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THE PRESENT AND POTENTIAL FOREST VEGETATION OF THE OTTAWA, ONTARIO, REGION

by

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ABSTRACT

This study provides detailed descriptions of 149 stands of the least disturbed, most mature forest communities in the Ottawa, Ontario region. For each of these sampled communities, a complete summary is provided of tree population structure, coverage and constancy of all vascular understory species and habitat data including topographic position, drainage class, and soil characteristics.

Six widespread and five locally-distributed forest alliances, comprising 21 forest associations, are defined and described on the basis of presently-dominant tree species. A dichotomous key to the associations is provided.

The successional trends exhibited by the present associations are integrated into a flowchart based on tree population structures, tree ages and habitat characteristics. A discussion of succession and climax theory, terminology, variability within and between associations, environmental controls and disturbance factors is provided with emphasis on comparisons with previous investigations in eastern North America.

La Végétation Forestière Actuelle et Potentielle de la Région d'Ottawa, Ontario

Résumé

Cette étude fournit des descriptions détaillées de 149 échantillons des communautés forestières les moins dérangées et les plus agées de la région d'Ottawa. Elle présente un sommaire complet de la structure de la population des arbres, de l'extension et de la constance des espèces vasculaires du sous-bois et de l'habitat incluant la position topographique, la classe de drainage et les caractéristiques du sol, pour chacune des communautés échantillionées.

Il y est donné une description et définition de onze alliances forestières comprenant vingt et une associations forestières sur la base des espèces d'arbres dominants. L'identification des associations est facilitée par une clef dichotomique.

Les tendances de succession ressortant des associations forestières ont été intégrées dans un modèle de succession basé sur les structures des populations d'arbres, les âges des arbres et les caractéristiques de l'habitat. La dernière partie présente une discussion de la théorie de la succession terrestre, de la terminologie, de la variabilité dans et entre les associations, des contrôles environnementaux et les facteurs de bouleversement en insistant particulièrement sur les comparaisons avec des études antérieures dans l'est de l'Amérique du Nord.

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CHAPTER 1. Introduction

The clearing of the original forests in the Ottawa region started with the arrival of the first settlers about 150 years ago. Since that time, the amount of forest cover has steadily decreased as the human population increased. Today, all forested areas within the Regional Municipality of Ottawa-Carleton are being threatened by suburban housing demands. A detailed inventory and classification of this forest resource has never been made, and as a result, woodlands are being lost before we know what their true value may be.

This study was undertaken to classify the present forest communities and to relate these mainly temporary associations to a small number of stable communities which express the potential vegetation of the Ottawa region.

The description and classification is, in itself, a very useful project as it provides forest managers, regional planners and scientific investigators with a quantitative summary of forest overstory, understory and habitat data for the major, recurring forest types in the Regional Municipality. Most of the study was carried out in tentative conservation-recreation zones and the data collected will thus provide an information baseline to evaluate future changes as development continues.

Most of the forests of the region are young, second or third growth stands, whose population structures show definite signs of instability. The characteristics of the seral communities have been evaluated to show the major successional trends and the environmental factors controlling community distribution. Factors such as drainage, percent slope, soil type and topographic position were analyzed so that differences in community composition due to habitat (e.g., permanently wet lowlands; dry, rocky ridges) could be separated from differences due to time (i.e., the gradual replacement of a species or group of species on the same site as time goes on).

This study offers three major contributions to our knowledge of the forests in the Ottawa area:

1. a detailed description, classification and key to the existing forest communities based on similarities of overstory, understory and habitat;

2. an evaluation of the roles played by environmental factors in forest community distribution; and

3. an analysis of the successional relationships among forest communities with identification of the major, stable forest associations.

CHAPTER 2. Description of the Study Area

A. Location

The study area lies in southeastern Ontario centred about the City of Ottawa at 45° 23' N latitude, 75° 43' W longitude (Figure 1). All of the forest community data comes from sites within the boundaries of the Regional Municipality of Ottawa-Carleton, an area of about 285,000 hectares. This regional municipality (established in 1968) encompasses the seven townships previously known as Carleton County and an eighth known as Cumberland Township, which was formerly part of the united counties of Prescott-Russell (Ottawa-Carleton Review Commission, 1975). According to the Official Plan of the Regional Municipality (1974), certain areas are proposed as conservation-recreation zones with uses ranging from restricted nature study to intensive recreation. It was in these proposed zones that the majority of the communities in the present study were located (Figure 2).

B. Bedrock Geology

The study area lies along the southern margin of the Canadian Shield in the area called the Ottawa-St. Lawrence

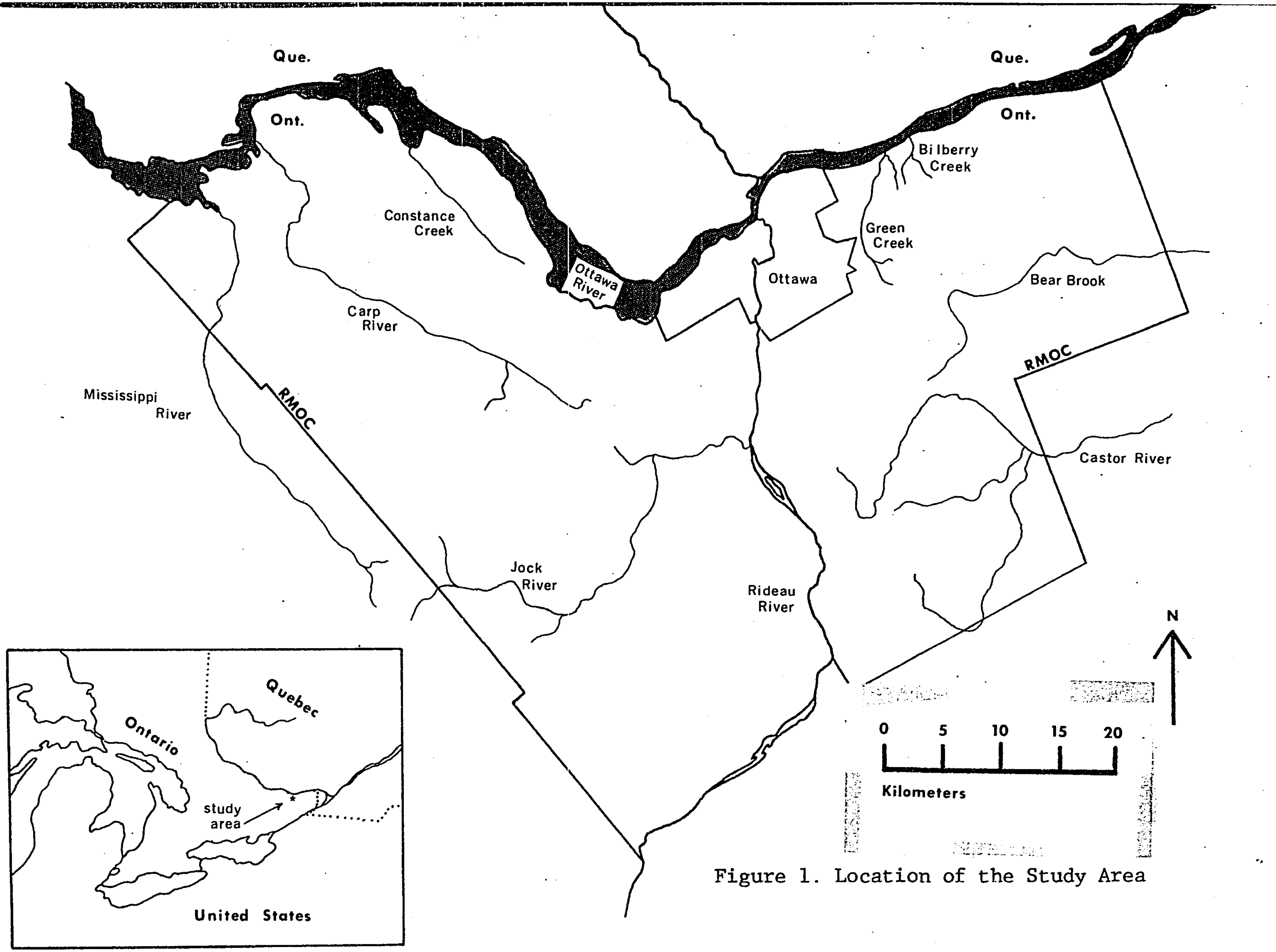


Figure 1. Location of the Study Area

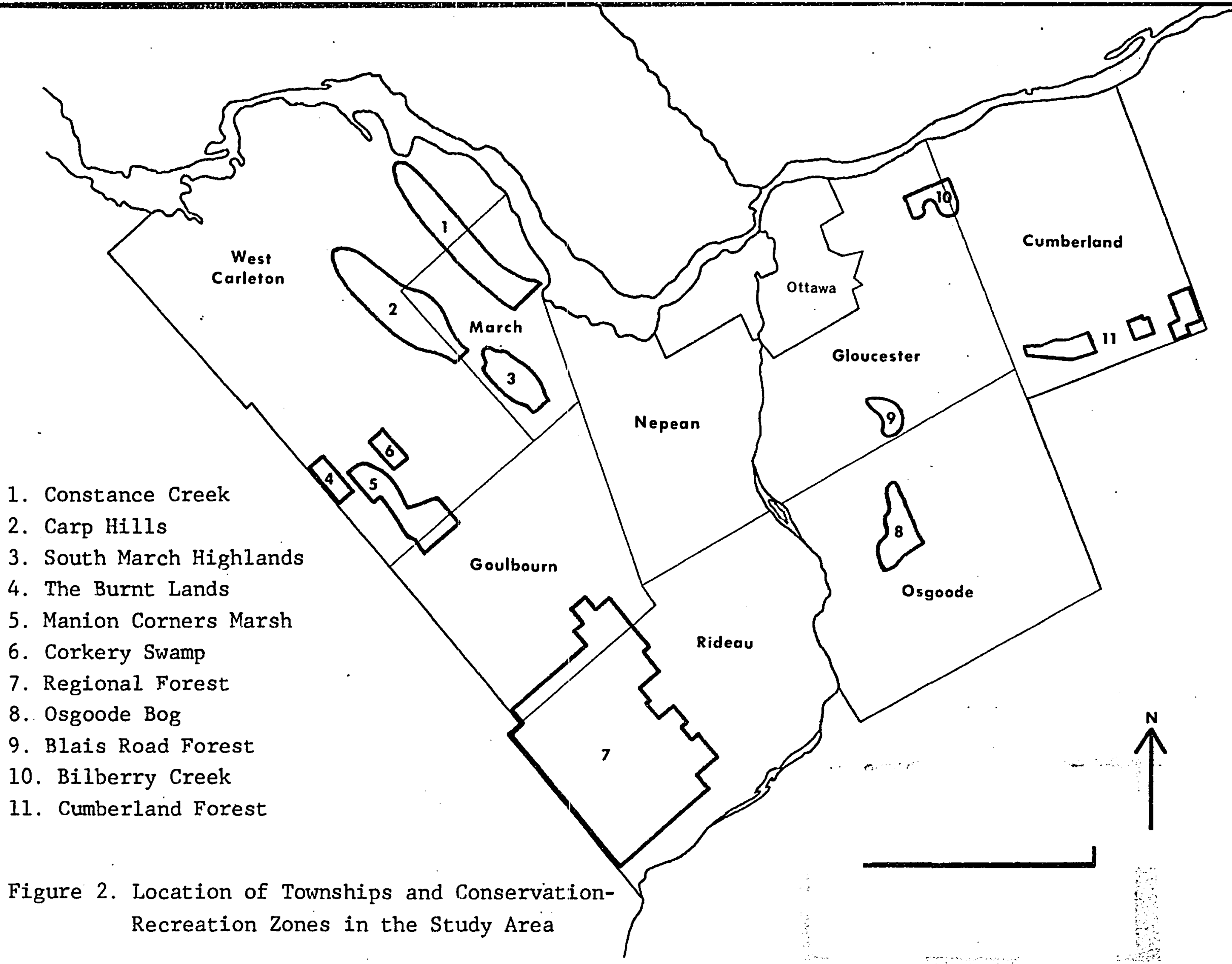


Figure 2. Location of Townships and Conservation-Recreation Zones in the Study Area

Lowlands (Figure 3). These lowlands are bounded by a precambrian rock triangle, namely, the Laurentian Highlands (locally called the Gatineau Hills) or Canadian Shield on the north, the Frontenac Axis on the west (a belt of granitic rock connecting the Canadian Shield and the Adirondacks of upper New York state) and the Adirondack chain on the south and southeast (Wilson, 1946).

These precambrian rocks are very old formations belonging to the Grenville precambrian province and are the roots of ancient mountain ranges formed about one billion years ago. Within the present study area, one significant outlier of these precambrian rocks is the Carp Ridge (composed of the Carp Hills area north of Highway 17 and the South March Highlands south of Highway 17). It extends in a southeasterly direction from the Canadian Shield at Fitzroy Harbour (Chats Falls) to Kanata (Kirwan, 1962).

Within the Ottawa-St. Lawrence Lowlands, the precambrian rocks dip below the surface forming a large basin which is filled by younger palaeozoic rock formations.

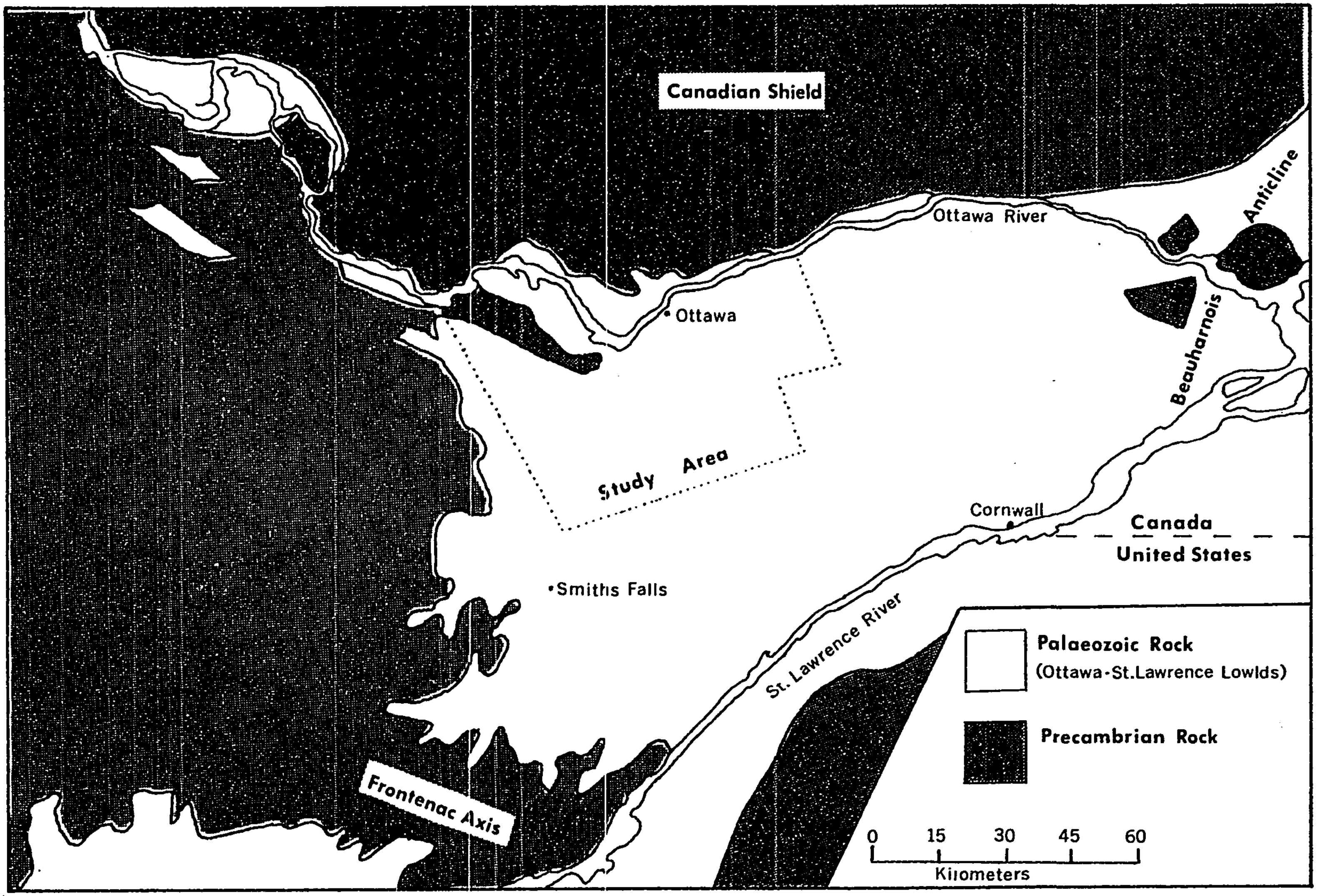


Figure 3. Ottawa-St.Lawrence Lowlands

These rocks underlie most of the study zone in a horizontal position except where the strata are close to the many large faults of the area (Wilson, 1946) (Figure 4). The dominant palaeozoic formations and parent material for soil development are:

1. Nepean sandstone which is exposed in the northwestern part of the area on the east side of the precambrian outlier (the Carp Ridge). Another smaller exposure is found southeast of Leitrim along the Gloucester fault;

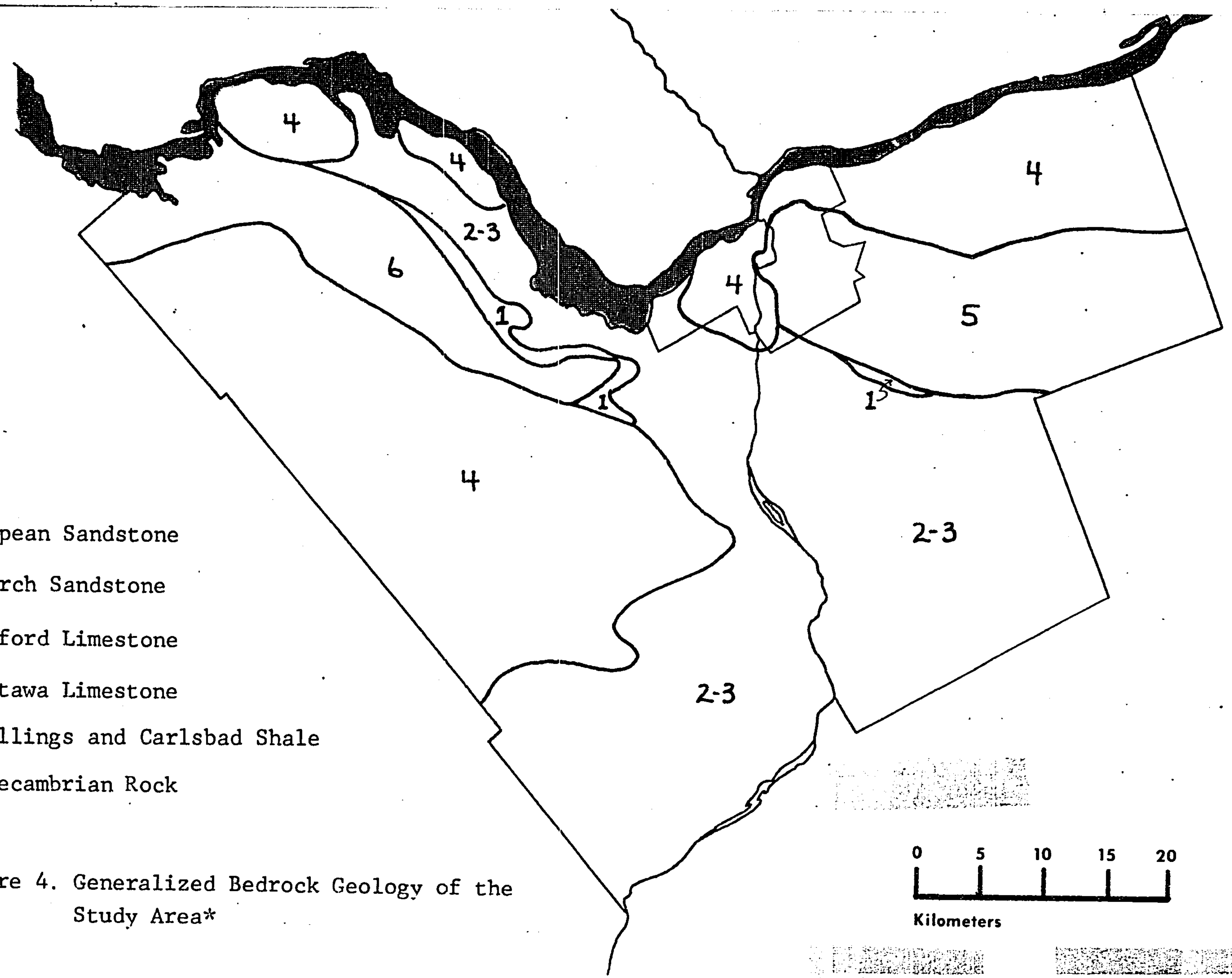
2. the March formation of interbedded sandstone and dolomite which is found predominantly on the eastern edge of the Nepean sandstone formations around the Carp Ridge and Gloucester fault;

3. the Oxford formation of grey limestone covering the majority of the south-central part of the study area;

4. the Ottawa formation, chiefly of grey limestone which outcrops in two major areas - a large area around and south of the City of Ottawa extending eastward in a broad plain and an extensive limestone plain area southwest of the Hazeldean fault centering around Stittsville;

5. the Billings and Carlsbad formations of black and grey shale which extend in a rectangular band east from Ottawa following the eastern edge of the Gloucester fault.

In general, there were three great periods of geological activity in eastern Ontario (Childe, 1968). The Precambrian period (starting about 500 million years



1 Nepean Sandstone

2 March Sandstone

3 Oxford Limestone

4 Ottawa Limestone

5 Billings and Carlsbad Shale

6 Precambrian Rock

Figure 4. Generalized Bedrock Geology of the Study Area*

*(adapted from Baird, 1968 and Wilson, 1946)

ago) was an era which saw massive sedimentary and igneous rock formations laid down (i.e., the precambrian rocks surrounding and deeply underlying the St. Lawrence Lowlands). About 350 to 450 million years ago, the Ordovician period started in which widespread sedimentation processes created much of the fossiliferous sandstones and limestones (Nepean, Oxford and Ottawa formations) of the area. Following this (starting about 1 million years ago), the Pleistocene epoch featured massive geological transport and erosional processes ending in the Wisconsin glacial period.

C. Glaciation and Submergence

During the Pleistocene epoch, eastern Canada and the northeastern United States were invaded by definitely two, and probably four, massive glaciers (Webber and Hoffman, 1967). The last of these ice invasions, the Wisconsin, left the Ottawa area free of glacial ice about 10,000 - 12,000 years ago. The Wisconsin glaciation is of primary concern because it left the greatest impression in terms of present topography, surficial geology, landforms and drainage patterns.

During glacial recession, a series of meltwater lakes were formed at the southern edge of the ice. Glacial Lake Algonquin (in the present Lake Huron-Georgian Bay basin) flowed at one time into glacial Lake Iroquois (in the present Lake Ontario basin). The present outlet of the Great Lakes via the St. Lawrence River was at this time blocked by ice, and drainage flowed through a lowland area to Rome, New York and into the Hudson River. In the St. Lawrence-Ottawa Valley, the land was depressed up to 210 meters, or well below sea level, by the weight of the ice (Webber and Hoffman, 1967). As the ice retreated northward and exposed the St. Lawrence Valley, marine water (the Champlain Sea) flooded the whole lowland (Figure 5).

