularia lanceolata
Scutellaria lateriflora
Setaria glauca
Setaria verticillata
Silene vulgaris
Sisyrinchium bermudianum
Sium suave
Smilacina racemosa
Smilax herbacea
Solidago caesia
Solidago canadensis (Incl. var. *scabrata*)
Solidago gigantea
Solidago graminifolia
Solidago nemoralis
Solidago rugosa
Solidago squarrosa
Solidago uliginosa
Sonchus arvensis
Sonchus uliginosus
Spergula arvensis
Spiranthes cernua
Spiranthes gracilis
Steironema ciliatum
Stellaria graminea
Stellaria longifolia
Stellaria longipes
Streptopus roseus
Taraxacum officinale
Teucrium canadense
Thelypteris noveboracensis
Thelypteris palustris
Thelypteris phegopteris
Tiarella cordifolia
Tragopogon dubius
Triadenum fraseri
Trientalis borealis
Trifolium agrarium
Trifolium hybridum
Trifolium pratense
Trifolium procumbens
Trillium erectum
Trillium undulatum
Typha angustifolia
Urtica dioica
Verbascum thapsus
Verbena hastata
Veronica scutellata
Vicia cracca
Viola cuculata
Viola eriocarpa
Viola nephrophylla
Viola pallens
Viola septentrionalis

(continued)

APPENDIX B

A list of shrubs, herb and bryophyte species identified from the Central Research Forest. (concluded)

Bryophytes

Atrichum crispum
Atrichum undulatum var. *altecristatum*
Aulacomnium palustre
Brachythecium salebrosum
Callicladium haldanianum
Calliergon cordifolium
Campylium hispidulum
Ceratodon purpureus
Climacium dendroides
Dicranum scoparium
Herzogiella turfacea
Hypnum lindbergii
Jungermannia lanceolata
Leptodictyum riparium
Mnium cuspidatum
Plagiothecium denticulatum
Pohlia nutans
Polytrichum commune
Polytrichum juniperinum
Polytrichum ohioense
Sphagnum girgensohnii
Sphagnum palustre
Thuidium recognitum

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[a] This species identification follows Marie-Victorin and Rouleau (1964) who recognize only *Aronia melanocarpa* in Flore Laurentienne, and Gillett (1958) who lists only *Purus melanocarpa* (=*A. melanocarpa*).

[b] These identifications to finer levels of distinction were done by J.M. Gillett and W.J. Cody following the treatment of Fernald (1950).

[c] The *Rubus* spp. group is not a total lumped *Rubus* group, but rather those *Rubus* species which were not identified.

APPENDIX C

Frequencies for trees, saplings and seedlings in five depth-to-groundwater classes (yr avg). The 391 stands used here were those having any data for tree, sapling or seedling sizes. All species encountered are included.

APPENDIX C

		1	2	3	4	5
Groundwater class		1	2	3	4	5
Depth to groundwater (cm)		249	50-74	75-99	100-124	≥ 125
No. of stands		60	84	95	63	89

Tree species which tend to be more frequent in the moist and intermediate classes (Classes 1-3)

		1	2	3	4	5
Alder, speckled	Clumps	43	43	45	37	16
	Seedlings	--	--	1	--	--
Ash, black	Trees	--	1	--	--	--
	Sa	--	--	--	--	--
	Se	--	--	--	--	--
Ash, red	Tr	3	5	3	--	1
	Sa	3	--	--	2	--
	Se	8	2	3	--	2
Birch, yellow	Tr	25	10	12	21	10
	Sa	12	7	4	5	1
	Se	12	6	5	6	--
Elm, American	Tr	30	11	19	14	12
	Sa	12	4	4	5	3
	Se	13	8	9	5	7
Maple, red	Tr	68	57	64	57	37
	Sa	35	43	47	44	22
	Se	38	50	38	38	29
Tamarack	Tr	2	4	2	2	2
	Sa	2	2	--	--	--
	Se	--	--	--	--	--
Willow, pussy	Clumps	7	10	5	--	1
	Se	--	--	--	--	--
Willow, white	Clumps	13	18	6	5	3
	Se	--	--	--	--	--

Tree species which tend to be more frequent in the intermediate classes (Classes 2-4)