At its peak, the Champlain Sea covered land below the present altitude of 194 meters (i.e., the highest known marine beach in the area) and probably submerged all land below 198 meters (Gadd, 1962). It thus covered the entire study area leaving only the high central portion of the Gatineau Hills exposed (Romanelli, 1975). Contemporary with the Champlain Sea invasion, a new outlet of glacial Lake Algonquin (the Fossmill Channel)

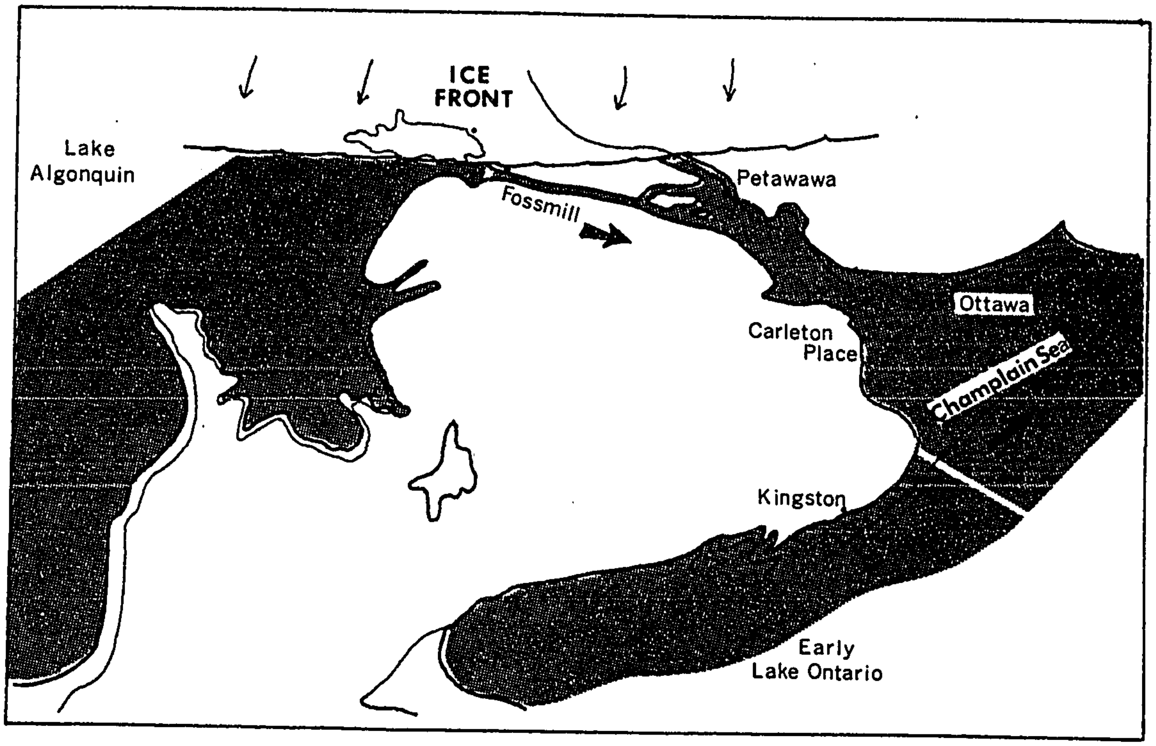


Figure 5. Champlain Sea in the Ottawa-St.Lawrence Lowlands *

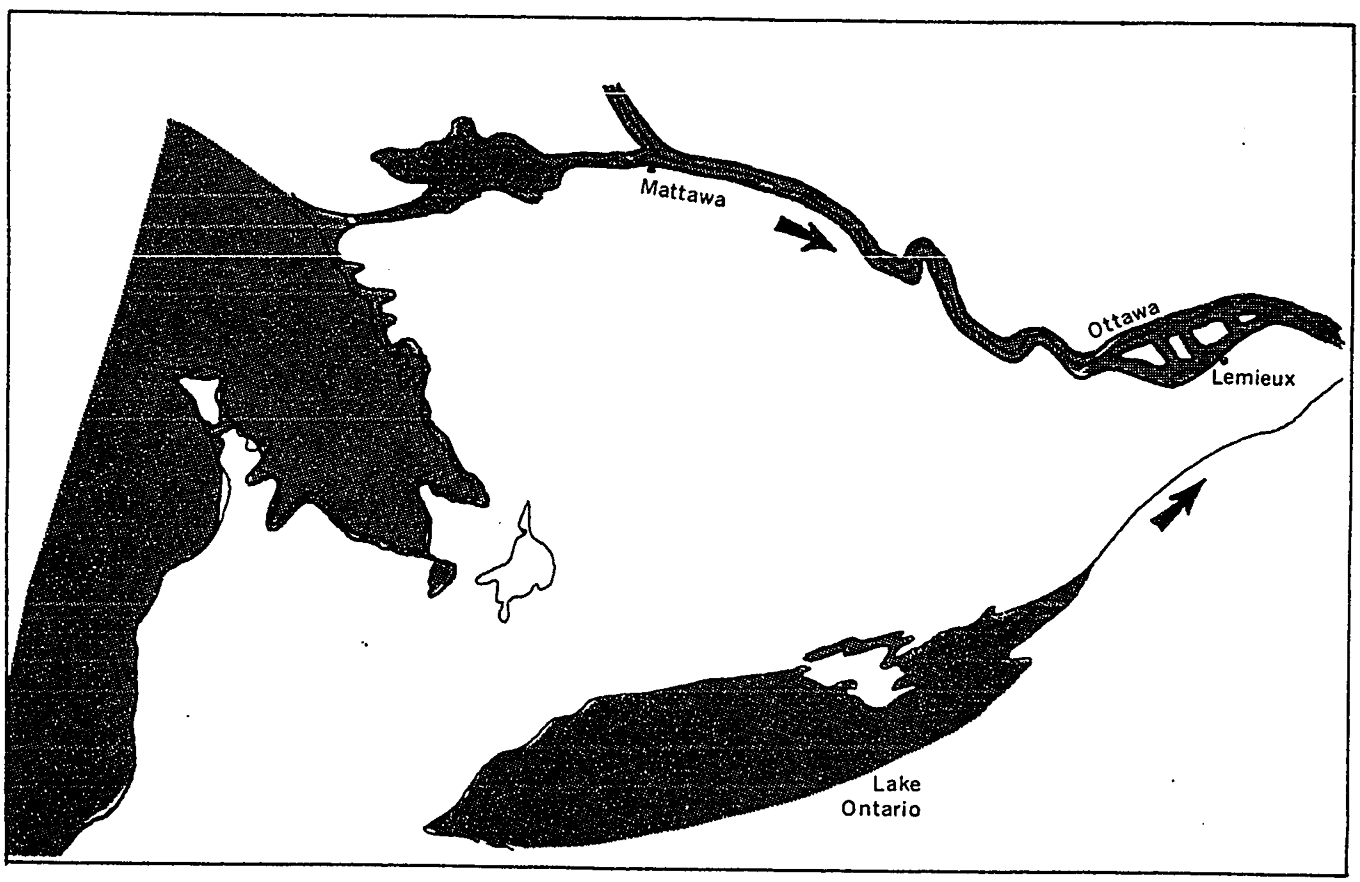


Figure 6. Crustal Uplift and Blockage of the Fossmill Channel *

* (adapted from Webber and Hoffman, 1967).

was formed and that huge lake began to drain through the valleys of the present day Petawawa and Barron Rivers into the Ottawa Valley.

As the ice retreated further north, progressive uplifting of the previously-depressed earth's crust blocked the Fossmill Channel and exposed a new outlet through Lake Nipissing, North Bay and down the Mattawa River (Figure 6). "At this time, all that remained of the Champlain Sea in Ontario was a bay in the valley east of Ottawa where the land below the 250 foot (76.2 m) contour was submerged" (Webber and Hoffman, 1967). This rapid land emergence caused successively lower marine beaches to form, the lowest being at Russell, Ontario, presently 70 meters above sea level (Romanelli, 1975). The new drainageway through Mattawa lowered the level of glacial Lake Algonquin by 30 meters, and the huge discharge of water cut through and suspended much of the Petawawa sand delta, carrying it downstream and redepositing it in the tidal bay east of Ottawa. This drainage path is also thought to have been a major migration route of plants characteristic of the flora of the Great Lakes region, which entered the Ottawa Valley at that time and have persisted to the present as relic populations along the shores of the old Champlain Sea (Marie-Victorin, 1964).

The Ottawa River followed several channels through the sand and clay deposits in the bottom of the former Champlain Sea, finally being restricted to the northern (present-day) course as isostatic adjustment continued. Several remnants of the older Ottawa River channels can still be seen in the study area. The Buckham Bay-Constance Creek-Mud Pond corridor in the west, the Mer Bleue and Alfred Bogs in the east and the Bowesville Moraine from Bell's Corners extending to about Greely, are present landform features related to this period of glaciation and submergence.

Eventually, crustal uplift raised the land to such an extent, that the North Bay outlet was higher than the level of the St. Clair River and so the present outlet of Lake Huron was established via Sarnia, Lake Erie, Lake Ontario and the St. Lawrence River (Webber and Hoffman, 1967).

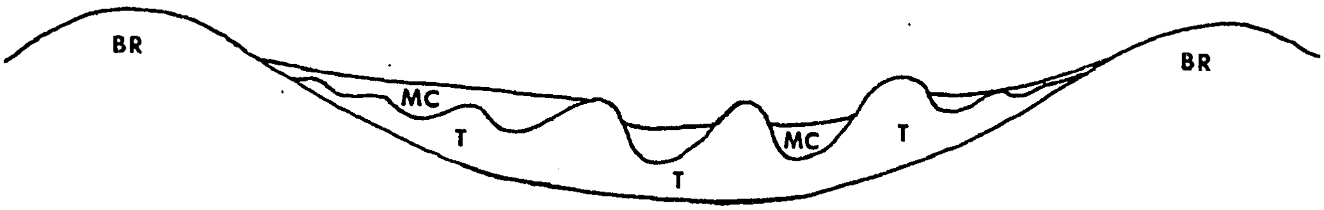
D. Topography, Surficial Geology and Drainage

The Ottawa-St. Lawrence Lowlands as a whole, has a minimum elevation of 21 meters above sea level at the mouth of the Ottawa River, rising gradually to a maximum of about 152 meters at the Frontenac Axis in the west (Wilson, 1946). This same general pattern applies to the study area in particular with the land generally rising slowly from east to west and south to north. Most of the study region lies between 61 and 107 meters in elevation with the highest point occurring in the northwest section, the Burnt Lands limestone plain, where the elevation exceeds 160 meters above sea level.

The Ottawa-Carleton region has been described as "...an undulating plain of clay and till materials with local outcrops of bedrock...in the northwest", (Hills *et al*., 1944). This pattern is interrupted by several glacial period features, most prominently, the Bowesville Moraine extending southeast from Bell's Corners to Greely with various, probably-related, spur moraines and sand beach deposits (Gadd, 1962). The surficial geology of the area is largely the result of fluvial and related water transport during Wisconsin times. Generally, the tills are locally-derived and highly calcareous due to the dominance of various limestone bedrock exposures (Gadd, 1962). Many areas of sand and gravel probably resulted from slumping of ice masses and later meltwater transportation and deposition.

On top of this gravelly material, various fine sediments are found reflecting post-glacial water transport and deposition. Glacial lake varves are restricted in occurrence and generally grade rapidly with marine clay deposits. The Champlain Sea invasion has left behind silty, marine clays mainly in depressions (Figure 7). Most of these marine sediments were later buried by new materials deposited during the retreat of the Champlain Sea when the Mattawa exit of Lake Algonquin allowed huge volumes of freshwater to rush down the Ottawa Valley and deposit sediments in the waters of the present Ottawa-St. Lawrence Lowlands. In addition, many alluvial sands in channel, bar, delta and sand spit deposits, as well as bogs, terraces and alluvium islands are locally important and represent

Figure 7. Surficial Topography of the Champlain Sea Floor [1]



BR = Bedrock   T = Till   MC = Marine Clay

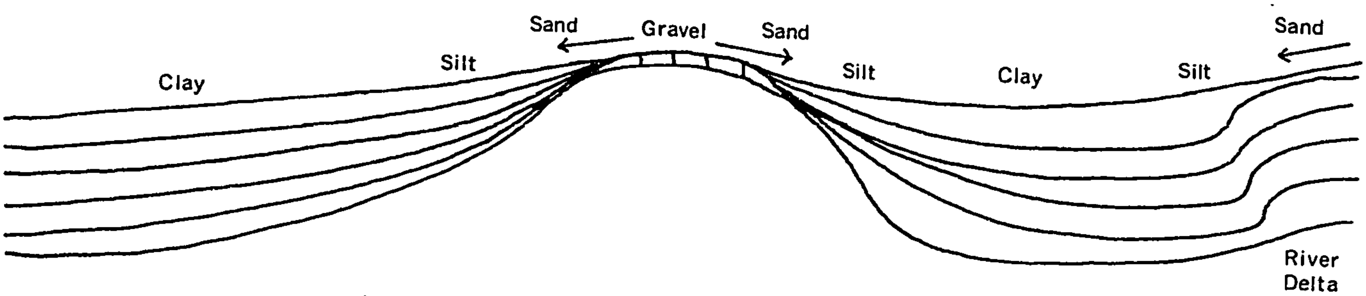


Figure 8. Reworking and Erosion of Exposed Land During Champlain Sea Recession[1]

1 (adapted from P.F.Karrow in R.F.Legget, 1961, p. 102-103)

landforms reworked (by wave action) during the recession of the Champlain Sea (Figure 8). The dominant water-borne sediments, within the study area, are therefore, non-marine (Gadd, 1962; Burger, 1967), although several areas of deep marine clays can be found.

Present drainage of the study area is through the Ottawa River and its tributaries (Figure 1). The central and southern part of the study area is drained by the Rideau River and its major tributary, the Jock River; the southern and eastern portion is drained by the North, Middle and South Castor Rivers which flow by way of the South Nation River into the Ottawa near Plantagenet; the northeastern section is served by Bear Brook and its tributaries flowing into the South Nation and by streams such as Green Creek and Bilberry Creek which flow directly north into the Ottawa River; the northwestern portion is drained by Constance Creek, and the Carp and Mississippi Rivers which join the Ottawa River above the City of Ottawa.

The relative youthfulness of the lowlands can be further interpreted from the many parallel tributaries and drainage channels carved in the sediments (Hills et al., 1944 and Karrow, in Legget, 1961). With increasing age, these rivers will take a more meandering path as they dig deeper into the soft lowland soils. The levelness of the plain can be demonstrated by the fact that the Jock River (flowing east into the Rideau) and the Carp River (flowing northwest into the Ottawa River) have a common source on the limestone plain near Stittsville. Further, only the low Bowesville Moraine forms the divide between the Rideau and the South Nation watersheds.

E. Climate

Three weather stations are maintained within the study area. The two principal stations are the Canada Department of Agriculture station and the Uplands Airport station in Ottawa, with a small station operating at the Chats Falls power dam, northwest of the city.

The majority of the study area lies in the Eastern Counties Climatic Region as defined by the Ontario Department of Agriculture and Food (1966). The north-western corner lies in the Renfrew Climatic Region. In general, the climate of the Ottawa area "...is characterized by a cool to warm summer, frontal summer rainfall, westerly winds, a cold winter and a long snow cover season" (Ouellet, 1975). This humid, continental climate is similar throughout the study zone and areas east (Wicklund and Richards, 1962) where the land remains level, although ecologically-significant, local variances in climate have been reported on the highlands of Gatineau Park to the north (Loupoukhine, 1974). Any moderating effects of the Great Lakes is scarcely noticeable within the area (Ouellet, 1975). Table 1 shows the major climatic parameters for the study area (Eastern Counties Climatic Region).

The most important climatic factors for forest and soil development are temperature, precipitation, length of the growing season and the potential and actual evapotranspiration rates. The temperature regime at Ottawa is favourable for forest growth and offers a mean annual growing season of 195 days and a mean annual frost-free period of 135 days.

The study area receives a mean annual precipitation of 86 centimeters evenly distributed throughout the year with a

Table 1. Climate of the Eastern Counties Climatic Region (Ottawa)*

Altitude (m above sea level)	122
Mean Annual Temperature (^{o}C)	6
Mean Daily Maximum Temperature (^{o}C)	
January	-5
July	28
Mean Daily Minimum Temperature (^{o}C)	
January	-14
July	13
Mean Annual Frost Free Period (days)	135
Mean Annual Length of Growing Season (days)	195
Mean Annual Precipitation (cm)	76-94
Mean Annual Snowfall (cm)	203
Greatest Snow Depth (cm)	117
Jan.31 Median Snow Depth (cm)	30
Feb.28 Median Snow Depth (cm)	28
Mar.31 Median Snow Depth (cm)	5
Median First Day of Cover	Nov.18
Median Last Day of Cover	April 7
Median Number of Days of Cover	117
Mean Annual Potential Evapotranspiration (cm)	61
Mean Annual Actual Evapotranspiration (cm)	56
Mean Annual Bright Sunshine (hours)	2000
Mean July Sunshine (hours/day)	9
Mean December Sunshine (hours/day)	2
July Insolation Energy (cal/cm^2)	540
December Insolation Energy (cal/cm^2)	109

*(Table modified from Brown, McKay and Chapman, 1974).

slight increase in the June to September period (Ontario Department Agriculture and Food, 1966). The area receives more than its expected share of snow based on latitude alone. The Gatineau Hills to the north are probably the cause of this phenomenon resulting in orographic precipitation on the windward (study area) side. In addition, eastern Ontario "...lies on one of the main storm tracks of North America and alternate high and low pressure systems moving to the east cause frequent weather changes, particularly in winter", (Ouellet, 1975).

The forests of the Ottawa area then, receive relatively consistent, abundant moisture although drought periods have occurred in the past, particularly in the late spring to early summer period.

The calculated mean annual potential evapotranspiration for the region is 61 centimeters. This figure also represents the estimated mean annual water requirement for plants in the area (Brown, McKay and Chapman, 1974). But this maximum or "potential" rate is never achieved because water is not normally in unlimited supply in the natural forest.

For the study area, the annual actual evapotranspiration is 56 centimeters which means that the vegetation of the region is under a mean annual water deficiency (stress) of 5 centimeters.

These values are derived for green field crops and necessarily include many assumptions which are certainly not directly applicable to the forest situation. The numerous local vagaries of physiography, drainage, slope, aspect and other microhabitat parameters may drastically change the water surplus/deficiency picture in every particular forest community. The reported data are useful, however, as a background against which to interpret individual forest situations.

Generally, the climate of the study area is a humid continental type characterized by large seasonal temperature variations, by consistent abundant precipitation and by a long period of thick snow cover. The snow cover is particularly favourable for the vegetation because it is an excellent insulation and moderates the temperature of the soil on which all plants are dependent. Without the snow, many species would not survive the winters and a very different flora would appear.

F. Soils

The soil resource of the study area has been mapped and classified by Hoffman, Matthews and Wicklund (1964), on the basis of the texture and parent material of the dominant soil families. Figure 9 is a generalized soil map of the study area. Soils are often shallow and poorly-developed due to the relatively short time for the soil maturation processes to occur (about 10,000 years). The most extensive soils are those of medium texture formed on till with bedrock at one foot or less below the surface which covers approximately 25% of the study area (Table 2). They are found predominantly in the southwest section of the area on the limestone plain. Coarse textured soils formed on sand and gravel are the second most extensive soil association and occupy lowland terrain east of Ottawa and in the Carp and Rideau River Valleys. Together, these two soil types occupy almost half of the total study area. Four other soil associations are presented in Table 2 with the dominant

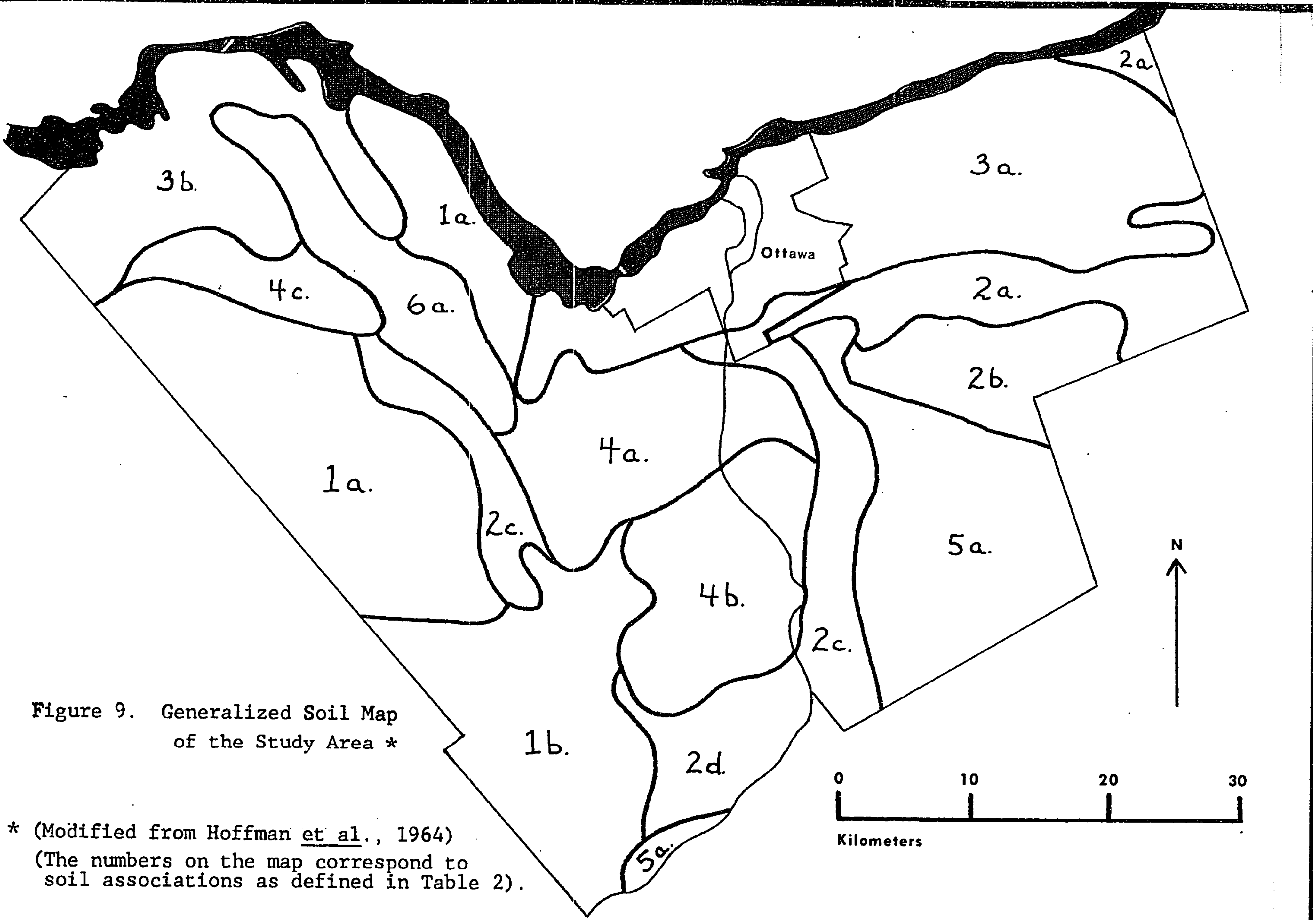


Figure 9. Generalized Soil Map of the Study Area *

* (Modified from Hoffman et al., 1964)
(The numbers on the map correspond to soil associations as defined in Table 2).

Table 2. Soil Associations in the Regional Municipality of Ottawa-Carleton (RMOC)*

Soil Ass'n	Dominant Soil Family (-ies)	Great Soil Group	Texture	Area Covered in RMOC (h)	Area Covered in RMOC (%)	
1. dominantly medium textured soils formed on till with bedrock at one foot or less						
1a	Farmington	Brown Forest	loam	39360	14.6	24.2
1b	Farmington	Brown Forest	loam	25830	9.6	
	Muck	Organic	muck			
2. dominantly coarse textured soils formed on sand and gravel						
2a	Rubicon	Podzol	loamy sand	19680	7.3	23.3
	Wendigo	Podzol	loamy sand			
2b	Rubicon	Podzol	sandy loam	17220	6.4	
2c	Rubicon	Podzol	sandy loam	13530	5.0	
	Granby	Dark Grey Gleisolic	sandy loam			
2d	Fox	Grey-Brown Podzolic	sandy loam	12300	4.6	
	Granby	Dark Grey Gleisolic	sandy loam			
3. dominantly very fine textured soils formed on till or lacustrine sediments						
3a	Lincoln	Dark Grey Gleisolic	clay	29520	11.0	19.2
3b	Rideau	Regosol	clay	22140	8.2	
4. dominantly fine textured soils formed on till or lacustrine sediments						
4a	Brookston	Dark Grey Gleisolic	clay loam	20910	7.8	16.5
4b	Brookston	Dark Grey Gleisolic	clay loam	17220	6.4	
	Grenville	Brown Forest	loam			
4c	Perth	Grey-Brown Podzolic	clay loam	6150	2.3	
5. dominantly medium textured soils formed on till						
5a	Grenville	Brown Forest	loam	28290	10.5	
	Brookston	Dark Grey Gleisolic	clay loam			
6. dominantly coarse textured soils with precambrian rock at one foot or less						
6a	Wendigo	Podzol	loamy sand	11070	4.1	

* (Table modified from Hoffman, Matthews and Wicklund, 1964).

soil family (or families) and Great Soil Groups to which they belong.