		1	2	3	4	5
Aspen, largetooth	Tr	3	5	7	8	7
	Sa	--	2	1	2	1
	Se	--	--	3	5	2

(continued)

APPENDIX C (continued)

		1	2	3	4	5
Groundwater class		1	2	3	4	5
Depth to groundwater (cm)		249	50-74	75-99	100-124	≥ 125
No. of stands		60	84	95	63	89
Tree species which tend to be more frequent in the intermediate classes (Classes 2-4) (cont'd)						
Birch, white	Trees	15	30	35	32	28
	Saplings	8	15	15	16	8
	Seedlings	7	7	8	3	1
Pine, white	Tr	5	20	23	21	16
	Sa	--	5	8	3	4
	Se	--	--	--	3	1
Beech	Tr	--	2	2	5	--
	Sa	--	--	--	2	1
	Se	--	1	3	2	1
Birch, grey	Tr	25	37	39	40	27
	Sa	22	32	22	25	10
	Se	2	12	6	8	4
Maple, sugar	Tr	--	1	1	6	--
	Sa	--	--	2	3	1
	Se	--	--	1	6	1
Poplar, balsam	Tr	--	--	2	--	2
	Sa	--	1	1	--	1
	Se	--	--	4	2	--
Service-berry	Tr	--	--	1	3	--
	Sa	--	--	2	3	1
	Se	7	5	13	10	3
Willow, bebb	Clumps	8	13	13	8	4
	Se	--	--	1	2	--
Tree species which tend to be more frequent in the intermediate-to-dry classes (Classes 3-5)						
Cherry, black	Tr	--	--	1	2	4
	Sa	--	2	2	--	--
	Se	2	2	5	19	3

(continued)

APPENDIX C (continued)

Groundwater class		1	2	3	4	5
Depth to groundwater (cm)		249	50-74	75-99	100-124	≥ 125
No. of stands		60	84	95	63	89
Tree species which tend to be more frequent in the intermediate-to-dry classes (Classes 3-5) (cont'd)						
Cherry, pin	Trees	3	7	6	11	13
	Saplings	2	5	6	8	19
	Seedlings	5	5	6	6	29
Maple, Manitoba	Tr	--	--	--	--	--
	Sa	--	--	--	--	1
	Se	--	--	--	--	--
Sumac, staghorn	Tr	--	--	--	--	--
	Sa	--	--	--	--	1
	Se	--	--	--	--	3
Species with no clear-cut preferences						
Aspen, trembling	Tr	37	52	48	51	51
	Sa	13	18	20	27	27
	Se	15	20	23	30	38
Basswood	Tr	--	--	--	--	1
	Sa	--	--	--	--	--
	Se	--	1	--	--	1
Cedar, white	Tr	13	13	14	17	13
	Sa	7	10	8	6	9
	Se	5	7	3	3	4
Cherry, choke	Tr	--	--	--	--	1
	Sa	--	4	1	--	1
	Se	5	4	4	5	10
Dogwood, alternate-leaved	Tr	--	--	--	--	--
	Sa	--	--	--	--	--
	Se	3	1	4	2	8
Fir, balsam	Tr	3	4	3	3	4
	Sa	5	1	3	3	3
	Se	2	4	1	2	2

(continued)

APPENDIX C (concluded)

		1	2	3	4	5
Groundwater class		1	2	3	4	5
Depth to groundwater (cm)		249	50-74	75-99	100-124	≥ 125
No. of stands		60	84	95	63	89
Species with no clear-cut preferences (cont'd)						
Hemlock, eastern	Trees	13	7	8	5	9
	Saplings	2	1	4	--	1
	Seedlings	2	2	3	2	--
Maple, striped	Tr	--	--	--	--	--
	Sa	--	--	--	2	--
	Se	--	4	2	2	1
Spruce, white	Tr	2	2	2	8	3
	Sa	--	--	--	--	1
	Se	2	--	1	--	1

APPENDIX D

Frequencies for trees, saplings and seedlings in five canopy cover classes (second ratings). All species found in the 480 sampled plots are included. For this sample, nine plots on the ends of lines were not rated for canopy cover.

APPENDIX D

Canopy cover class		1	2	3	4	5
Cover class range		0-25%	26-50%	51-75%	76-87%	88-100%
No. of stands		121	52	46	80	181
Species favoring closed forests (Classes 4-5)						
Alder, speckled	Clumps	4	21	35	36	44
	Seedlings	--	--	--	1	--
Ash, black	Trees	--	--	--	--	1
	Saplings	--	--	--	--	--
	Seedlings	--	--	--	--	--
Ash, red	Tr	--	--	--	1	4
	Sa	--	--	--	3	1
	Se	--	4	2	3	4
Aspen, large-tooth	Tr	--	2	--	8	9
	Sa	--	2	--	4	1
	Se	--	6	--	3	2
Basswood	Tr	--	--	--	--	1
	Sa	--	--	--	--	--
	Se	--	--	--	--	1
Beech	Tr	--	--	--	--	4
	Sa	--	--	--	1	1
	Se	--	--	2	1	2
Birch, white	Tr	1	8	17	35	40
	Sa	--	2	2	23	16
	Se	1	4	7	13	3
Birch, yellow	Tr	--	6	7	10	23
	Sa	--	--	2	4	9
	Se	--	2	4	9	6
Cedar, white	Tr	2	4	17	15	17
	Sa	--	2	11	9	10
	Se	--	2	9	4	6
Cherry, black	Tr	--	2	--	3	2
	Sa	--	--	--	1	2
	Se	--	--	4	6	9

(continued)

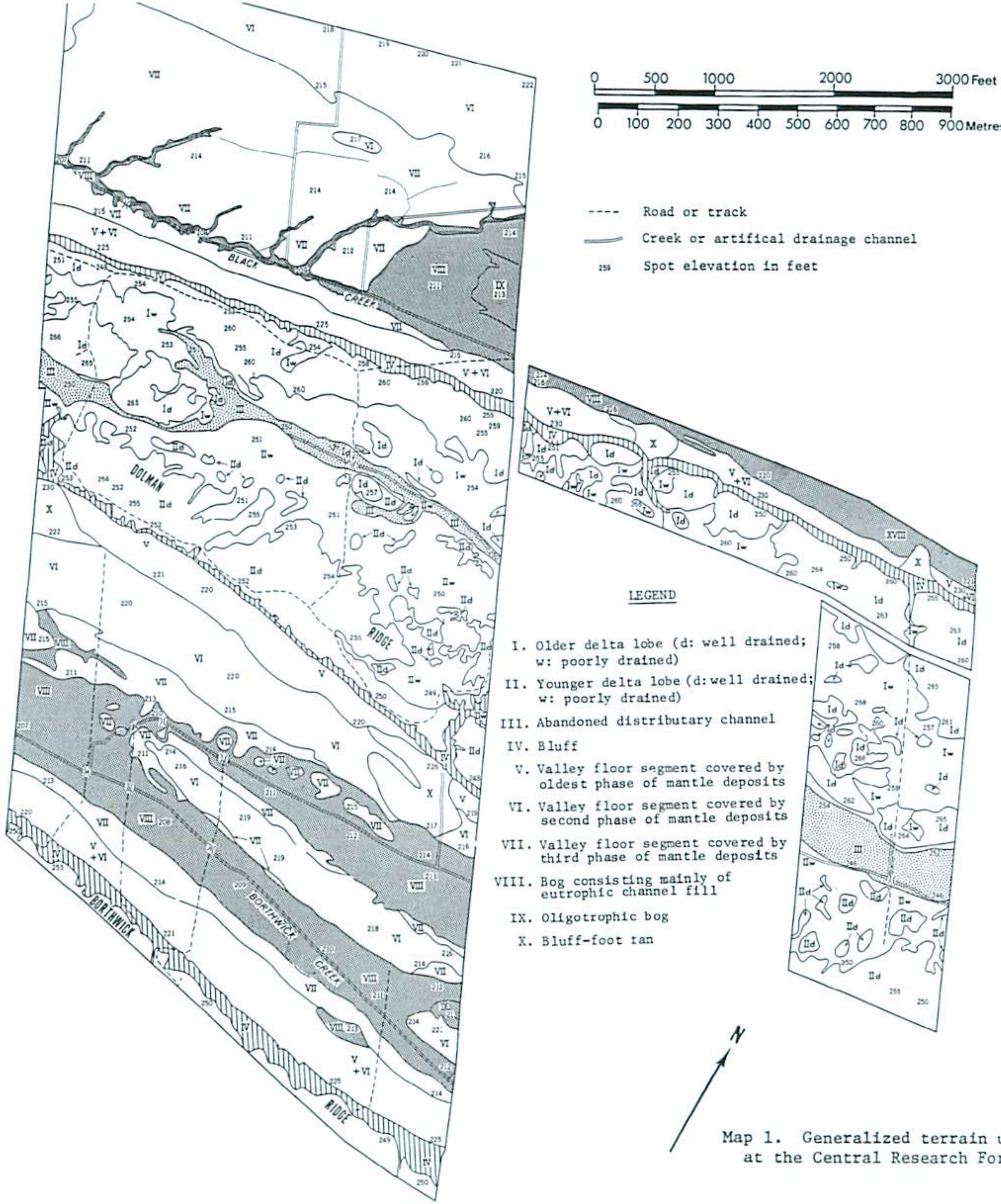
APPENDIX D (continued)