The mosaic of soil families and Great Groups in the study area is one of the most complex in southern Ontario. The complexity results from the position of the study zone at the edge of two physiographic provinces (Ottawa-St. Lawrence Lowlands and the Canadian Shield) and its pleistocene history of glaciation, marine submergence and water transport.

A detailed soil survey describing the series and phases making up the soil families in the region was prepared by Hills, Richards and Morwick (1944). Forest communities studied during this project occurred on a total of 21 soil mapping units as defined by Hills *et al.*, (1944). These are given in Appendix "B".

G. Forest Vegetation

The forest cover of the Ottawa area has been studied in a general fashion by several earlier workers (Nichols, 1935; Halliday, 1937; Braun, 1950). All agree that the regional forest vegetation is characterized by a mosaic of three basic types - deciduous associations, coniferous associations and mixed deciduous-coniferous associations. Because of the mixed nature of these forests, they are often considered to be transitional between the Deciduous Forest Region to the south and the Coniferous Boreal Forest Region farther north.

According to Rowe (1972), the Ottawa region lies in the L2 Upper St. Lawrence Section of the Great Lakes-St. Lawrence Forest Region. In this Section, the forests are described as mainly deciduous on the lowlands with a coincident change to mixed deciduous-coniferous communities on the surrounding precambrian uplands. Rowe states that the dominant cover type of the L2 section is sugar maple and beech with substantial representation of red maple, yellow birch, white elm, basswood and red oak. On coarser-textured soils and exposed sites, Rowe mentions the occurrence of numerous conifers such as white pine, hemlock, balsam fir, white spruce and cedar.

Dansereau (1959) produced an extensive description of the principal plant associations of the St. Lawrence

Valley which includes the present study area. His preliminary map of the climax vegetation areas shows the Ottawa region divided approximately in half, the north central and eastern portion belonging to the Laurentian sugar maple climax (i.e., no coniferous representation in climax situations), and the southern half and the northwest part of the study area as part of the Northern Hardwood climax area (which contains yellow birch or hemlock or both, although sugar maple retains its dominance). In addition to defining the climax forests of the region, Dansereau described the general characteristics of many of the temporary forest associations which presently occur in the area.

Lafond and Ladouccur (1968) have described the normal forest sere to be expected in the Ottawa River basin. Riverside forests, including red and silver maple, white elm and black ash, lead to lower slope forests of sugar maple and elm. The favourable mid-slope locations are occupied by the Laurentian sugar maple forest with basswood and white ash, while on the upper slopes, red oak and usually white pine become increasingly prominent.

The transitional character of the regional forests can be seen from Table 3 which shows the numbers of trees and herbs-shrubs enumerated during various studies on an approximate transect from southern Ontario through to the Appalachian foothills of southern Quebec. Despite the limitations involved due to the different sampling techniques, purposes and areas, this table well illustrates the decline in the number of species of trees and herbs-shrubs as one goes north into the harsher, more seasonal conditions (shorter growing season, and longer, colder winters). Grandtner (1966) has mentioned the same trend of species diminution in a southwest to northeast line in Québec. Along with declining number of vascular plant species, is a noticeable shift in the proportions of broadleaved trees as opposed to coniferous trees. The Deciduous Forest Region of extreme southern Ontario gives way to the Great Lakes-St. Lawrence Forest Region (of mixed deciduous-coniferous cover) which in turn blends into the Boreal Forest Region of almost continuous coniferous communities (Rowe, 1972). Along the frontiers of these

Table 3. Numbers of Tree and Herb-Shrub Species Recorded in Studies from Southern Ontario to Southern Quebec.

Author	Location	Number of Tree Species* Recorded	Number of Herb-Shrub Species Recorded
Maycock (1963)	extreme southern Ontario	62	800
Davies (1968)	central southern Ontario	53	500
present study (1977)	eastern Ontario	39	575
Jeglum, Bik, Salm (1974)	eastern Ontario (Central Research Forest)	29	316
Loupoukhine (1974)	southwestern Quebec (Gatineau Park)	33	103
Walther (1963)	southern Quebec (Monteregian Hills)	38	408
Bouchard (1970)	southern Quebec (Appalachian Foothills)	41	366

* (In the majority of these studies, trees are defined as woody perennials normally attaining a diameter of greater than 4 inches (about 1 dm) at breast height.)

forest regions, communities of both types exist as pockets or interpenetrating fingers (Dansereau, 1944; Warder, 1970) and it is an exceedingly difficult task to accurately map such regions at anything but a small scale. Occasionally, communities characteristic of a different region can be found far in the interior of neighbouring regions, wherever drainage, microclimate and man have allowed them to remain. This applies to species of southern affinity found far to the north of their normal range such as the exposed southerly aspect of the Eardley Escarpment in the Gatineau Hills (Brunton and Lafontaine, 1974), as well as to species or communities isolated far to the south of their main area of dominance (Warder, 1970). Such communities, more or less cut off frcm their present ranges, are variously called inclusions, islands or relics and are often useful in helping to unravel past glacial and climatic events and the resulting migrations of plants.

The study area lies partly then in a transition zone between the southern deciduous forest and the northern boreal forest (Braun, 1950), although the mixed deciduous-coniferous forest types present have several tree species (hemlock, yellow birch, white pine and red pine) essentially characteristic of only this transition forest (Nichols, 1935). It is further distinguished by exhibiting a characteristic alternation of deciduous, coniferous and mixed communities.

CHAPTER 3. Methodology

A. Reconnaissance Methods

Extensive clearing and settlement have taken place over much of the study area. As a result of a long history of such land use, the forested areas are becoming smaller, more widely scattered and increasingly modified by the actions of man. Because of these factors it was first necessary to sample the forested zones in Figure 2 rapidly and extensively. A reconnaissance procedure involving both air photo interpretation and field investigation was followed. In the lab, the most recent aerial photographs (normally 1975) were examined to define tentative cover types and/ or ecologically homogeneous subareas. Field teams then examined these areas to describe their floristics and dominance and to define the limits of the subareas. After locating the subarea in the field and having assessed the homogeneity of the community, a "typical site" was selected for sampling using the following criteria:

1. the site within the subarea with the largest possible trees (i.e., communities as old as possible);
2. sites free of major, recent disturbances (i.e., grazing, logging, fire);

3. sites where the habitat was as uniform as possible (i.e., no major discontinuities such as gullies, cliffs or paths;

4. sites with relatively homogeneous species composition in both overstory and understory; and

5. sites large enough to sample (circle approximately 20 meters in diameter without obvious edge effects from nearby fields or different vegetation subareas.

At each reconnaissance site, the following information was recorded:

1. a list of all vascular plant species;

2. an estimate of the canopy coverage of each species listed;

3. a list of other species in the subarea but not in the sample area; and

4. qualitative information on animal activity, disturbance, soil drainage, topography, slope, aspect of the slope and any other data appearing to have importance in understanding the environmental controls and vegetation distribution in the area.

A copy of the reconnaissance data sheet is included in Appendix A 1.

The canopy coverage estimates were based on the cover scale proposed by Daubenmire (1968) and is shown in Table 4.

Table 4. Daubenmire Cover Scale*

Coverage Class	Range of Cover (%)	Class Midpoints
1	0-5	2.5
2	5-25	15
3	25-50	37.5
4	50-75	62.5
5	75-95	85
6	95-100	97.5

* (after Daubenmire, 1968).

The field teams located and recorded over 1000 such reconnaissance samples during the 1975 and 1976 field seasons.

This reconnaissance technique is very useful in community classification, since it permits a rapid evaluation of the forest complex prior to more detailed quantitative study. Its' purpose was to identify and document the recurring forest types and to describe their distribution in the Ottawa region.

Analysis of this field data resulted in the recognition of 14 basic vegetation cover types which were used in mapping all the study areas shown in Figure 2 at a scale of 1:5000 (Reed, 1975; Reed, Billington and Johannsen, 1976).

B. Detailed Plot Methods

Based on the reconnaissance data, air photo interpretation and increased knowledge of the regional vegetation, a second phase involving quantitive sampling was initiated to obtain data on community composition, structure of the tree populations and the habitat characteristics of the sites.

Sampling procedures used were those described by Daubenmire and Daubenmire (1968) and involved the following steps:

1. selection of a homogeneous area within a stand;
2. placing of a macroplot (15 x 25 meters) in this homogeneous area;
3. subdivision of the macroplot into three subplots, each 5 x 25 meters;
4. measuring and recording the diameter at breast height (dbh) of all tree stems, and counting all tree seedlings, saplings and shrubs present within the plot; and
5. estimating the canopy coverage and recording the frequency of all non-tree, vascular plant species in a series of 50 microplots (20 x 50 centimeters) systematically placed at meter intervals along the inside edge of the central subplot.

In addition, detailed notes on animal activity, heights of the forest strata, plant species in the area but not in the sample and topographic position (percent slope, aspect, verbal description) were recorded. An example of the detailed data sheet has been placed in Appendix A 2. A representative soil sample (spade slice) and two tree cores were brought back to the lab for further analysis.

The criteria for the selection of these detailed plot locations were the same as for the reconnaissance samples with the addition of:

1. areas scattered throughout the study zone to enable generalization by having representation from as many different geographical, geological and microclimatic situations as possible; and

2. areas within certain pre-determined forest types to ensure that a minimum of 15 detailed samples were obtained from each of the six major forest alliances.

These detailed samples require more time to perform but they, in return, yield more information and are the most satisfactory way to gather quantitative data on the population structure of forest communities. A total of 149 detailed sample plots were recorded during the 1975 and 1976 field seasons.

In the lab, field records of numbers of tree and shrub stems by species per size class, were converted to basal area figures (m^2/ha) for each detailed sample plot. Basal area is a measure of the cross-sectional area of a stem at breast height (standardized at 4.5 feet above ground level). It is a well-documented measurement in ecological research and gives an indication of the impact or total influence (in terms of competition for space and nutrients) of a species in an area.

The formula used for calculating basal area/hectare was:

$$\left(\begin{array}{l}\text{number of stems in the}\\ \text{size class}\end{array} \times \begin{array}{l}\text{basal area of the}\\ \text{midpoint of the}\\ \text{size class}\end{array} \times 100\right) \div 375$$

The diameters of stems within any particular size class are assumed to fluctuate evenly about the mean; thus the midpoint of the diameter range within the size class was used as the basis for calculating basal area figures (see Table 5).

Knowing the total basal area of all species, the relative dominance value of a species is obtained by the following formula:

$$\frac{\text{total basal area of a species}}{\text{total basal area of all species}} \times 100$$

Within each sample plot, fifty microplots were recorded and each understory species was given a coverage value according to Table 4. The mean percent coverage of each understory species was calculated as follows:

$$\left(N_1(2.5) + N_2(15) + N_3(37.5) + N_4(62.5) + N_5(85) + N_6(97.5) \right) \div 50$$

Where N_1 is the number of occurrences of coverage class 1, N_2...etc.

Table 5. Tree Size Classes

Size Class	Diameter at breast height (dbh) in dm	Midpoint of Diameter Range	Basal Area of One Stem (dm^2)
1-2	0-.5	0.25	0.05
3	.5-1	0.75	0.44
4	1-2	1.5	1.8
5	2-3	2.5	4.9
6	3-4	3.5	9.6
7	4-5	4.5	15.9
8	5-6	5.5	23.8
9	6-7	6.5	33.2
10	7-8	7.5	44.2
11	8-9	8.5	56.7

The percent frequency of an understory species is calculated by the following formula:

$$\frac{\text{number of microplots in which species occurred}}{\text{total number of microplots}} \times 100$$

Percent coverage indicates how successful a plant species is at monopolizing the habitat and indicates how well suited it is to occupy that site. Percent frequency gives an indication of how widespread (adaptable) a species is and whether or not it can occupy diverse microhabitats under a generally homogeneous arboreal stratum.

The detailed sample plot data were then subjected to Braun-Blanquet's tabulation technique (Mueller-Dombois and Ellenberg, 1974) in which species lists for plot samples from similar vegetation types are re-arranged and re-ordered through a series of tables to highlight the most important qualitative differences between the samples. Before transferring the source data into the tables, the samples were sorted according to dominance (i.e., the greatest basal area in square meters/hectare). Communities dominated by species of *Populus* were tabulated separately from communities dominated by *Thuja*, communities dominated by *Pinus strobus* were tabulated separately from

Acer saccharum communities, and so on. These communities dominated by a single tree species are the forest alliances of the region. By using the Braun-Blanquet technique, subdivisions within each alliance (i.e., associations) are readily discernible. Often, subdivisions of the associations (i.e., subassociations) come to light, which were not at first recognizable in the field.

This "...method of orderly comparison, in which more (but not total) emphasis is given to the presence or absence of a species, than to quantitative criteria...", is useful in clarifying the similarity relations among individual communities of the same alliance (Mueller-Dombois and Ellenberg, 1974). This tabular process is an objective treatment of the data and can be repeated by different workers (even those unfamiliar with the local vegetation) to achieve the same results. Marginal relevés (i.e., relevés which were close to the floristic patterns of more than one association)were placed according to the total evidence (i.e., topography, drainage, understory) of the individual stand.

Three important parameters frequently used in describing vegetation are:

1. percent constancy which reflects the number of sample plots in which a species was present, and therefore gives an indication of how widespread a particular species is;

2. mean percent coverage for understory species which is the average of all cover estimates (using the midpoints of the coverage classes - Table 4) made for a particular species for a particular sequence of samples, giving a quantitative assessment of the species influence (areal coverage) in a particular association; and

3. relative dominance, or that proportion of the total basal area of the sampled community, composed of a particular species of tree.

Further analysis included tabulating and comparing habitat features within each association.

In addition to the classification of the samples into associations, an examination of successional trends among the communities was performed by analysis of the tree population structure (i.e., the distribution of size classes of stems by species) and by understory and habitat similarities and differences.

C. Interpretation of Succession and Climax

Certain associations exhibited stable population structure or no evident changes in future dominant species. The recognition of such relatively stable, "climax" forest communities is based on present floristic composition, successional trends within and between present associations and correlation with habitat features such as topography and drainage. The recognition of these climax forest communities is controversial and not always possible when observations are restricted to small areas. In addition, the terms of reference (i.e., the time scale, areal inclusion, degree of allowable dissimilarity) greatly influence the recognized climax vegetation. Several authors, such as Dansereau (1959) and Braun (1950), outline generalized, regional climatic climaxes based on long-term climatic, geological and vegetational characteristics.

In this study, various types of stable forests are recognized based on medium-term edaphic, topographic, microclimatic and vegetational effects. The recognition of stable communities is based on certain "indicators" (after Braun, 1950) such as:

1. essential accordance (i.e., same species) in overstory and sapling stages;
2. convergence of seres (i.e., the tendency of the same community to develop as a result of unlike successions as the end product in the hydrosere and the xerosere);
3. the occupation of topographically mature sites;

4. state of the soil (i.e., maturity of profile equilibrium with vegetation);

5. essential similarity over large areas.

D. Soil Analysis, Tree Cores, Plant Determinations

A total of 53 spade slice soil samples were collected in the field, primarily during the summer of 1976. Each spade slice was a vertical soil profile 30 centimeters deep, 15 centimeters wide and 8 centimeters thick. Samples were taken in an effort to represent each forest association at least once. The samples were brought to the lab where analysis included complete profile description, determination of the pH of all horizons, determination of percent organic matter, soil moisture and textural analysis for composite samples of mineral soil horizons.

Tree core samples were taken from the largest possible trees within the detailed plot borders using a standard Swedish increment borer 36 centimeters in length. In the lab, the cores were air-dried and then glued into slotted boards for sanding with a rotary sander. After a light oiling to more clearly distinguish the annual rings, they were counted with the aid of a binocular microscope following the techniques of Stokes and Smiley (1968).

Preliminary determinations of vascular plant species were made in the field using Hosie (1973) and Preston (1961) for trees, and Peterson and McKenny (1968) and Cobb (1956) for forbs and other herbaceous plants. Collections of unknown and difficult specimens were made. Final determinations were made in the lab using Marie-Victorin (1964) and Gleason and Cronquist (1963). Nomenclature for plants (unless otherwise noted) follows Hosie (1973) for tree species and Gleason and Cronquist (1963) for other vascular plants. Verifications and voucher specimens of the difficult groups have been reviewed by Dr. J. Gillett at the National Herbarium in Ottawa.

CHAPTER 4. Present Forest Vegetation

This study of the forest communities of the Ottawa area revealed six major and five minor forest alliances based on the presence and dominance of the tree species (Table 6). The alliances are named for the dominant tree species and each member stand of the alliance features this named species. Each of the six major alliances is further subdivided into two or more associations which show different, associated species composition. The five minor alliances are of local distribution because of specialized habitat requirements or specific, unusual successional histories. These alliances are relatively uncommon and as a result, the number of samples of each of the minor alliances is low. In addition, each has but one typical association. The associations are named for the dominant tree species and a distinctive understory species (shrub , forb or fern). A total of eleven alliances comprising 21 associations have been recognized. The following descriptive tables of each association are summary tables, normally showing only those species (understory and overstory) with constancy greater than 20% within any particular alliance. Similarly, the population structure tables (Appendix "B") and percent composition graphs are constructed only for those species presently or potentially dominant. Complete association tables listing all vascular plant species found within each association are given in Appendix "B".

The distribution of the forest alliances is correlated to various topographical, hydrological, pedological and geological factors, and the associations are not therefore, equally distributed throughout the region. In particular, the extensive limestone plains of the southwestern part of the area are presently dominated by *Thuja occidentalis* and mixed coniferous forests, although many deciduous forest communities occupy specific local areas. Hardwood swamps of *Fraxinus nigra* and *Ulmus americana* are common. The level, low sand-clay plains in the eastern part of the study zone are often covered by wet *Acer rubrum* or *A. rubrum*-mixed coniferous communities. Broadleaved communities, mainly *Acer saccharum* associations occur throughout, wherever deep, calcareous soils exist. On shallow soils, or acidic, eroding materials, coniferous communities of *Pinus strobus*, *Picea glauca*, *Abies balsamea* and *Tsuga canadensis* are often present, particularly in the northwestern portion of the area. The present study does not include marginally forested areas such as bogs, willow-alder vegetation or other wetland thickets, although these vegetation types have been mapped for selected areas within the study zone (Reed, 1975; and Reed, Billington and Johannsen, 1976), and are described for Ontario elsewhere (Jeglum, Boissoneau and Haavisto, 1974).

The transitional nature of the forests in the study area is seen in Table 6. Of the 21 forest associations present, eight are deciduous communities, seven are mixed deciduous-coniferous forests and the remaining six are coniferous forest communities.

A. Major Alliances

A.1 *Acer Saccharum* Alliance

General Features of the Alliance

Forest communities of the *Acer saccharum* alliance are common in the study area, normally occurring on the deeper, fertile, medium textured loam soils of mid and lower slopes where drainage is good and soils are well-developed. The location of the 28 communities

Table 6. Present Forest Vegetation of the Ottawa Region.

Forest Alliances	Forest Associations	General Character of the Association*
Major Deciduous		
1. *Acer saccharum*	*A.saccharum*-*Parthenocissus quinquefolia*	D
	A.saccharum-*Trillium grandiflorum*	D
2. *Acer rubrum*	*A.rubrum*-*Galium triflorum*	D
	A.rubrum-*Trientalis borealis*	D
3. *Fraxinus nigra*	*F.nigra*-*Matteuccia Struthiopteris*	D
	F.nigra-*Mitella nuda*	M
4. *Populus*	*P.balsamifera*-*Corylus cornuta*	D
	P.tremuloides-*Pteridium aquilinum*	D
	P.tremuloides-*Aster macrophyllus*	M
Major Coniferous		
5. *Thuja occidentalis*	*T.occidentalis*-*Dryopteris austriaca*	M
	T.occidentalis-*Maianthemum canadense*	C
	T.occidentalis-*Pteridium aquilinum*	C
	T.occidentalis-*Botrychium virginianum*	M
6. *Pinus strobus*	*P.strobus*-*Rhus radicans*	C
	P.strobus-*Maianthemum canadense*	C
	P.strobus-*Rhamnus Frangula*	M
Minor Deciduous		
7. *Acer saccharinum*	*A.saccharinum*-*Onoclea sensibilis*	D
8. *Quercus rubra*	*Q.rubra*-*Maianthemum canadense*	M
Minor Coniferous		
9. *Picea glauca*	*P.glauca*-*Waldsteinia fragarioides*	C
10. *Pinus banksiana*	*P.banksiana*-*Pteridium aquilinum*	C
11. *Tsuga canadensis*	*T.canadensis*-*Gymnocarpium Dryopteris*	M

* (D-deciduous, C-coniferous, M-mixed deciduous and coniferous).

sampled is shown in Figure 10.

The tree stratum of the communities is dominated by Acer saccharum and characteristically has species such as Tilia americana, Fraxinus americana, Ostrya virginiana, Ulmus americana and Fagus grandifolia associated with it. Common shrubs include Cornus rugosa, Dirca palustris and Prunus virginiana. The sparse understory is characterized by Dryopteris austriaca, various species of Viola, Trillium grandiflorum, Maianthemum canadense and a rich vernal flora of Erythronium americanum, Dicentra canadensis and Allium tricoccum. Samples of this alliance were the easiest to locate because it is often an Acer saccharum woodlot which was left uncleared on local farmland as a source of maple sugar and wood. Disturbances in the form of hiking trails and garbage dumps were obvious in stands near residential areas, while grazing of the understory by cattle was often a feature of farm woodlots. Sample plots were chosen where such factors were minimal.

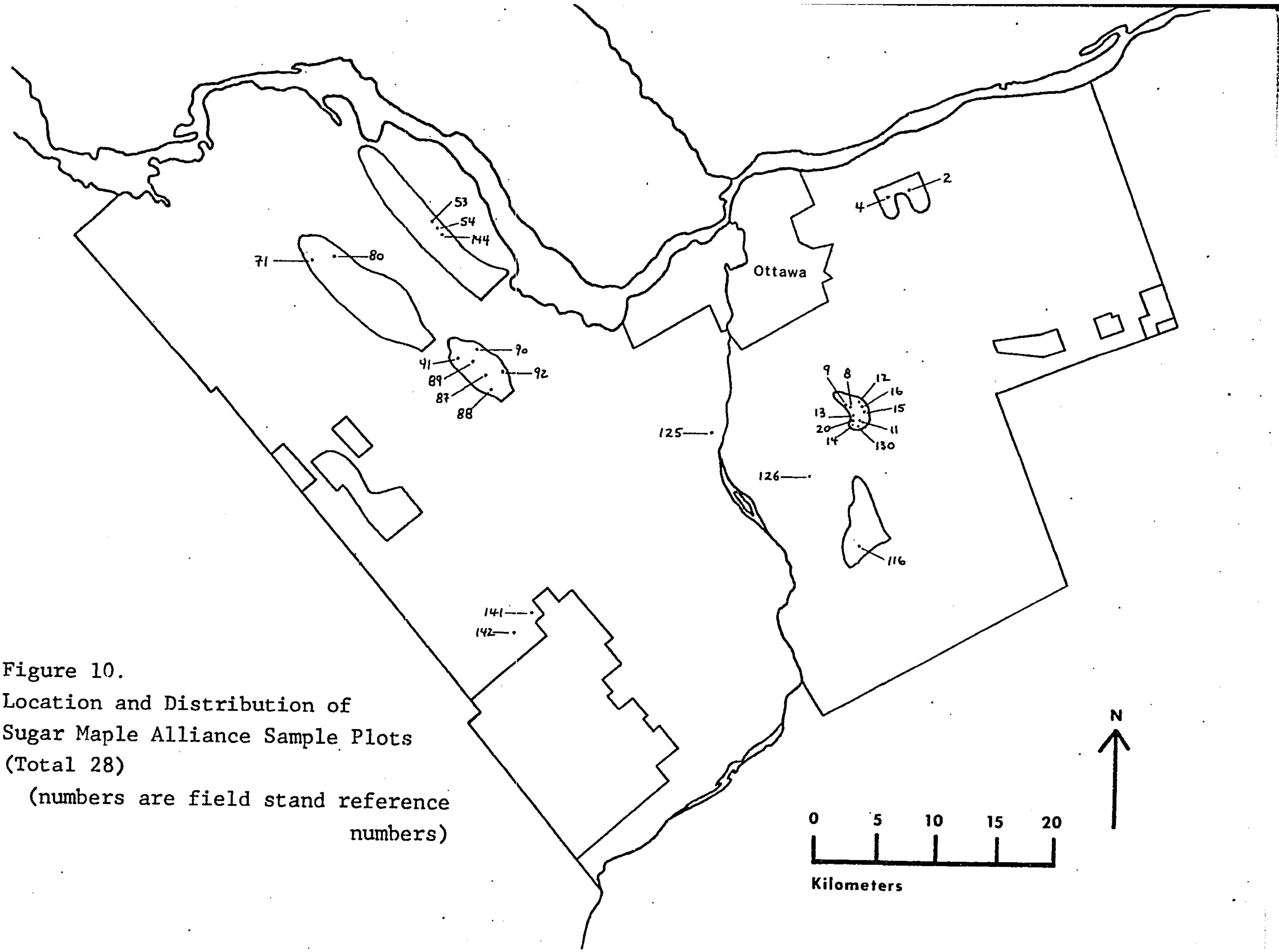


Figure 10.
Location and Distribution of
Sugar Maple Alliance Sample Plots
(Total 28)
(numbers are field stand reference numbers)

Relative dominance and percent constancy values of the tree and shrub species in the 28 communities are given in Table 7.

This table shows the existence of two associations within the *Acer saccharum* alliance namely; *Acer saccharum-Parthenocissus quinquefolia* and *Acer saccharum-Trillium grandiflorum*.

Associations

1. *Acer saccharum-Parthenocissus quinquefolia* Association

In addition to the overstory characteristics of the *Acer saccharum* alliance, the *Acer-Parthenocissus** association is distinguished by the presence and abundance of *Ulmus americana* and *Quercus macrocarpa* (Table 7). Various species of *Amelanchier* characterize the sparse shrub layer. Although the understory (Table 8) is highly similar in all stands of the alliance, the high

*After first mention of the full name of an association, it may be referred to using a binomial composed of only the generic names of the dominant overstory and characteristic understory species.

Table 7. Relative Dominance and Percent Constancy Values (Acer saccharum Alliance)[1]

Acer saccharum Alliance

Plot #	15	11	13	142	71	116	89	130	141	9	12	8	91	14	20	2	80	4	92	16	88	125	90	87	144	54	126	53	Acer-Parthenocissus Association[3]	Acer-Trillium Association[3]
Trees[2]																														
Acs	48	38	76	82	34	23	79	92	66	+	99	80	55	69	61	50	50	41	69	74	54	40	71	35	44	61	94	64	60.100	58.100
Fra			22	1	3	7	+	1	4	13	+	10	7	14		2	18		+		9		+	11	7	+		3	6.86	4.64
Tia	46	14	1	+	16			+		12		2	7		+	7	26		20		+		+	33	4	+	+	+	8.64	6.79
Osv			+		+	18	+	2	7			3	2	1	11	8			6	+	6	3	+	4	14	4			3.64	4.71
Ula	2	18	+	4	23		18	+		43		+	20	12					2		4	+			+		+	+	10.79	+.43
Fag					+										14	19	5	22	2	26	23	57	27	10	24	29	+	22	+.07	20.100
Caco				1	+		+	4	+				9	4	8		+		2		1		+	1	2		+		1.50	1.57
Qur					+		1														+		+	+	+			10	+.14	+.36
Tsc				3					+						+								+		+	+		+	+.14	+.36
Abb					3										+	+					+					+	+		+.07	+.36
Frn	8	18				+										4										2	2		2.21	+.21
Tho		3								+		5		+	1											+			+.29	+.14
Bea	2					6				+					4			2									2		+.21	+.21
Acr				8		2						+				+		2								+			+.21	+.21
Qum				+		12	+	+			+																		+.36	.
Shrubs																														
Cor	+							+		+		+		+		+			+	+					4	3		+	+.36	+.43
Dip						+		+						+	+	+		+							+	+			+.21	+.36
Amel			+				+		+	+	+	+																	+.43	.
Prv							+	+												+			+				+		+.14	+.21
Vir	+							+			+								+	+									+.21	+.14
	Acer-Parthenocissus Association (plots 15–14)														Acer-Trillium Association (plots 20–53)															

1 (Table 7 lists only those species showing 15% constancy or greater within the alliance; complete species list is found in Appendix Table B.1.1).
2 (Species abbreviations are defined in Appendix Table C ;normally, the abbreviation is the first two letters of the genus name and the first letter of the specific name).
3 (Number to the left of the dot is relative dominance, number to right of dot is percent constancy).

Table 8. Understory Species in the *Acer saccharum* Associations[1]

Forbs	*Acer-Parthenocissus* Association[2]	*Acer-Trillium* Association[2]
Carex spp.	4.86	4.79
Viola spp.	+.71	+.57
Trillium grandiflorum	+.29	3.64
Maianthemum canadense	+.29	+.43
Smilacina racemosa	+.21	+.50
Epipactis helleborine	+.29	+.43
Ribes spp.	+.36	+.29
Polygonatum biflorum	+.29	+.29
Caulophyllum thalictroides	+.21	1.36
Asarum canadense	+.14	+.43
Parthenocissus quinquefolia	2.43	+.07
Actaea alba	+.21	+.29
Galium triflorum	+.29	+.14
Ranunculus abortivus	+.29	+.14
Taraxacum officinale	+.29	+.14
Arisaema triphyllum	+.21	+.14
Solidago spp.	+.21	+.14
Ferns and Allies		
Dryopteris austriaca	1.57	+.64
Botrychium virginianum	+.29	+.36
Athyrium Filix-femina	+.07	+.29
Botrychium multifidum	+.14	+.21
Understory Characteristics		
Mean Understory Coverage (%)	24.4	21.0
Mean Number of Species	17.4	14.9
Mean Number of Species With Coverage Greater Than 1%	4.5	3.6

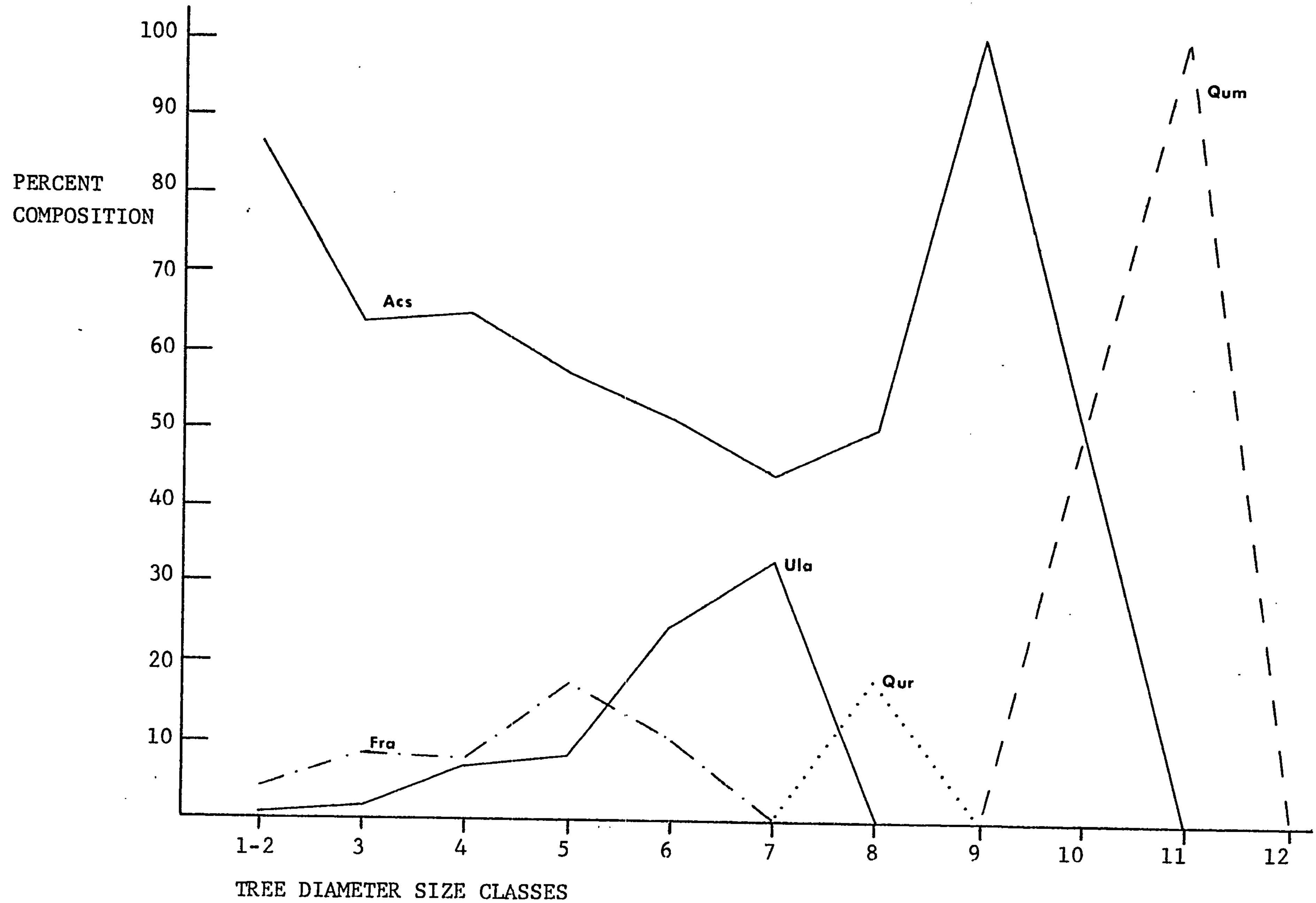
1 (Table 8 lists only those species showing 15% constancy or greater within the alliance; complete species list is found in Appendix Table B.1.2).
2 Number to the left of the dot is percent coverage, number to right of dot is percent constancy).

constancy of both Parthenocissus quinquefolia and numerous species of Viola are the best understory indicators of this association. Stands have an average of 17 species and a mean understory coverage of about 24%.

The size class distribution of the five major tree species in the Acer-Parthenocissus association is graphed in Figure 11. This represents the "typical" distribution of the major tree species by size class within the association. An assessment of the variation within the association can be made by inspection of Appendix Table B.1.3.

Figure 11 shows the over-riding importance of Acer saccharum in all size classes. Less important but characteristic populations of Fraxinus americana, Tilia americana and the sub-canopy species, Ostrya virginiana are present up to size class 6, 8 and 4 respectively. Ulmus americana exerts increasing influence and competition in the larger size classes, but it too,

Figure 11. Percent Composition of the Major Tree Species in the *Acer*-*Parthenocissus* Association



stops short of the largest sizes attained by *Acer saccharum* possibly because of elimination by Dutch Elm Disease. Lack of space in Figure 11 prohibited the plotting of *Quercus rubra*, *Prunus serotina* and *Quercus macrocarpa*, but these species are restricted to the larger size classes, indicating presence only as occasional, very large individuals.

This association achieves maximum average stand basal area of 59 m^2/ha in mesic, medium topographic situations with a decline from this maximum as sites become either more wet or more dry (Table 9). Over the total range of drainage class conditions, the *Acer-Parthenocissus* association attains an average basal area of 45 square meters/hectare.

These data indicate that the *Acer-Parthenocissus* association is a late, stable successional stage. It developed from an earlier seral stage in which *Quercus rubra*, *Q. macrocarpa* and *Prunus serotina* were prevalent.

Table 9. Average Basal Area of the Associations by Drainage Class[1]

Association	Average Basal Area	Range of Basal Area	Basal Area By Drainage Class: Wet	Wet-Mesic	Mesic	Dry-Mesic	Dry
Acer-Parthenocissus	45	11-125		32(1)	*59(7)	50(1)	27(5)
Acer-Trillium	51	26-132		33(1)	*53(13)		
Acer-Galium	51	35-67	65(1)	*51(5)	35(1)		
Acer-Trientalis	47	25-71	44(1)	52(3)	*48(7)		
Fraxinus-Matteuccia	34	24-47	33(4)	*35(3)	36(1)		
Fraxinus-Mitella	42	33-57	*41(6)	55(1)	35(1)		
Populus-Corylus	46	25-72		*46(4)			
Populus-Pteridium	38	18-67		*48(3)	42(1)	18(1)	24(1)
Populus-Aster	36	20-50			*37(3)	39(2)	28(1)
Thuja-Dryopteris	56	46-77	*61(3)	52(1)	46(1)		
Thuja-Maianthemum	48	23-66	*56(2)		52(1)	53(3)	36(3)
Thuja-Pteridium	74	14-150		95(1)	*90(6)	65(2)	25(2)
Thuja-Botrychium	42	23-62	23(1)	32(1)	*62(1)	53(1)	40(2)
Pinus-Rhus	31	12-46			28(4)		*34(4)
Pinus-Maianthemum	55	13-108			*70(5)		19(2)
Pinus-Rhamnus	49	25-94			66(1)	*94(1)	38(6)
Acer-Onoclea	63	50-75	*75(1)	50(1)			
Quercus-Maianthemum	39	36-44			*40(2)		38(1)
Picea-Waldsteinia	42	30-53			*46(2)		40(2)
Pinus-Pteridium	45	31-59				31(1)	*59(1)
Tsuga-Gymnocarpium	43	33-61			*43(5)		

1 (Basal area is in m^2/ha;number in brackets is the number of samples represented in that drainage class).

* (Drainage class in which the maximum individual stand basal area was recorded).

These species presently exist only as scattered large individuals within a forest dominated by *Acer saccharum* and *Ulmus americana* and will slowly disappear with the deaths of the remaining old trees. *Ulmus americana* will remain as an important member of the association for many years, although it will probably not be a permanent member because of the paucity of its seedlings and the ravages to large trees by Dutch Elm Disease. This association will slowly lose several species with no apparent invading species. It is expected that, without further disurbances, it will become increasingly dominated by *Acer saccharum* in all size classes while maintaining small but characteristic populations of *Tilia americana*, *Fraxinus americana* and *Ostrya virginiana*.

Table 9 shows that the *Acer-Parthenocissus* association is found within a wide range of drainage classes from wet-mesic to dry, with the average condition, being towards the drier end of the moisture gradient. The association is generally absent from the favourable mid-slope locations and tends to occupy relatively flat sites which range from moist lowlands and mesic plateaus to dry, rocky ridge tops (Figure 12). Degree of slope and aspect appear to have little importance in the distribution of these communities, although a slight tendency toward northerly-facing locations is apparent (Appendix Table B.1.3).

Soil samples collected from stands of the association shows the soils to be sandy loams with an average organic matter content of about 8% and a pH of 5.5 (Table 10). According to the Soil Survey of Carleton County (Hills *et al.*, 1944), these communities occur on substrates classified as organic mucks, roughly-stratified acidic sands and medium-textured till soils (Appendix Table B.1.3). Although local differences are not apparent on the general soils map, it appears that the *Acer-Parthenocissus* association is most frequently found on medium-textured, sandy loams even within mapping units dominated by very different soils.

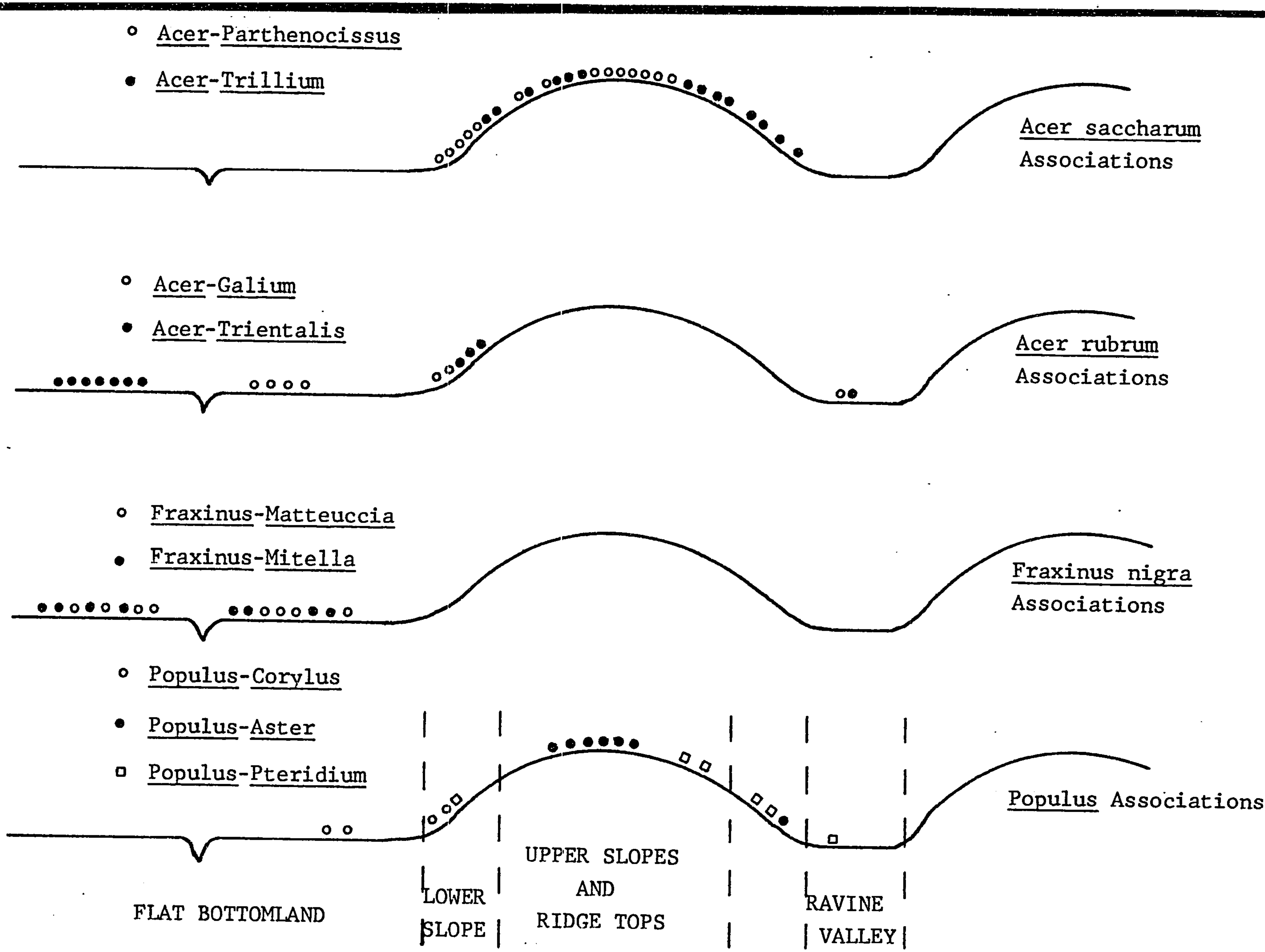


Figure 12. Relative Topographic Positions of the *Acer saccharum*, *A. rubrum*, *Fraxinus nigra* and *Populus* Associations

Table 10. Soil Characteristics of the Forest Associations[1]

	Drainage Class	Textural Class[3]	% Sand	% Silt	% Clay	% Organic Matter	pH
Acer-Parthenocissus	3.7	SL	61	30	9	7.6	5.5
Acer-Trillium	2.9	SL	58	34	8	7.0	6.0
Acer-Galium	2.0	LS	81	14	5	4.5	5.8
Acer-Trientalis	2.5	SL	71	23	6	5.9	4.7
Fraxinus-Matteuccia	1.6	SL	57	33	12	6.6	5.9
Fraxinus-Mitella	1.3	L	44	40	17	10.5	7.0
Populus-Corylus	2.0	L	50	37	13	6.2	7.0
Populus-Pteridium	3.0	LS	86	9	5	3.0	4.9
Populus-Aster	3.7	LS	82	13	6	7.0	5.0
Thuja-Dryopteris	1.6	O	-	-	-	100	6.5
Thuja-Maianthemum	3.4	SL	51	36	13	7.8	7.2
Thuja-Pteridium	3.5	SiL/O	23	74	3	9.4	7.0
Thuja-Botrychium	3.3	SL	51	42	7	8.8	6.3
Pinus-Rhus	4.0	S	89	6	5	2.3	4.7
Pinus-Maianthemum	3.6	LS	82	12	6	4.7	4.4
Pinus-Rhamnus	4.6	SL	59	33	8	6.7	4.8
Acer-Onoclea	1.5	L	43	32	25	16.3	5.1
Quercus-Maianthemum[2]	3.7	-	-	-	-	-	-
Picea-Waldsteinia	4.0	SiL/O	28	52	20	4.3	5.7
Pinus-Pteridium	4.5	S	93	4	3	2.3	5.1
Tsuga-Gymnocarpium	3.0	L	38	37	26	9.9	5.5

1 (Values in the table are averaged for all soil samples taken in the association).

2 (No soil samples were taken from this association).

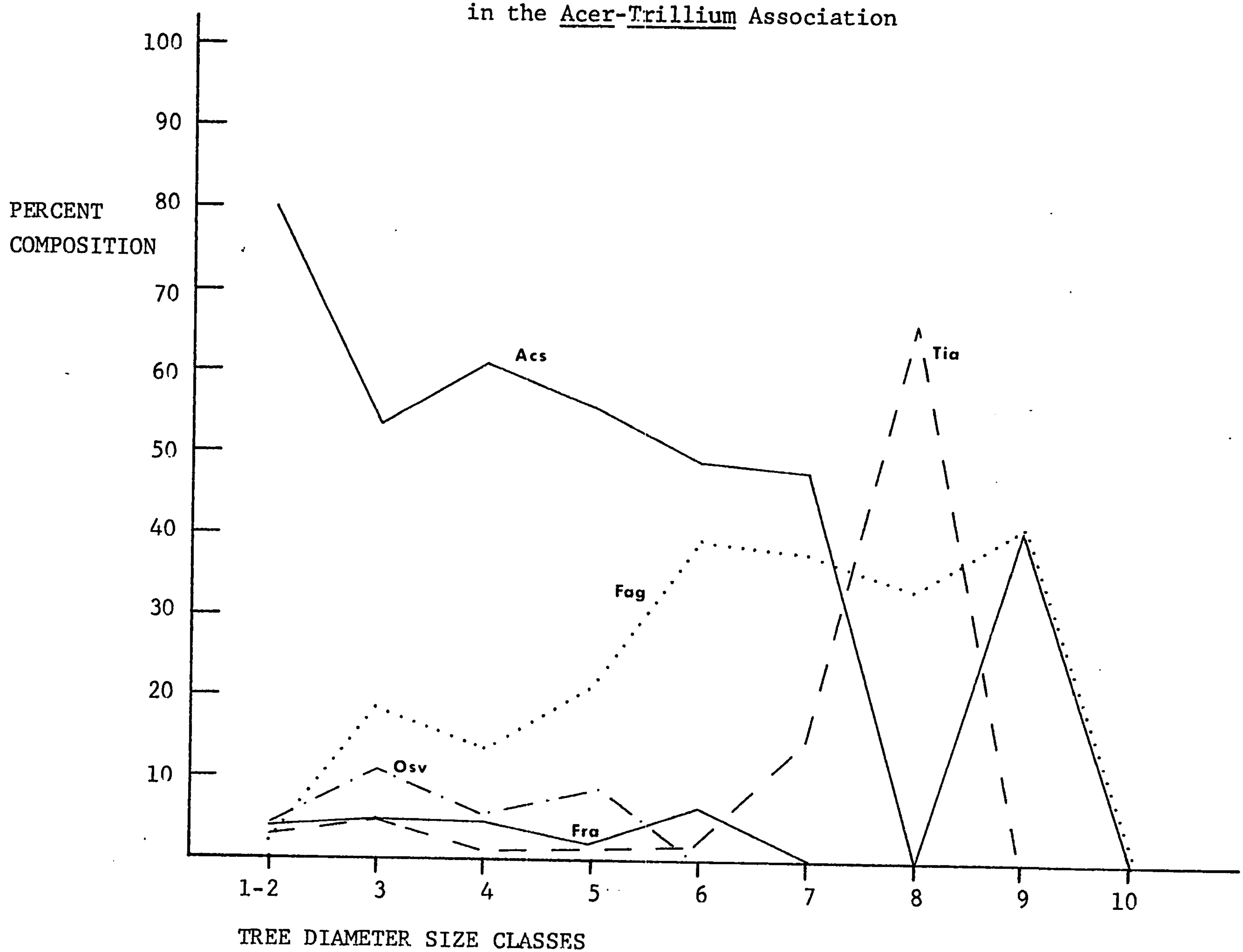
3 (SL - sandy loam; LS - loamy sand; L - loam; O - organic; S - sand; SiL - silt loam).