Canopy cover class		1	2	3	4	5
Cover class range		0-25%	26-50%	51-75%	76-87%	88-100%
No. of stands		121	52	46	80	181
Species favoring closed forests (Classes 4-5) (cont'd)						
Dogwood, alternate-leaved	Trees	--	--	--	--	--
	Saplings	--	--	--	--	--
	Seedlings	--	--	4	4	6
Elm, American	Tr	1	2	17	20	21
	Sa	--	2	4	6	7
	Se	2	2	9	11	9
Fir, balsam	Tr	--	--	2	4	6
	Sa	--	--	2	1	6
	Se	--	--	2	3	3
Hemlock, eastern	Tr	--	6	4	6	13
	Sa	--	--	--	3	3
	Se	--	--	--	4	2
Maple, red	Tr	2	19	30	56	82
	Sa	1	6	15	28	65
	Se	2	12	22	59	48
Maple, striped	Tr	--	--	--	--	--
	Sa	--	--	--	--	1
	Se	--	--	--	--	4
Maple, sugar	Tr	--	--	2	3	2
	Sa	--	--	--	3	2
	Se	--	--	2	3	2
Pine, white	Tr	1	6	6	18	27
	Sa	--	2	2	5	7
	Se	--	--	2	1	1
Poplar, balsam	Tr	--	--	--	3	1
	Sa	--	--	2	3	--
	Se	--	--	--	3	2
Serviceberry	Tr	--	2	--	1	1
	Sa	--	--	--	--	3
	Se	--	--	4	13	9