2. *Acer saccharum-Trillium grandiflorum* Association

In addition to the tree species characteristic of the alliance, the overstory of the *Acer-Trillium* association is distinguished by the consistent presence of *Fagus grandifolia* (Table 7). The shrub stratum is similar to that of the *Acer-Parthenocissus* association except that *Amelanchier* is absent and *Corylus cornuta* is occasionally present. The understory has a high constancy and percent coverage of *Trillium grandiflorum*, *Caulophyllum thalictroides* and *Asarum canadense* (Table 8). The average number of understory species is 15 with a mean percent coverage of 21%.

Figure 13 shows the population composition of the major tree species of the association. *Fraxinus americana*, *Tilia americana* and *Ostrya virginiana* show very similar patterns to those found in the *Acer-Parthenocissus* association. The two major tree species here, *Acer saccharum* and *Fagus grandifolia* show almost opposite population composition through increasing size

Figure 13. Percent Composition of the Major Tree Species in the Acer-Trillium Association



classes. *Acer saccharum* has very high percent composition in size class 1-2, but this slowly decreases (although it remains higher than all other species) until size class 9 in which it is equal in percent composition with *Fagus grandifolia*. *Fagus*, on the other hand, is represented very sparsely as seedlings (size class 1-2) but slowly gains importance through larger size classes until at the largest recorded size, it contributes as many stems as *Acer saccharum*. The remaining 20% composition of size class 9 is made up of a solitary specimen of *Quercus rubra*. The absence of *Acer saccharum* from size class 8 is considered to be an artifact either of sampling size, since the number of stems involved at these large size classes is small, or the result of selective cutting at an earlier date. Over all sites, this association maintains an average basal area of 51 m2/ha (Table 9).

The *Acer-Trillium* association is an advanced successional stage which developed from forest in which _Quercus rubra_ was present. _Acer saccharum_ will maintain its dominance in the future based on the abundance of its seedlings and saplings. _Fagus grandifolia_ will similarly maintain its importance in this association since it presently has an adequate sapling population to replace older members dying out. Typical of the alliance is the minor but stable populations of _Fraxinus americana_, _Ostrya virginiana_ and _Tilia americana_ which will persist as time goes on. No potential invading species exist here to displace the present dominants, and barring disturbance, this association will regenerate itself perhaps with changes in the degree of dominance but not in species composition.

The _Acer-Trillium_ association typically occupies a much more uniform habitat than does the _Acer-Parthenocissus_ association. Member communities are almost entirely restricted to mesic drainage conditions on mid-slope locations, ranging from upper plateaus to mesic lower slopes (Figure 12). In general, these sites are south-facing and growing conditions appear to be more favourable.

Samples from this association show the soil to be medium-textured sandy loam with moderate organic matter content and a slightly acidic character (Table 10). According to the soils map of Carleton County (Hills *et al*., 1944), member stands of the *Acer-Trillium* association are rarely located on sandy or coarse-textured soils, but very often on a wide range of mature, medium-textured, fertile substrates (Appendix Table B.1.3).

A.2 *Acer rubrum* Alliance

General Features of the Alliance

Forest communities of the *Acer rubrum* alliance are found in many areas within the study zone and invariably occupy flat bottom land or lower slope situations. They are particularly abundant as wet to mesic communities on the lower slopes of Constance Creek, as mesic stands on the plateaus above Bilberry Creek and as extensive lowland forests in Cumberland Township. In the southern and central portions of the study area, communities belonging to this alliance are not well developed being particularly scarce on the shallow limestone soils in these regions. Figure 14 displays the location and distribution of the 18 members of the *Acer rubrum* alliance sampled during the present study.

The tree stratum of member communities is always dominated by *Acer rubrum* with *Ulmus americana*, *Fraxinus nigra*, *Populus tremuloides* and *Betula papyrifera* often associated with it. The shrub layer is composed of *Cornus stolonifera*, *Viburnum* species, *Prunus virginiana* and/or *Corylus cornuta*. Understory species characteristic of the alliance include *Maianthemum canadense*, *Dryopteris austriaca*, *Onoclea sensibilis* and *Aralia nudicaulis*.

Table 11 shows the complete array of the 18 *Acer rubrum* stands with relative dominance of the tree and shrub species within the alliance. The table shows the differentiation of two *Acer rubrum* associations; namely *Acer rubrum-Galium triflorum* and *Acer rubrum Trientalis borealis*.

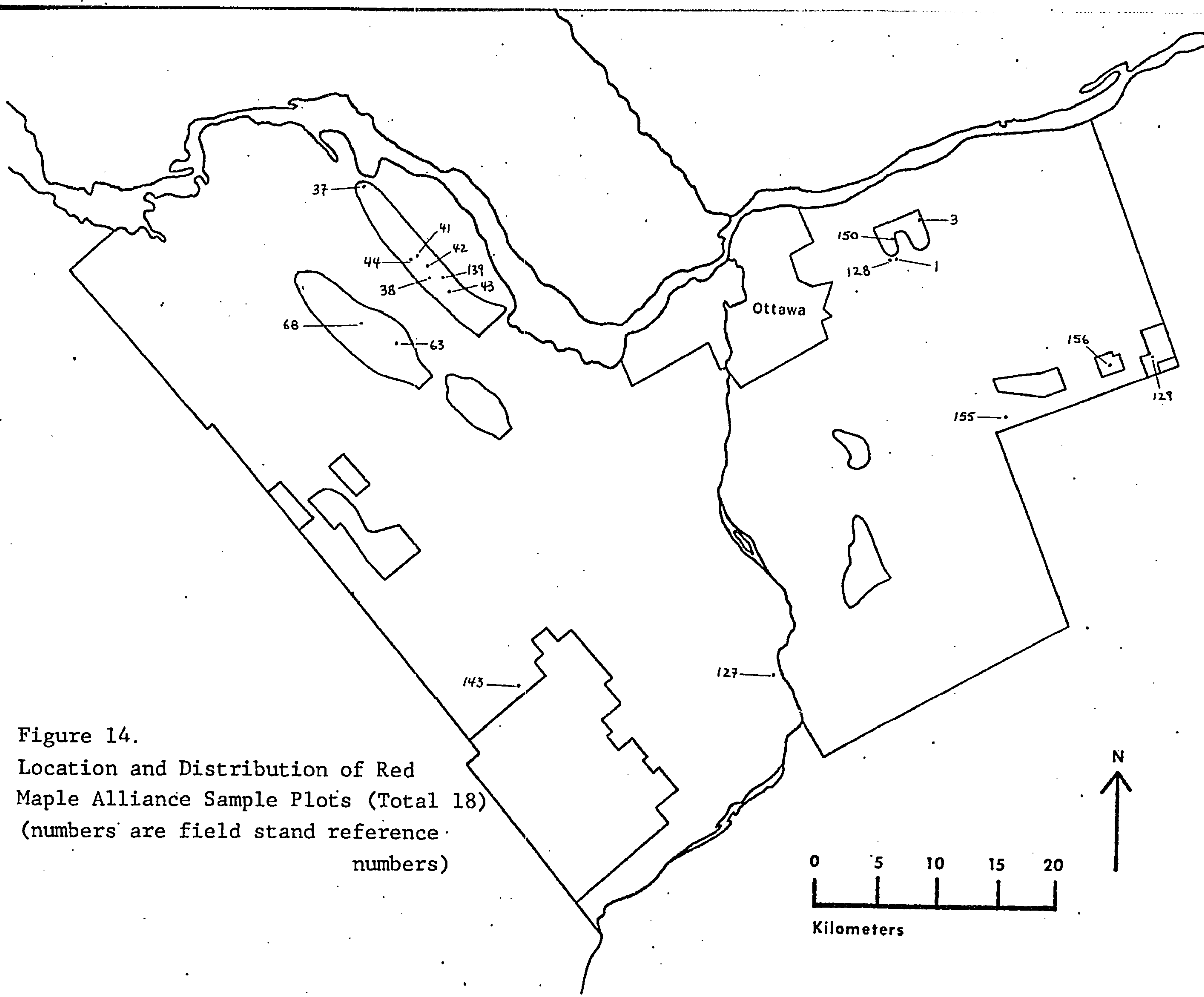


Figure 14.
Location and Distribution of Red Maple Alliance Sample Plots (Total 18) (numbers are field stand reference numbers)

Table 11. Relative Dominance and Percent Constancy Values (*Acer rubrum* Alliance)[1]

	Acer rubrum Alliance																		
	Acer-Galium Association							Acer-Trientalis Association												
Plot #	143	127	41	43	139	42	3	68	156	129	128	1	37	150	44	38	63	155	Acer-Galium Association[3]	Acer-Trientalis Association[3]
Trees[2]																				
Acr	60	57	85	35	81	94	36	40	87	58	71	75	52	79	44	54	44	72	64.100	63.100
Bep			+	1				8	1	4	4	2	2	3	4	2	4	+	+.29	3.100
Ula	35	+	1	20	2	+	12	27		+	+			8				+	10.100	4.50
Frn	4	20	6	2	13	4	25			+		+	+		8				11.100	+.40
Pot				20				11	3	6	2		19	+	12	26	22	12	3.14	9.90
Fra				13		+	23	5			+	+		+	+		5	+	5.43	+.60
Pob				+	+			+			+	11			+	+	+	+	+.29	1.60
Abb			6	+					+				+	+	1	+			+.29	+.50
Prs		8		1					4		+			+			+	+	1.29	+.40
Qum		2	+				4	+			+				+	+			+.43	+.40
Pog										7	6		+				11	13	.	3.45
Shrubs																				
Coco		6					+	1	2	4	+	+	14	2	7	18	1	+	+.29	5.100
Cos	+			+		1	+	+		6	+		+		+		+		+.57	+.50
Prv		5	+	+	+	+	+				+			5			+	+	+.86	+.30
Amel		+					+		+	3	1	+		+			+	+	+.29	+.60
ViL		+	+					+	+	9	13	+		+				+	+.29	2.70
Loc		+						+	+	+					+			+	+.14	+.50
RhF								+	2		+						+	+	.	+.40
Acsp		2		+	+									+	18				+.43	2.18
Dil										+	+				+	+		+	.	+.45

1 (Table 11 lists only those species showing 25% constancy or greater within the alliance; complete species list is found in Appendix Table B.2.1).
2 (Species abbreviations are defined in Appendix Table C).
3 (Number to left of dot is relative dominance, number to right of dot is percent constancy).

Associations

1. Acer rubrum- Galium triflorum

The overstory of this association is characterized by the consistent presence of Ulmus americana and Fraxinus nigra in association with the dominant Acer rubrum (Table 11). The most constant shrub species is Prunus virginiana. The understory flora, while maintaining the general characteristics of the alliance, is distinguished by the consistent presence and abundance of Onoclea sensibilis and Galium triflorum (Table 12). The luxuriant understory of this association has a mean total coverage of about 83% and an average of 25 species.

The typical distribution of the major tree species by size class is displayed for the Acer-Galium association in Figure 15. The dominance of Acer rubrum is obvious throughout the size class spectrum while Ulmus americana is of lower influence but present throughout. Fraxinus nigra maintains low numbers of stems up to size class 5 and Populus tremuloides shows a sporadic,

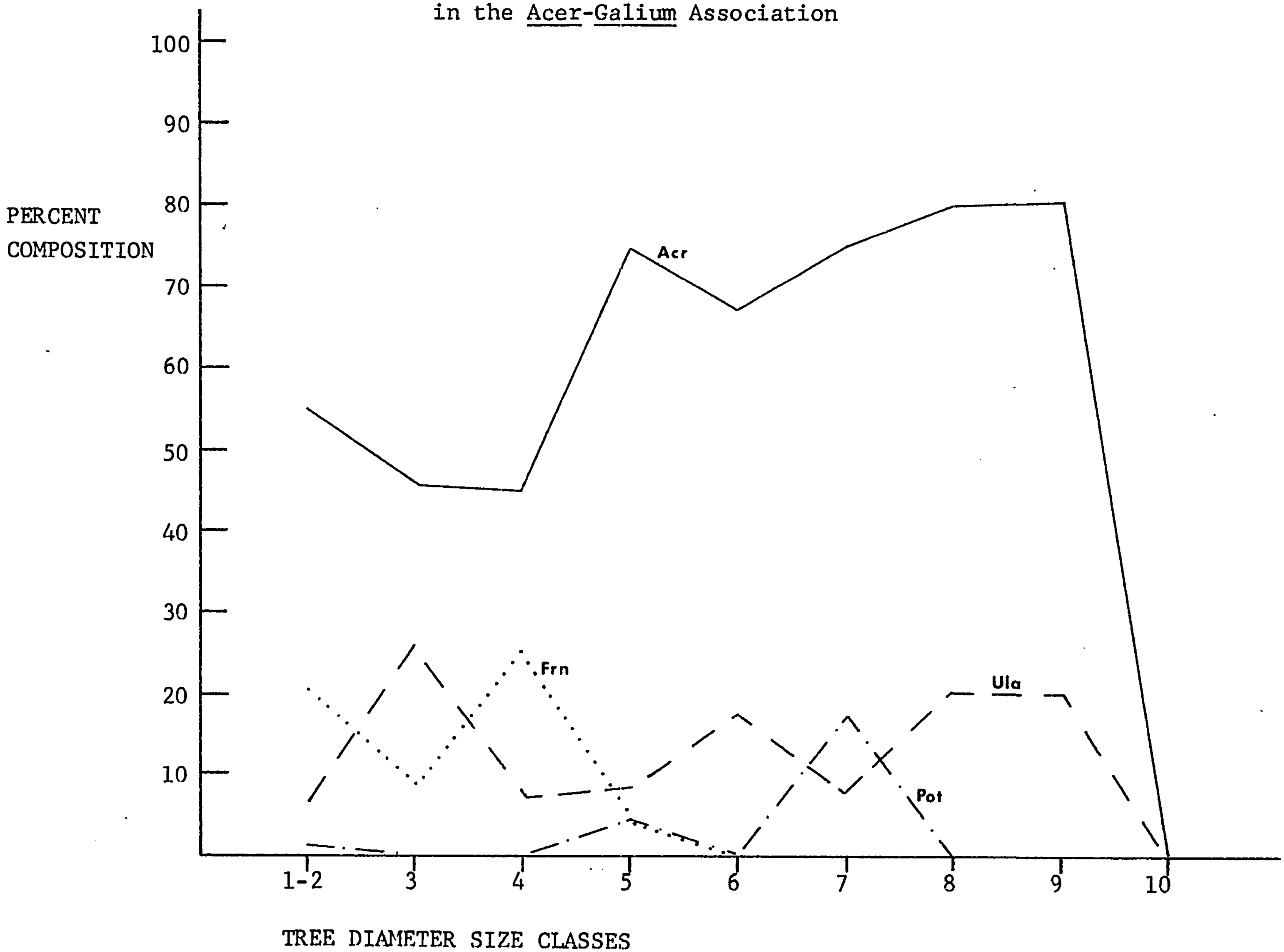
Table 12. Understory Species in the *Acer rubrum* Associations[1]

Forbs	Acer-Galium Association[2]	Acer-Trientalis Association[2]
Carex spp.	12.86	3.91
Rubus spp.	7.100	5.82
Maianthemum canadense	2.57	9.100
Aralia nudicaulis	3.57	6.91
Trientalis borealis	+.29	+.82
Ribes spp.	3.71	+.55
Viola spp.	+.43	+.73
Clintonia borealis	+.43	3.64
Galium triflorum	1.86	+.27
Pyrola elliptica	+.29	+.55
Rhus radicans	2.57	+.36
Cornus canadensis	+.14	+.64
Parthenocissus quinquefolia	+.57	+.36
Lycopus americanus	+.29	+.45
Aster spp.	+.43	+.36
Trillium grandiflorum	+.29	2.36
Waldsteinia fragarioides	+.14	+.45
Fragaria virginiana	1.29	+.36
Ferns and Allies		
Onoclea sensibilis	13.100	6.73
Dryopteris austriaca	2.86	3.64
Pteridium aquilinum	+.43	3.82
Athyrium Filix-femina	1.71	2.45
Thelypteris palustris	+.29	+.45
Equisetum sylvaticum	+.43	+.45
Osmunda cinnamomea	2.43	4.55
Lycopodium obscurum	.	3.64
Osmunda regalis	+.14	+.45
Understory Characteristics		
Mean Understory Coverage (%)	82.5	67.5
Mean Number of Species	25.1	26.5
Mean Number of Species With Coverage Greater Than 1%	12.1	11.0

1 (Table 12 lists only those species showing 30% constancy or greater within the alliance; complete species list is found in Appendix Table B.2.2).

2 (Number to left of dot is percent coverage, number to right of dot is percent constancy).

Figure 15. Percent Composition of the Major Tree Species in the <u>Acer-Galium</u> Association



inconsistent number of stems mainly in the larger size classes. The best development of this association, in terms of total stand basal area, occurs on the wet and wet-mesic sites with a decline towards drier locations. The average stand basal area is 51 m2/ha over all sites (Table 9).

Population analysis indicates that, although both *Fraxinus nigra* and *Ulmus americana* are producing numerous seedlings, these have difficulty in surviving through the sapling stage. Barring future disturbance, the overstory of the *Acer-Galium* association will witness the loss of seral species such as *Populus tremuloides* and the slow elimination of both *Fraxinus nigra* and *Ulmus americana* through failure of regeneration. These latter two species will remain as the most important associated tree species for many years. The successional trend in this association is towards a more homogeneous *Acer rubrum* community since, on all sites, this species shows a strong population continuation and no evidence of failing regeneration. As stands mature other species may invade, but our data show no evidence that this will happen in the foreseeable future.

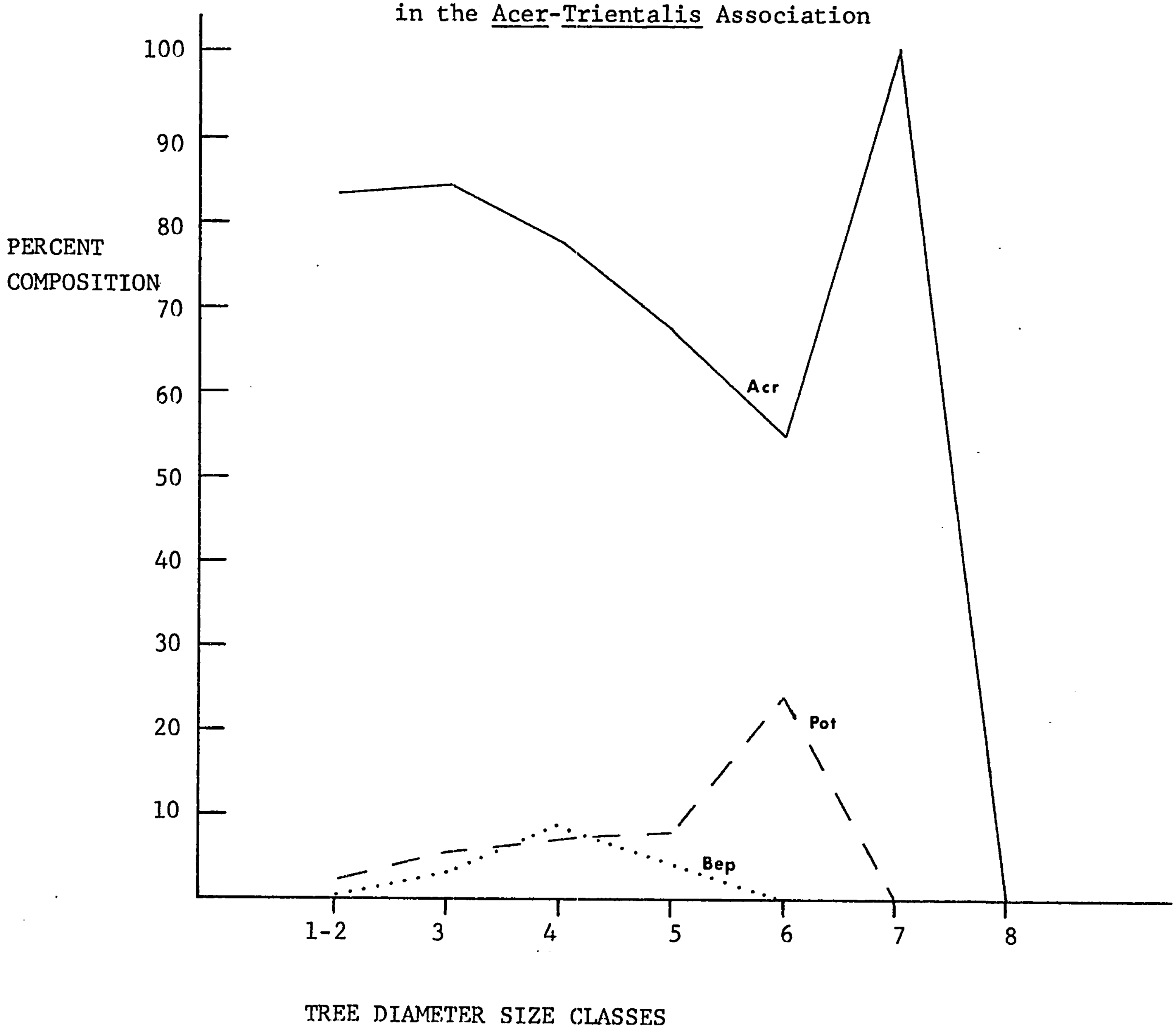
The _Acer-Galium_ association exhibits a decided preference for wet-mesic sites, although it can be found in situations ranging from very wet to mesic (Table 9). Most sampled communities were on relatively flat topography, while those which occurred on gentle slopes tended to be oriented in an easterly direction (Appendix Table B.2.3). An analysis of the topographic positions of these communities shows that they occur on flat bottom lands or extreme lower slopes sites (Figure 12). The _Acer-Galium_ association frequently develops on either acidic, loamy sands (often of deltaic or water-lain origin) or deep, organic soils which are normally well-decomposed, acidic and of low fertility. These muck deposits are particularly prevalent in former channels of the Ottawa and Rideau Rivers such as along Constance Creek and at Cranberry Marsh. Supplementary information from the Soil Survey of

Carleton County (Hills *et al*., 1944) corroborate these results (Appendix Table B.2.3).

2. *Acer rubrum*-*Trientalis borealis* Association

The overstory of this association is characteristically dominated by *Acer rubrum* with *Populus tremuloides* and *Betula papyrifera* as associated species (Table 11). The shrub stratum is more diverse and luxuriant than that of the *Acer*-*Galium* association. Here, *Corylus cornuta*, various *Amelanchier* species and *Viburnum Lentago* are constant and abundant. The understory is distinguished by a rich fern flora, including *Osmunda regalis* which is rarely seen elsewhere. In addition, the consistent presence of *Trientalis borealis*, *Clintonia borealis*, *Cornus canadensis* and *Waldsteinia fragarioides* clearly differentiate this member of the *Acer rubrum* alliance (Table 12). This diverse understory is composed, on the average, of 27 species which cover about 68% of the forest floor. Figure 16 represents the population composition of the major tree species in this association. *Acer rubrum*

Figure 16. Percent Composition of the Major Tree Species in the Acer-Trientalis Association



clearly shows monopolization of all size classes. Populus tremuloides and Betula papyrifera are the only other species presently maintaining lower populations in this association. Populus tremuloides is most important relative to other trees in size class 6.

Maximum stand basal area develops on the mesic sites with the largest recorded being 71 m2/ha. Over the total range of drainage classes, the Acer-Trientalis association maintains an average stand basal area of 46 m2/ha. Succession within the Acer-Trientalis association will continue towards a relatively pure Acer rubrum association. This species exhibits healthy, continuous populations in all member stands (Appendix Table B.2.3). The other two important species, Populus tremuloides and Betula papyrifera show distinct breaks in population structure (i.e., lack of stems in certain size classes) and will slowly be eliminated under the competitive pressure of Acer rubrum.

The *Acer*-*Trientalis* association tends to occupy slightly drier sites than the other member of the alliance (Table 9). Its average drainage class indicates close to mesic conditions, although it can be found on sites ranging from wet to mesic. These communities occupy flat bottom lands and lower slopes, as do members of the *Acer*-*Galium* association (Figure 12).

The *Acer*-*Trientalis* association generally occurs on fine-textured, acidic, sandy loam soils with an organic matter content of about 6% and an average pH of 4.7 (Table 10). According to the Carleton County Soil Survey (Hills *et al.*, 1944), these communities occur predominantly on substrates classified as acidic sands of deltaic origin, containing low amounts of lime and organic matter (Appendix Table B.2.2).

A.3 *Fraxinus nigra* Alliance

General Features of the Alliance

Communities in which *Fraxinus nigra* and *Ulmus americana* are commonly associated and dominant are found throughout the study zone, wherever flat areas occur adjoining ponds or slow-moving streams. As a result of site restriction, these communities tend to be linear in outline, paralleling rivers, creeks and beaver ponds in a thin band between open water and solid upland slopes. In some cases, extensive areas of the *Fraxinus nigra* alliance occur as a result of widespread slow drainage through a lowland area (e.g., Osgoode Bog, Waterfowl Area). In other cases, the width of the community is so narrow that it was impossible to lay out the macroplot boundaries without including influences from surrounding forests or wetlands. Sixteen sample plots were located within the study zone as shown in Figure 17.

The overstory of the alliance normally contains both *Fraxinus nigra* and *Ulmus americana*. *Fraxinus nigra* is often dominant, although *Ulmus americana* may exhibit dominance in some stands. The diverse and abundant shrub flora generally includes *Cornus stolonifera*, *Sambucus canadensis* and *Prunus virginiana*. The luxuriant understory includes *Galium triflorum*, various

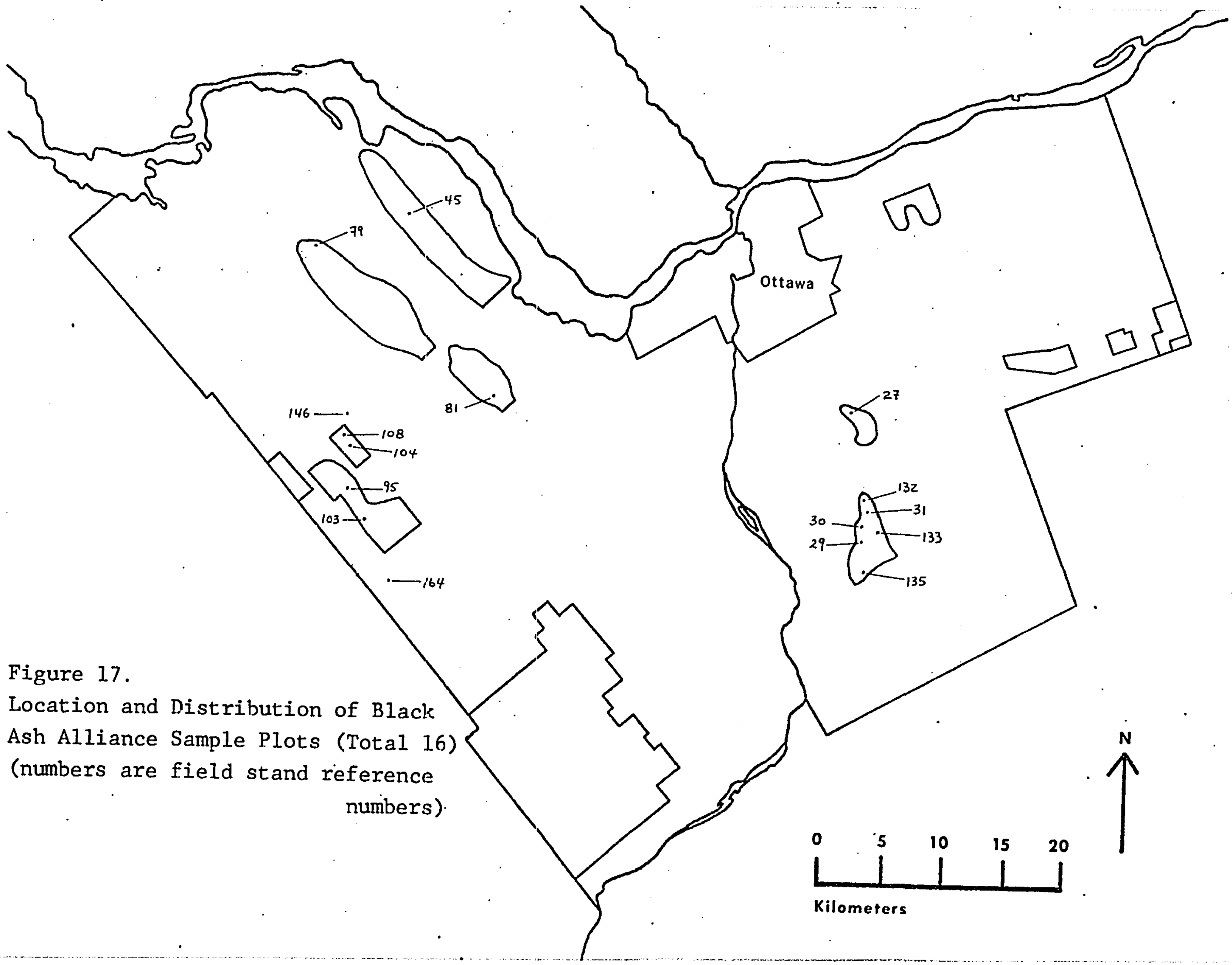


Figure 17.
Location and Distribution of Black Ash Alliance Sample Plots (Total 16) (numbers are field stand reference numbers)

species of *Ribes* and *Rubus*, and a rich fern assortment featuring *Onoclea sensibilis*, *Dryopteris austriaca* and *D. cristata*.

Relative dominance and percent constancy values of the tree and shrub species in the sixteen communities are given in Table 13, which shows the existence of two associations within the alliance, namely: *Fraxinus nigra-Matteuccia Struthiopteris* and *Fraxinus nigra-Mitella nuda*.

Associations

1. *Fraxinus nigra-Matteuccia Struthiopteris* Association

   The overstory of the *Fraxinus-Matteuccia* association is characterized by the dominance of *Fraxinus nigra* and the presence of *Ulmus americana* although in rare cases, one or the other of these major species becomes dominant to the exclusion of the other. Various associated species may include *Acer rubrum*, *Populus tremuloides*, *Acer negundo*, *Tilia americana*, *Juglans cinerea* and *Betula alleghaniensis* (Table 13). The shrub stratum includes *Cornus stolonifera*, *Sambucus canadensis*,

Table 13. Relative Dominance and Percent Constancy Values (Fraxinus nigra Alliance)[1]

Fraxinus nigra Alliance

Plot #	30	135	79	81	29	27	132	103	31	45	104	95	146	164	133	108	Fraxinus-Matteuccia Association[3]	Fraxinus-Mitella Association[3]
Trees[2]																		
Frn	41	91	84	41	77		68	98	2	58	39	44	46	30	5	51	63.88	34.100
Ula	2	5	15	33	7	99	5		10	+	23	23	51	30	21	4	21.88	20.100
Tho									+	11	6	14	+	14	+	5	.	6.100
Acr	29			15	+		18		13	19	+	6					8.50	5.50
Pot	27					+			23			9			13	+	3.25	6.50
Pob											21		+	24	8		.	7.50
Abb				+			+		+	7							+.25	+.25
Bep									11	2				2			.	2.38
Acne	+						+	2									+.38	.
Tia			+	1			2										+.38	.
Shrubs																		
Cos	+	+		+	+			+		+	1	1	+	+	29	3	+.63	4.88
Sac	+	1			+		+		+				+				+.50	+.25
Prv		+		+			+		+				+		+		+.38	+.38
Vic		+		+	+		+		+								+.50	+.13
Amel	+			+		+			+								+.38	+.13
Acsp	+			2			5										+.38	.
RhF													2	+	19		.	3.38
Spl		+													+	+	+.13	+.25
Sal		+			14		+										2.38	.

Plots 30–103: Fraxinus-Matteuccia Association; plots 31–108: Fraxinus-Mitella Association

1 (Table 13 lists only those species showing 15% constancy or greater within the alliance; complete species list is found in Appendix Table B.3.1).
2 (Species abbreviations are defined in Appendix Table C).
3 (Number to left of dot is relative dominance, number to right of dot is percent constancy).

Prunus virginiana, Acer spicatum and various species of Viburnum. The dense, rich understory is often composed of almost unbroken carpets of ferns such as Onoclea sensibilis, Matteuccia Struthiopteris and Dryopteris austriaca. In addition, herbaceous forbs such as Impatiens biflora and Laportea canadensis are occasionally found covering large areas (Table 14). This association has an average of 25 understory species covering 100 percent of the forest floor.

The population composition of the four major tree species (Figure 18) shows the superiority in numbers of Fraxinus nigra throughout all size classes but the largest, where Ulmus americana becomes dominant. This switch appears to be a result of inherent genetic and physiological restrictions as to the maximum diameter which Fraxinus nigra can attain. Rarely are trees of this species seen larger than size class 6, whereas Ulmus americana is known to grow regularly to giant status of size class 8 or more. The other important tree species are Acer rubrum which is

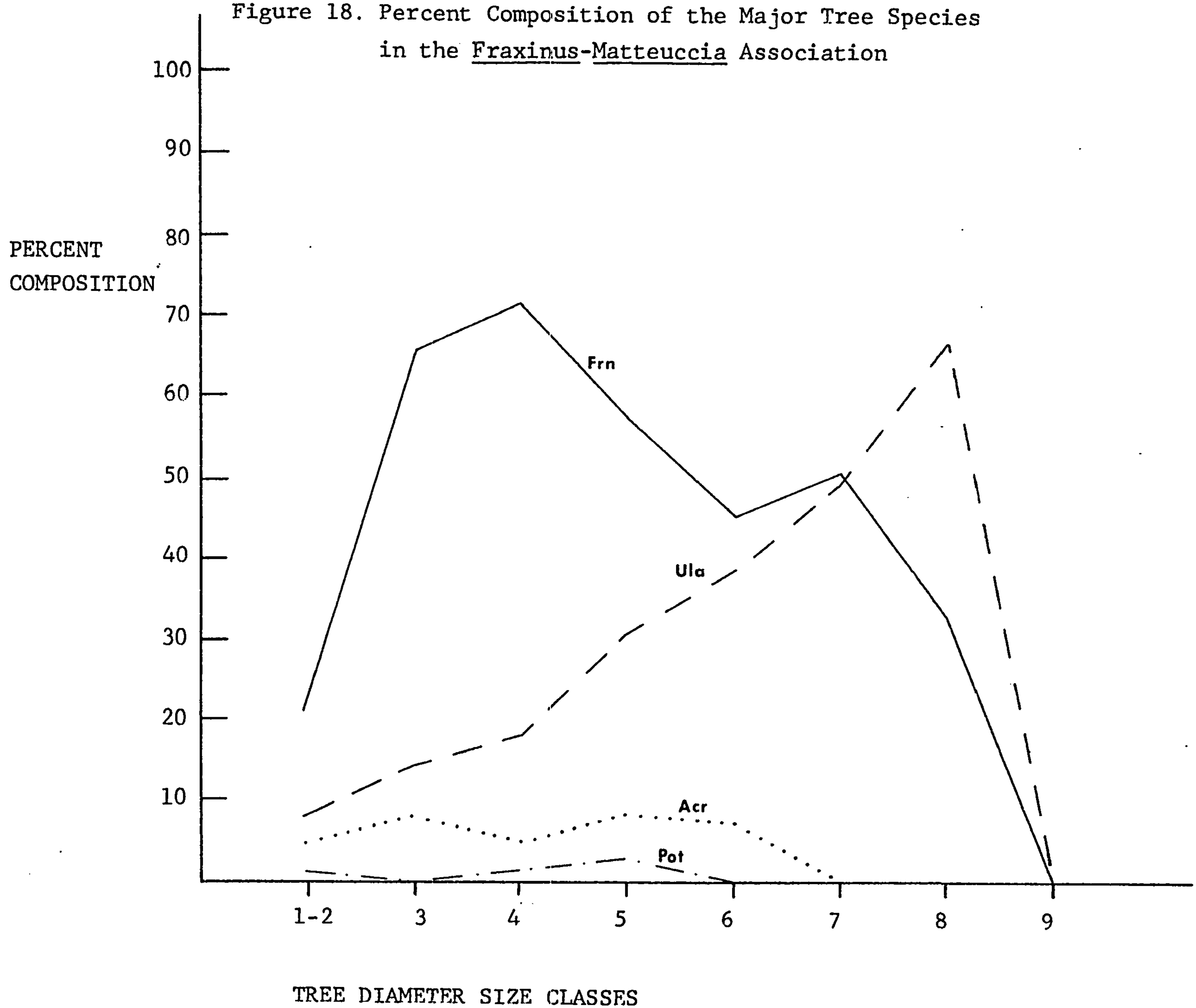
Table 14. Understory Species in the *Fraxinus nigra* Associations[1]

Forbs	*Fraxinus-Matteuccia* Association[2]	*Fraxinus-Mitella* Association[2]
Ribes americanum	3.88	3.88
Galium triflorum	2.75	4.100
Rubus spp.	2.63	13.100
Parthenocissus quinquefolia	3.88	7.75
Carex spp.	5.75	5.88
Viola spp.	2.75	1.63
Impatiens biflora	28.63	7.50
Solanum dulcamara	+.63	+.38
Lycopus americanus	2.38	1.50
Tiarella cordifolia	1.50	+.25
Urtica dioica	4.38	3.38
Mitella nuda	+.13	2.63
Maianthemum canadense	+.38	+.38
Solidago canadensis	+.38	+.25
Boehmeria cylindrica	+.25	+.38
Rhus radicans	+.25	4.38
Thalictrum polygamum	1.13	1.50
Circaea quadrisulcata	+.25	3.38
Aster app.	+.25	+.25
Aralia nudicaulis	+.13	+.38
Mentha spicata	1.13	+.38
Ferns and Allies		
Onoclea sensibilis	15.100	10.75
Dryopteris austriaca	2.88	2.75
Dryopteris cristata	+.25	+.50
Thelypteris palustris	+.25	+.38
Athyrium Filix-femina	+.38	+.25
Thelypteris noveboracensis	11.38	+.13
Matteuccia Struthiopteris	14.50	.
Understory Characteristics		
Mean Understory Coverage (%)	100.0	100.0
Mean Number of Species	25.0	26.4
Mean Number of Species With Coverage Greater Than 1%	11.9	13.1

1 (Table 14 lists only those species showing 20% constancy or greater within the alliance; complete species list is found in Appendix Table B.3.2).

2 (Number to left of dot is percent coverage, number to right of dot is percent constancy).

Figure 18. Percent Composition of the Major Tree Species in the *Fraxinus*-*Matteuccia* Association



found here with 50% constancy and normally, when found, shows a young but stable population. *Populus tremuloides* is occasionally found as a less important tree species. Shrubs and minor trees account for more than half of the composition of combined size class 1-2 indicating a fairly dense shrub layer. The association has an average stand basal area of 34 m2/ha (Table 9).

Fraxinus nigra is maintaining a stable, regenerating population here that will persist for many years assuming no further disturbance. *Ulmus americana* shows a smaller but stable population which will continue to co-exist with *F. nigra* assuming *Ulmus* is not eliminated by Dutch Elm Disease. *Populus tremuloides* exhibits breaks in its population structure (particularly in the seedling and sapling size classes). It may remain as a minor tree member of the association whenever a gap in the canopy and suitable substrate conditions allow it to become established. *Acer rubrum* shows a stable population under the *Fraxinus-Ulmus* canopy. If these sites became slightly drier, by whatever means, *Acer rubrum* would have an advantage over *Fraxinus nigra* and *Ulmus americana* in that it produces abundant, shade-tolerant seedlings. Such disturbances in the form of shifting beaver populations, road construction or land reclamation would tend to change this association into an *Acer rubrum*-*Galium triflorum* association. Without disturbance, the *Fraxinus-Matteuccia* association will remain as a stable community.

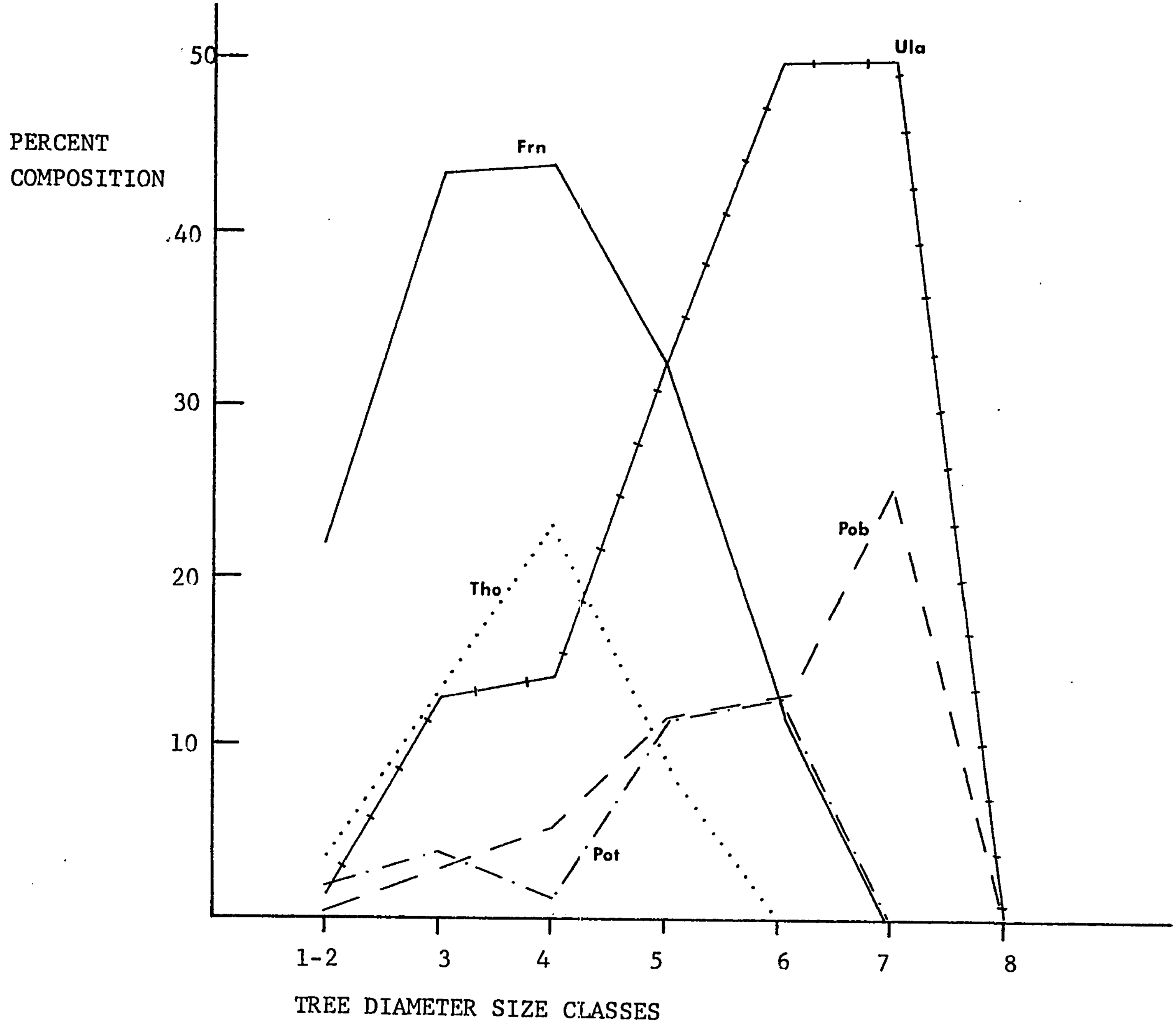
This association occupies flat, wet lowlands and river floodplains (Figure 12). Soil samples collected from stands of the association show the soils to be sandy loams or organic mucks with high organic matter content and a pH of 5.9 (Table 10). According to the soils map of Carleton County (Hills *et al*., 1944), these communities occur on either wet, acid, bog soils or shallow, wet acidic soils of alluvial origin and low fertility. The soil conditions under this association may be summarized as wet, acidic soils of high organic matter content.

2. *Fraxinus nigra-Mitella nuda* Association

The overstory of this association is characterized by the reduced dominance of *Fraxinus nigra*, continued co-dominance of *Ulmus americana* and the low but consistent presence of *Thuja occidentalis* (Table 13). In addition, the occasional presence of *Populus balsamifera* and *Betula papyrifera* further distinguish this association. The shrub layer is characteristically composed of *Cornus stolonifera* with the occasional specimens of *Prunus virginiana*, *Rhamnus Frangula* and *Alnus rugosa*. The understory is distinguished by a rich and luxuriant fern flora including *Onoclea sensibilis*, *Dryopteris austriaca* and *D. cristata* (Table 14). The notable absence of *Matteuccia Struthiopteris* and increased abundance of *Galium triflorum*, various species of *Rubus* and *Mitella nuda* further characterize this association. On the average, 26 understory species can be found covering 100 percent of the forest floor.

The population structure of the *Fraxinus-Mitella* association (Figure 19) shows *Fraxinus nigra* to be

Figure 19. Percent Composition of the Major Tree Species in the *Fraxinus*-*Mitella* Association



the dominant member of the communities, although its influence is restricted to size classes 5 and less, with only one size class 6 stem recorded. Ulmus americana is thus, a relatively more important member in this community. Acer rubrum, found in half of the stands of this association, shows a more sporadic and unstable population structure than that found in the Fraxinus-Matteuccia association (Appendix Table B.3.3). Thuja occidentalis is a minor component of the population, exerting its maximum influence in size class 4. In addition, occasional minor populations of Populus tremuloides and P. balsamifera can be found. This association maintains an average stand basal area of 42 m2/ha.

Future succession within this association (Table 9) is closely tied to the success of Thuja occidentalis. This slow-growing species will probably increase in importance and eventually, transform the Fraxinus-Mitella association into a Thuja occidentalis-Dryopteris austriaca association.

The Fraxinus-Mitella association will persist for many years since it may require two or more tree generations for Thuja occidentalis to establish sufficient numbers of individuals to displace the Fraxinus nigra as dominant. The sporadic populations of Acer rubrum, Populus tremuloides and P. balsamifera will remain as these opportunistic species continue to establish themselves in light gaps and on community edges.

The Fraxinus-Mitella association occupies wet, flat lowlands (Figure 12). Soil samples collected from stands of this association are organic mucks or fine-textured loams of high organic matter content and an average pH of 7.0 (Table 10). The increased pH of these soils as opposed to those of the Fraxinus-Matteuccia association is the result of development on the shallow limestone plain south of Ottawa. The presence of Thuja occidentalis in the Fraxinus-Mitella association may be the result of the presence of these non-acid soils since germination and development of this species is facilitated under such conditions. According to the soil survey of Carleton County (Hills et al., 1944), these communities occur on substrates classified as wet bog soils, shallow wet acidic soils or wet neutral loams. It appears that the *Fraxinus-Mitella* association occurs most frequently on neutral, fine-textured loams or organic soils over limestone, even within mapping units dominated by soils of a different character.