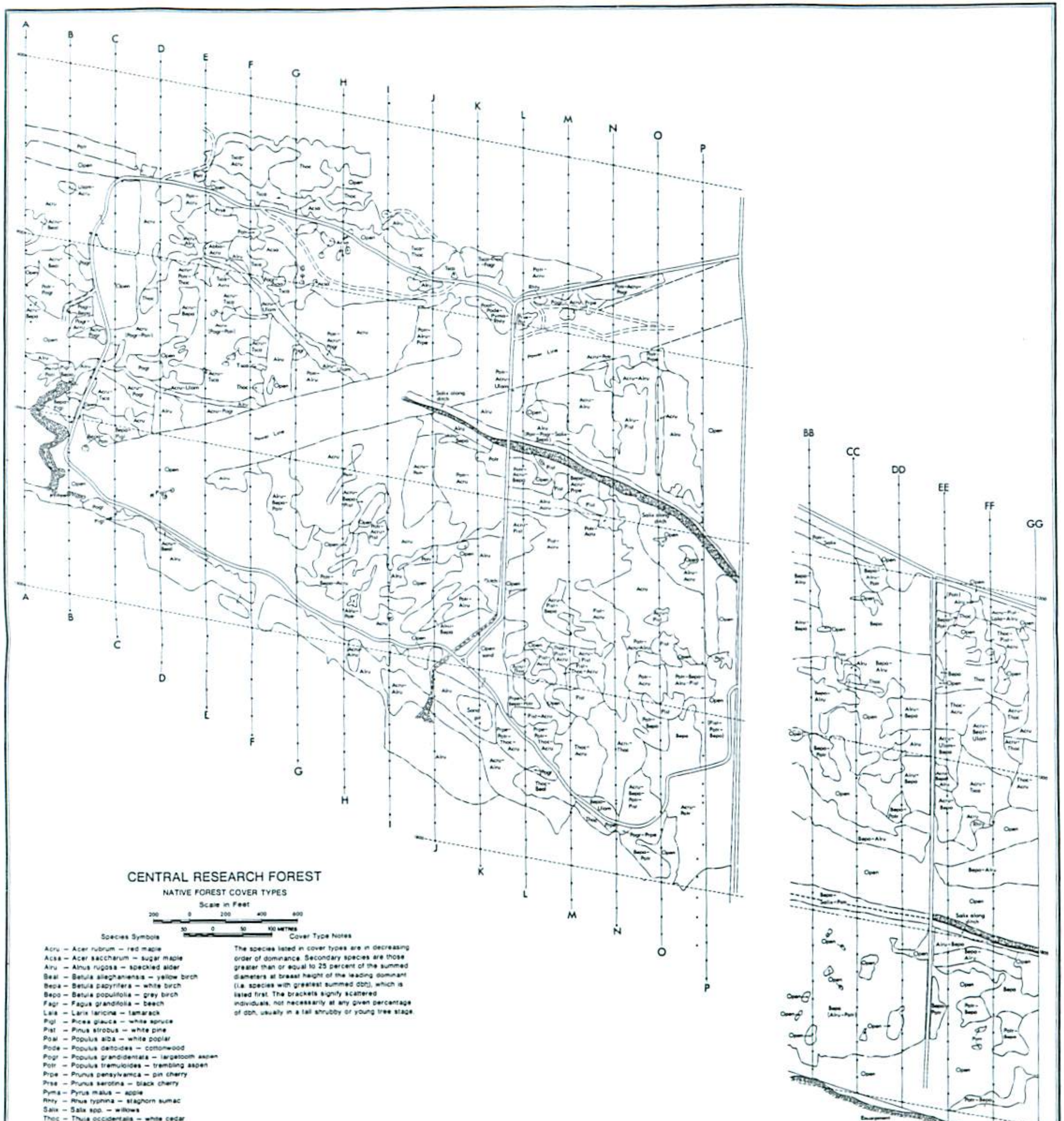
(continued)

APPENDIX D (concluded)

Canopy cover class		1	2	3	4	5
Cover class range		0-25%	26-50%	51-75%	76-87%	88-100%
No. of stands		121	52	46	80	181
Species favoring closed forests (Classes 4-5) (cont'd)						
Spruce, white	Trees	1	2	--	4	4
	Saplings	--	--	--	1	--
	Seedlings	--	--	--	1	1
Tamarack	Tr	--	2	--	4	3
	Sa	--	--	--	3	1
	Se	--	--	--	--	--
Willow, pussy	Clumps	--	4	4	5	5
	Se	--	--	--	--	--
Species favoring intermediate cover classes (Classes 2-4)						
Aspen, trembling	Tr	7	38	41	56	54
	Sa	2	29	28	35	13
	Se	2	31	26	38	23
Birch, grey	Tr	4	37	41	38	33
	Sa	2	25	17	28	23
	Se	5	8	9	9	2
Cherry, choke	Tr	--	1	--	--	--
	Sa	1	--	4	--	1
	Se	2	4	--	4	8
Cherry, pin	Tr	2	2	11	11	9
	Sa	5	4	20	6	7
	Se	5	13	22	13	5
Sumac, staghorn	Tr	--	--	--	--	--
	Sa	--	--	--	1	--
	Se	1	2	--	1	--
Willow, bebb	Clumps	1	12	15	11	7
	Se	--	--	--	1	1
Willow, white	Clumps	4	19	11	9	4
	Se	--	--	--	--	--
Species favoring open sites (Classes 1-3)						
Maple, Manitoba	Tr	--	--	--	--	--
	Sa	1	--	--	--	--
	Se	--	--	--	--	--



Map 1. Generalized terrain units at the Central Research Forest.



Map 3. Forest and vegetation cover types at the Central Research Forest.