A.4 *Populus* Alliance

General Features of the Alliance

Forest with *Populus tremuloides*, *P. grandidentata* and/or *P. balsamifera* as the dominant trees are found scattered throughout the study area on a variety of habitats. Although young stands of this alliance are common, sites meeting the criteria for inclusion as sample stands (in particular, the criteria of sampling the largest possible trees in areas of minimal disturbance) were often difficult to locate. Figure 20 shows the location and distribution of the 16 sampled communities.

The overstory of these stands is dominated by one of the three *Populus* species and often has *Ulmus*

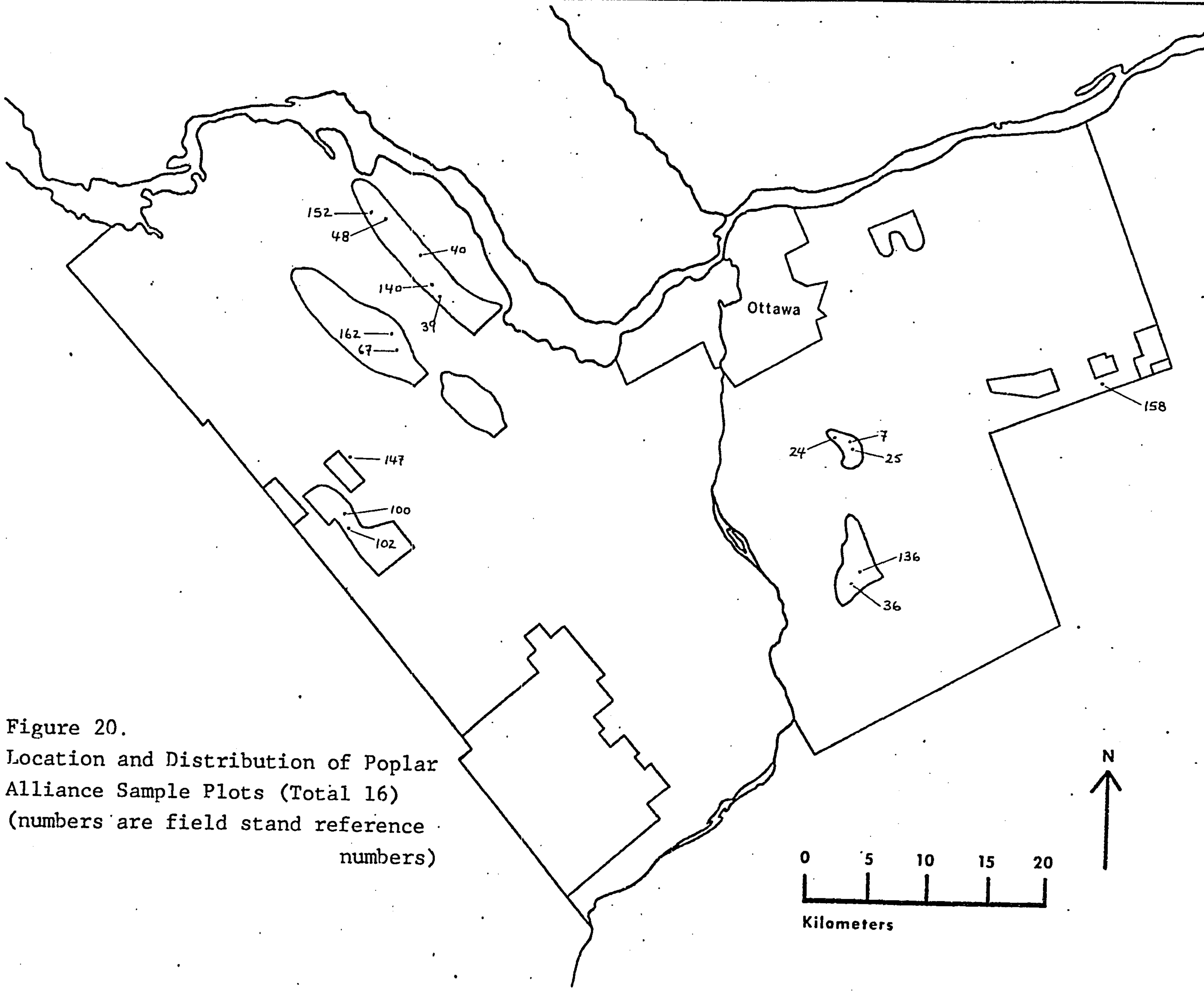


Figure 20.
Location and Distribution of Poplar Alliance Sample Plots (Total 16)
(numbers are field stand reference numbers)

americana, Acer rubrum, Betula papyrifera, and Tilia americana associated with it. The abundant shrub layer is normally composed of Prunus virginiana, Cornus stolonifera, Corylus cornuta and various species of Amelanchier. Common ferns and forbs include Pteridium aquilinum, Dryopteris austriaca, various species of Rubus, Galium triflorum, Maianthemum canadense, Rhus radicans and Fragaria virginana.

Relative dominance and percent constancy values of the tree and shrub species are given in Table 15. It shows the existence of three associations within the Populus alliance, namely Populus balsamifera-Corylus cornuta, Populus tremuloides-Pteridium aquilinum and Populus tremuloides-Aster macrophyllus.

Associations

1. Populus balsamifera-Corylus cornuta Association

The overstory of this association is characterized by the consistent presence and abundance of Populus balsamifera, P. tremuloides and Ulmus americana, and the general absence of Populus grandidentata and Acer rubrum (Table 15).

Table 15. Relative Dominance and Percent Constancy Values (Populus Alliance)[1]

Plot #	24	36	136	147	158	67	162	140	39	7	48	40	102	100	152	25	Populus-Corylus Association[3]	Populus-Pteridium Association[3]	Populus-Aster Association[3]
Trees[2]																			
Pot	5	44	32	1	40	59	6	45	74	42		47	66	80	24	75	21.100	44.100	49.83
Acr				+	4	10	9	2	4	2	3	4	+	+	33		+.25	5.100	7.83
Pog					35	8	67	36	13	15	58		4	4	25		.	29.100	15.67
Pob	31	36	36	59		+	+	+				+			+		41.100	+.50	+.33
Ula	6	3	3	5			+			+			5		+	11	4.75	+.33	3.50
Tia	+			+		+	+		+	12			+			+	+.50	2.67	+.33
Bep	48			+		14	10		1			5	+	7			12.50	4.50	2.50
Acs	+			1		+	+						+	+		+	+.50	+.33	+.50
Frn		9		14	3				+	2		22				8	6.50	+.50	5.33
Abb				+							36	5	4	2	11		+.25	.	10.83
Pig											+	5		+	4	+	.	.	2.83
Fra			13			+	+			8						2	3.25	1.50	+.17
Tho				+								11	+	3			+.25	.	2.50
Shrubs																			
Prv			2	4		+	+	+	+		+	+		+	+	+	2.50	+.67	+.83
Cos		+	1	3	+		+			+		+	5	3	+	+	1.75	+.50	1.83
Coco	4	6	+	1		6	4	13		+							3.100	4.67	.
Amel	+	+				+	2	+							+	+	+.50	+.50	+.33
Alr	1		2		18				7							2	+.50	4.33	+.17
RhF			+	12	+		+	+									3.50	+.50	.
Acsp	2									+		+	15				+.25	+.17	3.33
Vic		+	6				+	1									2.50	+.33	+.17
Dil					+			+	+		+						.	+.50	+.17

Plots 24, 36, 136, 147: Populus-Corylus Association; plots 158, 67, 162, 140, 39, 7: Populus-Pteridium Association; plots 48, 40, 102, 100, 152, 25: Populus-Aster Association.

1 (Table 15 lists only those species showing 25% constancy or greater within the alliance; complete species list is found in Appendix Table B.4.1).
2 (Species abbreviations are defined in Appendix Table C).
3 (Number to left of dot is relative dominance, number to right of dot is percent constancy).

Occasionally, _Betula papyrifera_ and _Fraxinus nigra_ may be found in abundance. A vigorous shrub layer of _Corylus cornuta_, _Cornus stolonifera_, _Prunus virginiana_, _Alnus rugosa_ and _Rhamnus Frangula_ is normally present. The most consistent understory members are various species of _Ribes_, _Viola_ and _Solidago_, _Parthenocissus quinquefolia_ and _Epipactis helleborine_, while the absence of _Rhus radicans_, _Aster macrophyllus_ and _Aralia nudicaulis_ enhance the distinctiveness of the ground cover (Table 16). The absence of _Pteridium aquilinum_ is particularly striking because of its relatively great importance in the other two poplar associations. The _Populus-Corylus_ association has an average of 36 understory species and a mean understory coverage of 79%.

The typical percent composition of the major tree species, in the association, (Figure 21) shows that the association is composed of dominant _Populus balsamifera_ (particularly prominent in size classes 5-8), and lower, younger populations of _P. tremuloides_, _Fraxinus nigra_

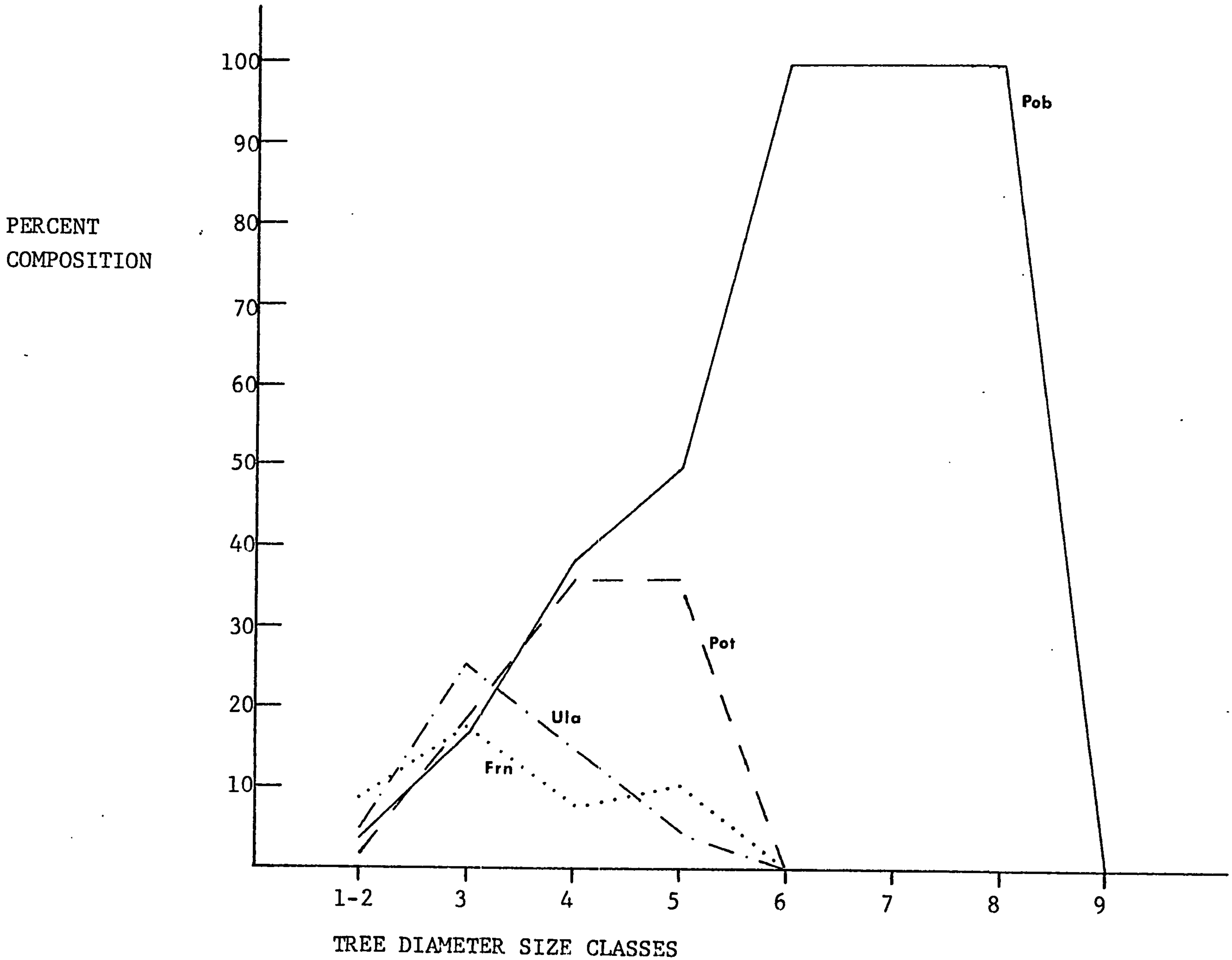
Table 16. Understory Species in the *Populus* Associations[1]

Forbs	*Populus-Corylus* Association[2]	*Populus-Pteridium* Association[2]	*Populus-Aster* Association[2]
Rubus spp.	9.67	13.100	4.83
Carex spp.	.	5.83	16.100
Galium triflorum	+.100	+.67	+.50
Maianthemum canadense	+.33	2.100	+.50
Rhus radicans	.	5.67	9.83
Fragaria virginiana	4.33	3.67	1.67
Ribes americanum	8.100	+.50	1.33
Viola spp.	+.100	+.67	+.17
Solidago canadensis	6.67	+.50	+.50
Aster macrophyllus	.	3.50	4.83
Aralia nudicaulis	.	2.67	6.50
Parthenocissus quinquefolia	5.100	+.17	+.33
Aster spp.	+.50	6.50	+.17
Ranunculus acris	+.67	+.17	+.33
Epipactis helleborine	+.67	+.33	+.17
Geum allepicum	+.67	+.17	+.33
Osmorhiza Claytoni	+.67	+.17	+.17
Trillium grandiflorum	+.67	+.17	+.17
Achillea millefolium	+.33	+.33	+.17
Pyrola elliptica	+.33	+.33	+.17
Cornus canadensis	.	+.17	+.50
Tiarella cordifolia	+.33	2.17	2.17
Laportea canadensis	.	+.33	+.17
Cypripedium acaule	+.33	+.17	+.17
Anemone canadensis	+.33	+.17	.
Trientalis borealis	.	+.33	+.17
Lactuca spp.	1.67	+.17	.
Ferns and Allies			
Pteridium aquilinum	.	18.83	15.50
Dryopteris austriaca	+.67	1.50	+.33
Onoclea sensibilis	1.33	+.50	4.17
Equisetum arvense	1.67	.	+.17
Botrychium virginianum	+.33	.	+.33
Lycopodium complanatum	.	+.17	+.33
Understory Characteristics			
Mean Understory Coverage (%)	79.0	83.1	88.0
Mean Number of Species	36.3	23.5	22.2
Mean Number of Species With Coverage Greater Than 1%	13.7	10.5	11.5

1 (Table 16 lists only those species showing 20% constancy or greater within the alliance;complete species list is found in Appendix Table B.4.2).

2 (Number to left of dot is percent coverage, number to right of dot is percent constancy).

Figure 21. Percent Composition of the Major Tree Species in the *Populus*-*Corylus* Association



and Ulmus americana up to size class 5. The average total stand basal area is 46 m2/ha (Table 9).

Figure 21 and the population structure table (Appendix Table B.4.3) indicate the Populus-Corylus association is a young seral community. Populus balsamifera will continue to be important until the present generation of saplings grows through to mature trees. During this time, regeneration will begin to fail (particularly, growth of seedlings into saplings) and eventually the P. balsamifera population will be composed of only old trees. The young, vigorous populations of Fraxinus nigra and Ulmus americana will mature and increase in dominance. In addition, the occasional presence of Thuja occidentalis as seedlings suggests that succession within the Populus-Corylus association may lead towards a Fraxinus nigra-Mitella nuda association. This observation is strengthened by the fact that some stands of that association have old, large Populus balsamifera trunks still standing.

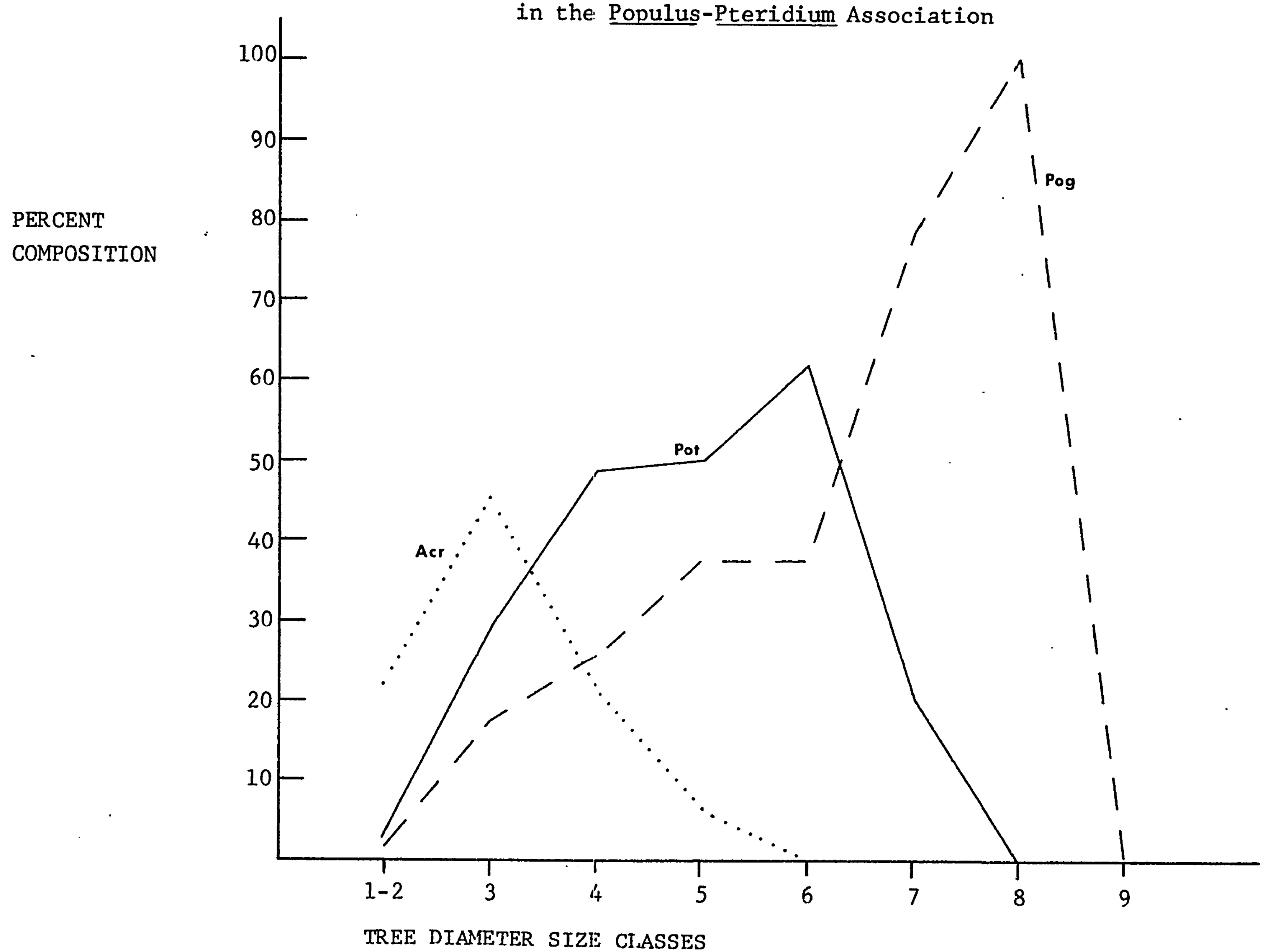
The *Populus*-*Corylus* association appears to be restricted to wet-mesic sites (Table 9). All member stands occur either on flat bottomlands or moist lower slope positions (Figure 12). Soil samples collected from stands of this association show the soil to be a fine-textured loam with an organic matter content of 6% and an average pH of 7.0 (Table 10). According to the Soil Survey of Carleton County (Hills *et al*., 1944), this association occurs on substrates classified as either shallow, basic soils over limestone, or acidic muck soils. This agrees well with the recorded topographic positions and wet-mesic moisture class preference of the *Populus*-*Corylus* association. The loamy nature of the soil may be explained by spring flooding, runoff and soil creep from upslope positions which would tend to accumulate fine textured materials here.

2. *Populus tremuloides*-*Pteridium aquilinum* Association

The overstory of the *Populus*-*Pteridium* (Table 15) association has large quantities of both *Populus tremuloides* and *P. grandidentata* although generally, only one of these species will dominate in a particular stand. It is further characterized by the low but consistent presence of *Acer rubrum*. Occasional associated species include *Tilia americana*, *Betula papyrifera*, *Fraxinus nigra* and/or *F. americana*. A varied shrub layer composed of *Prunus virginiana*, *Corylus cornuta*, *Amelanchier* species, *Cornus stolonifera* and *Diervilla lonicera* is generally present. The understory, while maintaining the species characteristic of the alliance, is distinguished by the abundance of *Pteridium aquilinum* and *Maianthemum canadense* (Table 16). The association has an average of 24 understory species with a mean coverage of 83%.

The percent composition of the major tree species by size class (Figure 22) illustrates the present dominance of *Populus tremuloides* and *P. grandidentata* particularly in size classes 4 and and larger. A vigorous, invading population of *Acer rubrum* with a large proportion of seedlings and saplings can be seen with only a few larger

Figure 22. Percent Composition of the Major Tree Species in the *Populus*-*Pteridium* Association



trees. The association has an average total stand basal area of 38 m2/ha with greatest basal areas being attained on wet-mesic sites (Table 9).

The Populus-Pteridium association is undergoing rapid succession. Both Populus species are showing less abundant regeneration than is the Acer rubrum. In addition, Populus grandidentata is already showing some definite gaps in its population structure. As time goes by, P. grandidentata will slowly be eliminated as the older trees die out of the community. Populus tremuloides, on the other hand, will remain an important member for a much longer time, although it too will eventually be eliminated as a result of seedling and sapling competition and intolerance to shade. At the same time, Acer rubrum will become increasingly dominant in these communities as its abundant, shade tolerant regeneration matures. The Populus-Pteridium association will most likely lead to the development of an Acer rubrum-Trientalis borealis association.

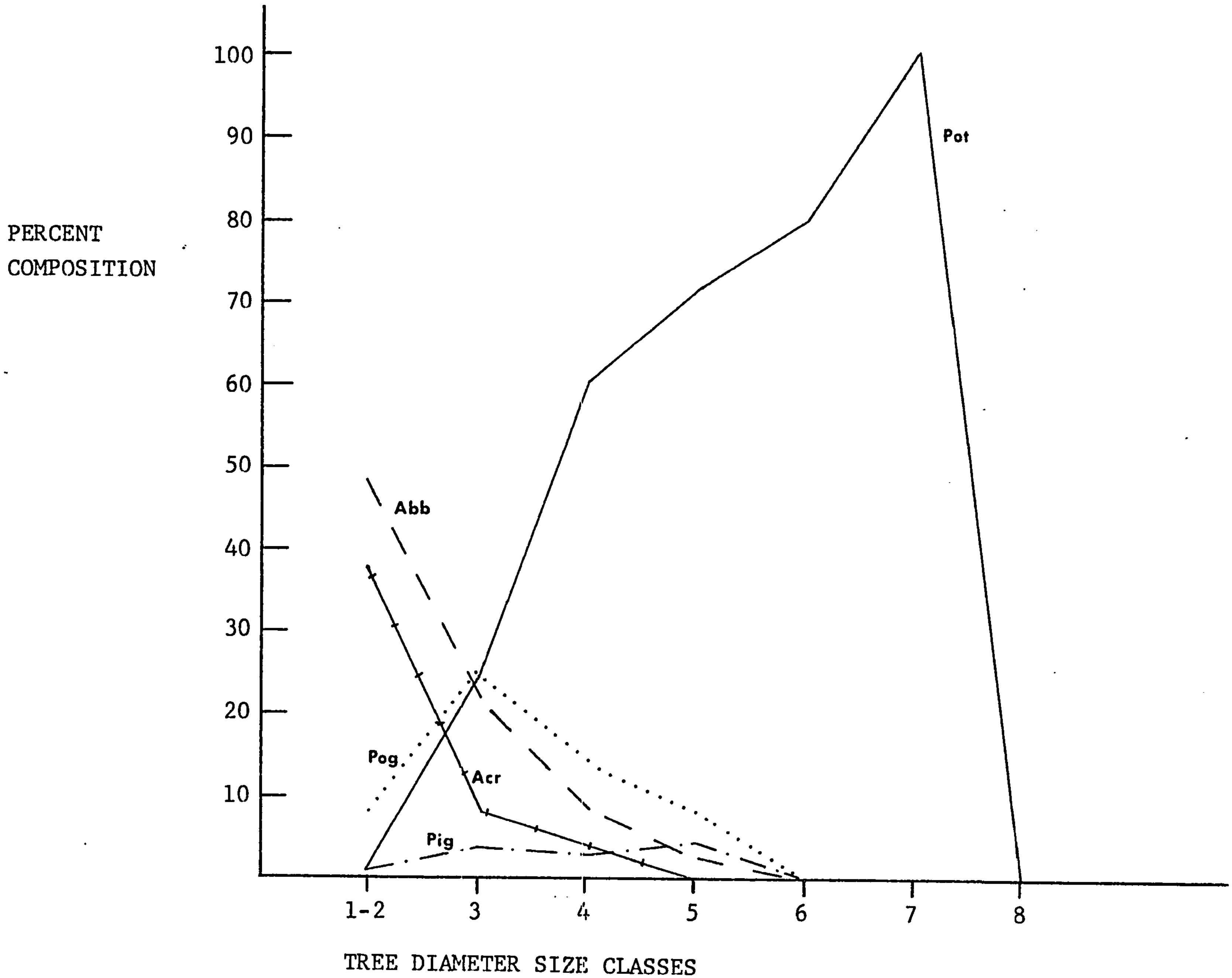
The *Populus-Pteridium* association grows in a wide range of moisture conditions ranging from wet-mesic to dry (Table 9) and is most frequently found on lower and mid-slope topography (Figure 12). Soil samples from the association are coarse-textured, sandy soils with a low organic matter content of about 3% and an acidic pH of 4.9 (Table 10). The Soil Survey of Ottawa-Carleton (Hills *et al*., 1944) indicates that these communities are found on soils classified as acidic, sandy, excessively-drained substrates or shallow, dry alkaline soils. The stand basal areas on the basic soils are less than the average on other soil types. The low organic matter content and the low pH are the result of rapid decomposition rates and the nature of the original parent material. The association appears to have its optimum growth on wet-mesic, sandy soils of low pH and low organic matter content.

3. *Populus tremuloides-Aster macrophyllus* Association

The overstory of this association is similar to that of the *Populus-Pteridium* association in that a combination of Populus tremuloides and P. grandidentata (sometimes only one or the other) is found with generally smaller amounts of Acer rubrum. The dissimilarity and distinctive feature of this association is the presence of coniferous tree elements in the form of consistently present Abies balsamea, Picea glauca and occasional Thuja occidentalis (Table 15). The shrub layer is also distinctive, being dominated almost entirely by Prunus virginiana and Cornus stolonifera. In addition to the species generally characteristic of the alliance, the luxuriant understory of this association includes Rhus radicans, Aster macrophyllus, Aralia nudicaulis and Cornus canadensis (Table 16). The association maintains an average of 22 understory species with a mean coverage of 88%.

The typical composition of the Populus-Aster association by tree species and size class is shown in Figure 23. Populus tremuloides and P. grandidentata presently dominate the association particularly in size classes above 3. Both species

Figure 23. Percent Composition of the Major Tree Species in the Populus-Aster Association



are already showing signs of failing reproduction (Appendix Table B.4.3). Picea glauca shows a low, inconsistent population in the association while both Acer rubrum and Abies balsamea exhibit strong invading populations as indicated by their high percentage in seedling and sapling size classes. The association maintains an average total basal area of 36 m2/ha and achieves maximum development on the dry-mesic site (Table 9).

These data indicate that the Populus-Aster association is a seral stage in which the two species of Populus will slowly pass out of the community and be replaced by the young and vigorous populations of Acer rubrum and Abies balsamea. The occasional presence of young Thuja occidentalis populations indicate that this association may develop towards either the Thuja occidentalis-Maianthemum canadense, the Picea glauca-Waldsteinia fragarioides or the Acer rubrum-Trientalis borealis association. The ultimate direction of successional development depends on the habitat conditions of each site and the rate and degree of dominance achieved by the species invading the *Populus* community. Slow-growing *Thuja* is known to respond well to dry basic soils as well as wet, acidic soils; *Abies balsamea* and *Acer rubrum* are fast-growing, shade-tolerant relatively short-lived trees which thrive under a variety of conditions; *Picea glauca* grows best on mesic sites having fertile soils. The early seral *Populus-Aster* association appears to have several potentials.

The *Populus-Aster* communities occur predominantly on ridge tops and upper slopes where the moisture conditions range from mesic to dry (Figure 12). Soil samples collected from the association show the substrate to be coarse-textured, acidic, sandy loam with an organic matter content averaging 7% (Table 10). According to the Soil Survey of Carleton County (Hills *et al.*, 1944), these stands generally occur on acidic sands, or more rarely on shallow, limestone soils.

A.5 *Thuja occidentalis* Alliance

General Features of the Alliance

Forest communities presently dominated by *Thuja occidentalis* are found throughout the study zone, although they become increasingly prominent towards the southern and western boundaries. Member communities of the alliance occur on a wide range of sites from wet, organic mucks to dry, flat, limestone plains. *Thuja* forests are a major feature of the Regional Forest, Manion Corners Marsh, Corkery Swamp, the Burnt Lands and the Blais Road Forest. Elsewhere in the study area, *Thuja* communities are a much less prominent part of the vegetation pattern and are usually found as a few, scattered stands. The location and distribution of the 31 community samples are shown in Figure 24. Many of the *Thuja* forests occupy low, wetland swamps where the vegetation has adapted to periodic flooding. On the other hand, continuous or progressive inundation with no seasonal reduction of the water table, results in the eventual destruction of the community. Areas to the west and south of Ottawa where there is little topographic variation, are particularly sensitive to such changes.

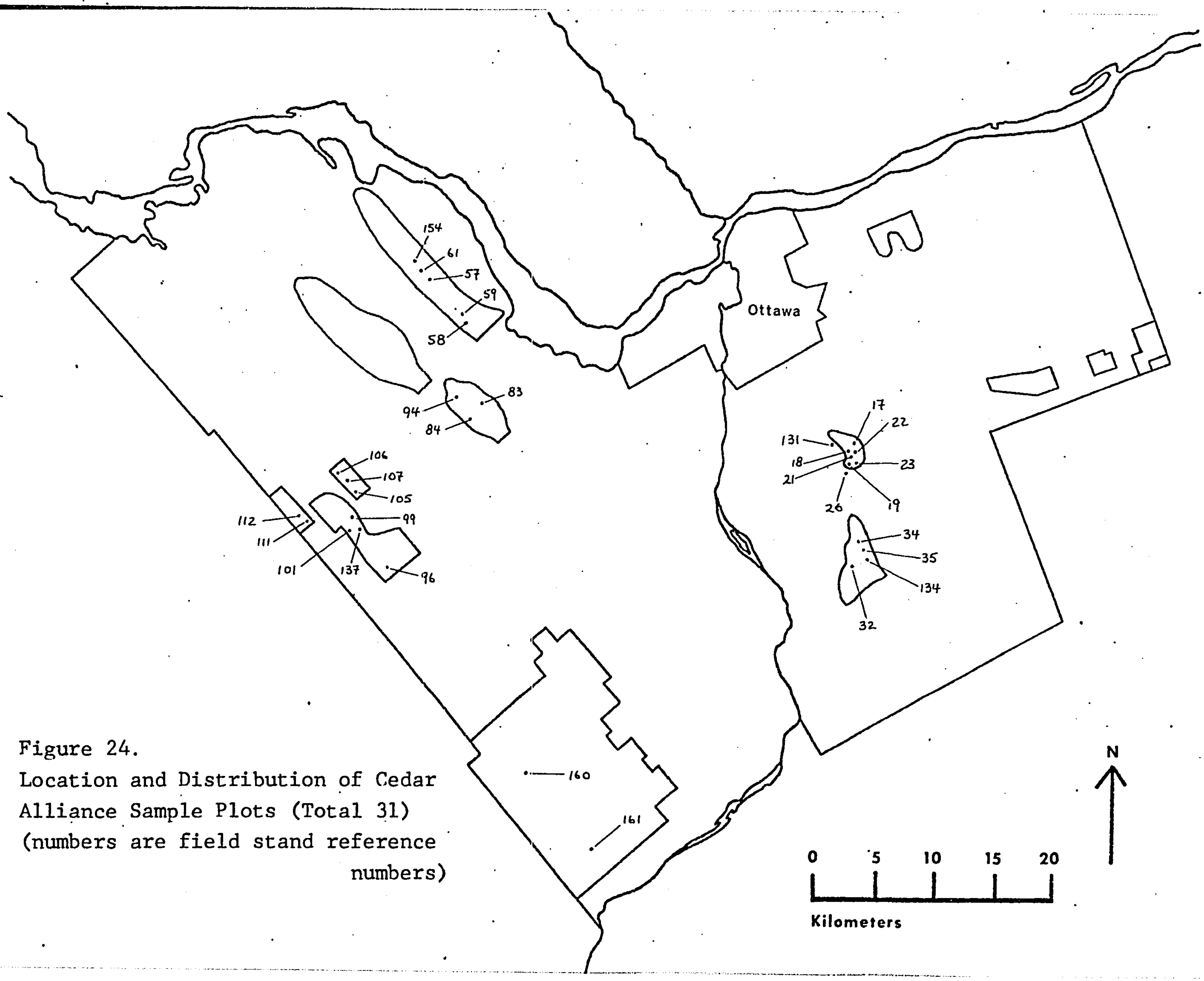


Figure 24.
Location and Distribution of Cedar Alliance Sample Plots (Total 31) (numbers are field stand reference numbers)

A number of dead-standing, skeleton forests now exist in flooded areas which formerly supported extensive Thuja occidentalis forests (e.g., the Waterfowl Area, southern corner of Manion Corners Marsh, and in the Regional Forest).

Communities dominated by Thuja occidentalis are the most interesting to sample because they often shelter some of the rarely seen orchids, ferns and forbs as well as being the scene of most deer wintering yards within the study area.

The overstory of the alliance is characterized by the dominance of Thuja occidentalis with associated tree species including Ulmus americana, Picea glauca, Acer saccharum, Fraxinus nigra and Abies balsamea. The shrub stratum is commonly composed of Cornus stolonifera, Rhamnus Frangula and occasionally Acer spicatum, Prunus virginiana and/or Corylus cornuta. The most constant understory species include Dryopteris austriaca Botrychium virginianum, Maianthemum canadense, Aralia nudicaulis and various species of Viola and Ribes.

The relative dominance and percent constancy values of the tree and shrub species are given for this alliance in Table 17 a, b. It shows the existence of four associations within the *Thuja occidentalis* alliance, namely: *Thuja occidentalis*-*Dryopteris austriaca*, *Thuja occidentalis*-*Maianthemum canadense*, *Thuja occidentalis*-*Pteridium aquilinum* and *Thuja occidentalis*-*Botrychium virginianum*.

Associations

1. *Thuja occidentalis*-*Dryopteris austriaca* Association

   The overstory of the association exhibits the characteristic dominance of *Thuja occidentalis* and the consistent presence of *Fraxinus nigra* and *Ulmus americana* with a variety of minor species of which *Abies balsamea* is the most constant. The shrub layer is characterized by *Cornus stolonifera* (Table 17 a, b). The rich understory features an abundant, consistent fern flora including *Dryopteris austriaca* *Osmunda cinnamomea*, *Dryopteris cristata*, *Onoclea sensibilis* and *Thelypteris palustris* as well as *Rhus radicans*, *Galium triflorum*, *Aralia nudicaulis*, *Mitella nuda*

Table 17a. Relative Dominance Values (Thuja occidentalis Alliance)[1]

Thuja occidentalis Alliance

Plot #	112	96	61	154	32	57	105	106	59	160	161	58	111	101	137	99	22	35	84	131	94	134	23	34	107	26	21	83	19	18	17
Trees[2]																															
Tho	66	66	50	57	84	50	83	71	47	69	50	26	91	72	63	85	99	100	93	97	100	95	100	100	100	25	51	58	64	53	39
Abb	+		+	+	+	4	6	7	4	+		3	+	17					4							1		1			
Ula	3	10	2	14	11	4			+						+				2			+					19	6	3	2	
Acs									1			+					1	+	+		+	+				14	8	7	27	21	61
Pig						5	2	9	15	21	40	2	8	4								+						2	4		
Pob	1		+	+		2	+				1	1			+				+			+						+			
Fra			5			3	+		7						+				+		+					5		+	2	5	
Acr		+		+	3		+				+				+				1	2								6			
Frn	19	1	6	23	2		+																			30	2			1	
Tia			33	+					2		+	+														9	+			+	
Lal	+	10				24									11	10															
Pot								10	15	3	1			8																	
Qur				+						+	+								+									+			
Osv			+								+															5				13	
Pis						+			5			9																9			
Tsc																										6	2			1	
Juc																										4			+	4	
Bep										6	6	9																			
Shrubs																															
Cos	7	12	+	+		5	9	+	3			5	+		2	4						+					+				
RhF				+						+	+				2				+	+		2						+			
Acsp			3	2		+		4							+												9			+	
Prv			+							+	+	5							+	+		+									
Coco	4					+	+		1							+															
Vir										+					+								+	+							
Amel															+									+						+	

Thuja-Dryopteris Association (plots 112–32); Thuja-Maianthemum Association (plots 57–101); Thuja-Pteridium Association (plots 137–107); Thuja-Botrychium Association (plots 26–17)

1 (Table 17a. lists only those species showing 10% constancy or greater within the alliance; complete species list is found in Appendix Table B.5.1).
2 (Species abbreviations are defined in Appendix Table C).

Table 17b. Relative Dominance and Percent Constancy Value Summary (*Thuja occidentalis* Alliance)[1]

Trees[2]	Thuja-Dryopteris Association[3]	Thuja-Maianthemum Association[3]	Thuja-Pteridium Association[3]	Thuja-Botrychium Association[3]
Tho	65.100	67.100	94.100	48.100
Abb	+.80	5.88	+.09	+.33
Ula	8.100	+.25	+.27	5.67
Acs	.	+.13	+.45	23.100
Pig	.	13.100	+.09	1.33
Pob	+.60	+.50	+.27	+.17
Fra	1.20	1.38	+.27	2.67
Acr	+.60	+.25	+.27	1.17
Frn	10.100	+.13	.	6.50
Tia	7.40	+.25	.	2.50
Lal	2.40	3.13	2.18	.
Pot	.	5.63	.	.
Qur	+.20	+.25	+.09	+.17
Osv	+.20	+.13	.	3.33
Pis	.	+.25	.	2.17
Tsc	.	.	.	2.50
Juc	.	.	.	1.50
Bep	.	2.33	.	.
Shrubs				
Cos	4.80	2.63	+.27	+.17
RhF	+.20	+.25	+.36	+.17
Acsp	1.40	+.25	+.09	2.33
Prv	+.20	+.25	+.27	.
Coco	+.20	+.38	+.09	.
Vir	.	+.13	+.27	+.17
Amel	.		+.18	+.17

1 (Table 17b. lists only those species showing 10% constancy or greater within the alliance; complete species list is found in Appendix Table B.5.1).

2 (Species abbreviations are defined in Appendix Table C).

3 (Number to left of dot is relative dominance, number to right is percent constancy).

and various species of Rubus (Table 18). The typical understory is composed of 26 species with a mean coverage of about 70%.

The percent composition by size classes of the major tree species (Figure 25) shows the high percentage of Thuja occidentalis in all size classes, demonstrating a stable population pattern. Ulmus americana has a large seedling and sapling population (size class 1-2) in some stands while in others, seedlings and saplings are totally absent (Appendix Table B.5.3). The species has very definite breaks in population continuity from one size class to the next, and is generally found only as large individuals. Fraxinus nigra, the other major tree species, exhibits a low but consistent population up to size class 5. The association maintains an average stand basal area of 56 m2/ha (Table 9).

The Thuja-Dryopteris association will probably undergo future change in species composition. The Fraxinus nigra and particularly,

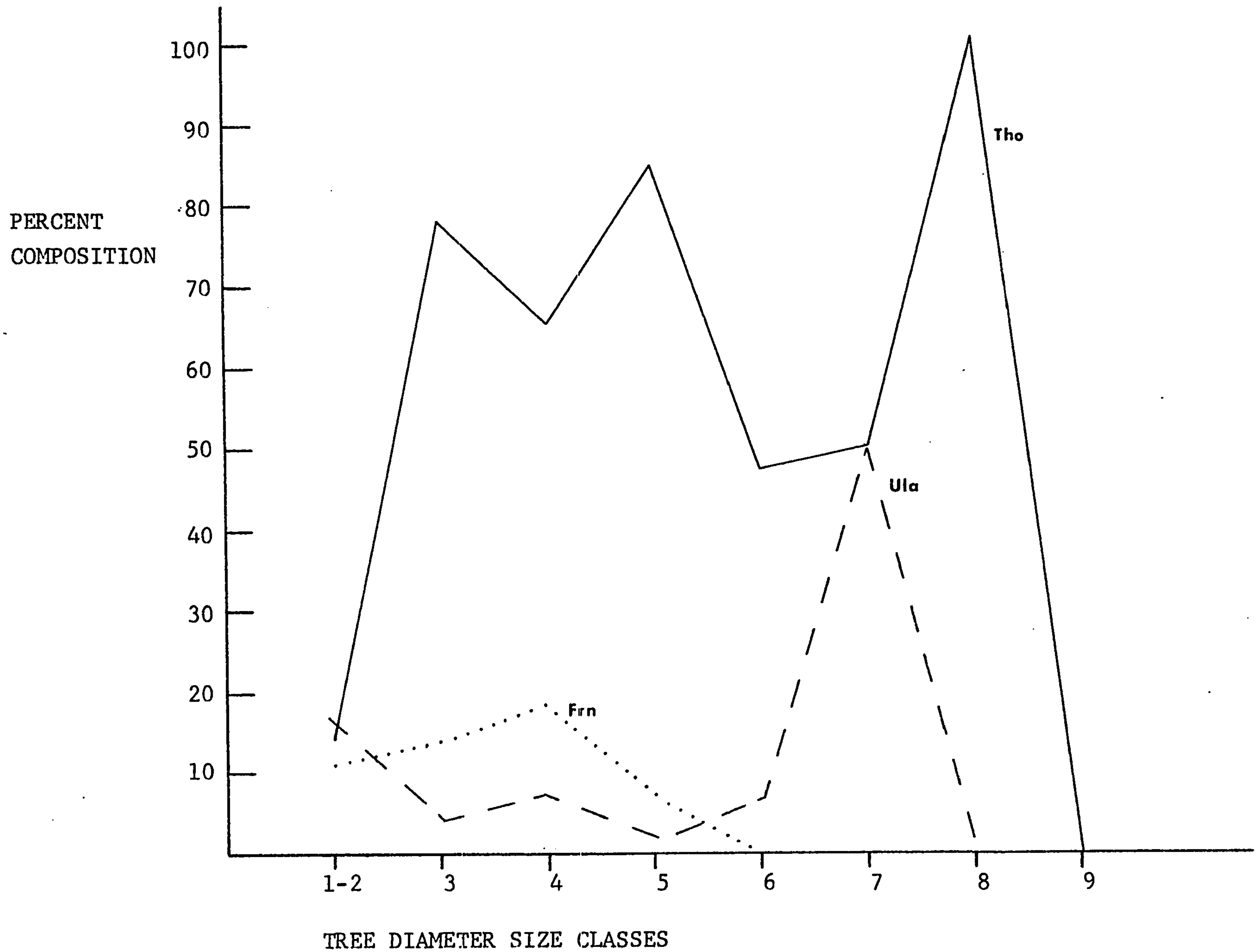
Table 18. Understory Species in the *Thuja occidentalis* Associations[1]

Forbs	Thuja-Dryopteris Ass'n[2]	Thuja-Maianthemum Ass'n[2]	Thuja-Pteridium Ass'n[2]	Thuja-Botrychium Ass'n[2]
Carex spp.	3.60	6.100	3.91	7.83
Viola spp.	+.80	+.88	+.63	2.83
Maianthemum canadense	+.60	3.75	+.45	+.100
Galium triflorum	2.100	1.88	+.36	.
Ribes spp.	+.100	+.50	+.27	+.33
Aralia nudicaulis	2.80	3.38	1.27	+.33
Rubus spp.	5.100	2.50	+.27	.
Rhus radicans	8.80	6.63	+.09	.
Fragaria virginiana	.	+.75	+.36	.
Mitella nuda	4.80	2.25	1.27	.
Epipactis helleborine	+.20	+.50	+.18	+.33
Parthenocissus quinquefolia	+.60	.	+.36	+.17
Trientalis borealis	+.60	+.25	+.18	.
Cornus canadensis	+.40	+.38	+.18	.
Arisaema triphyllum	1.60	.	+.18	+.33
Hieracium spp.	.	+.38	+.27	+.17
Lycopus americanus	4.60	+.13	+.18	.
Eupatorium maculatum	+.40	.	+.27	+.13
Circaea quadrisulcata	+.20	+.13	+.27	+.13
Waldsteinia fragarioides	.	4.33	+.09	+.17
Aster spp.	+.20	+.22	+.27	.
Ferns and Allies				
Dryopteris austriaca	8.80	+.25	+.36	2.50
Botrychium virginianum	+.20	+.38	+.36	+.75
Dryopteris cristata	+.60	+.25	+.18	.
Cystopteris bulbifera	2.20	1.25	1.36	.
Pteridium aquilinum	.	+.13	2.36	+.13
Onoclea sensibilis	6.60	.	+.18	+.13
Osmunda cinnamomea	+.80	.	1.18	.
Thelypteris palustris	1.60	+.13	+.18	.
Dryopteris marginalis	+.40	+.13	+.18	+.13
Understory Characteristics				
Mean Understory Coverage (%)	69.7	42.0	20.0	25.6
Mean Number of Species	26.4	16.3	13.7	14.3
Mean Number of Species With Coverage Greater Than 1%	12.2	5.9	4.9	4.3

1 (Table 18 lists only those species showing 19% constancy or greater within the alliance; complete species list is found in Appendix Table B.5.2).

2 (Number to left of dot is percent coverage, number to right of dot is percent constancy).

Figure 25. Percent Composition of the Major Tree Species in the <u>Thuja</u>-<u>Dryopteris</u> Association



Ulmus americana show major gaps in their seedling and sapling populations. *Thuja occidentalis*, on the other hand, shows strong regenerative potential. The influx of *Tilia americana*, *Ostrya virginiana* and *Fraxinus americana* at higher stand basal areas suggest the possible invasion of *Acer saccharum*. Thus, two directions in future succession are possible; one towards a *Thuja*-*Pteridium* association, the other towards a *Thuja*-*Botrychium* association. The ultimate direction depends on the ability of *Thuja* to form a dense canopy before *Acer saccharum* has the chance to establish itself. The *Thuja*-*Dryopteris* association will persist without clear direction for many years as increasing organic matter accumulation and the natural lowering of the water table occur. During this time, either *Thuja* will form a homogeneous forest or, if light gaps occur, *Acer saccharum* may invade and become co-dominant with the *Thuja*.

The *Thuja*-*Dryopteris* association appears on sites ranging from wet to mesic on the drainage gradient, with a marked affinity for the wet conditions (Table 9). The most frequent topographic position of these communities is flat lowlands, particularly floodplains along streams (Figure 26). Soils underlying these communities are predominantly wet organic soils of low fertility (Table 10). The Soil Survey of Carleton County (Hills *et al*., 1944) reports similar substrate conditions.

2. *Thuja occidentalis*-*Maianthemum canadense* Association

The overstory of this association is distinguished by the consistent presence of *Picea glauca*, *Abies balsamea* and various species of *Populus*, particularly *P. tremuloides* (Table 17 b). The modest shrub layer is often composed of *Cornus stolonifera*, *Prunus virginiana* and *Corylus cornuta*. The understory has a greatly reduced fern complement, being marked most notably by the total absence of *Onoclea sensibilis* and *Osmunda cinnamomea* (Table 18). The abundance and constancy of *Maianthemum canadense* is the best understory indicator. Generally, a total of

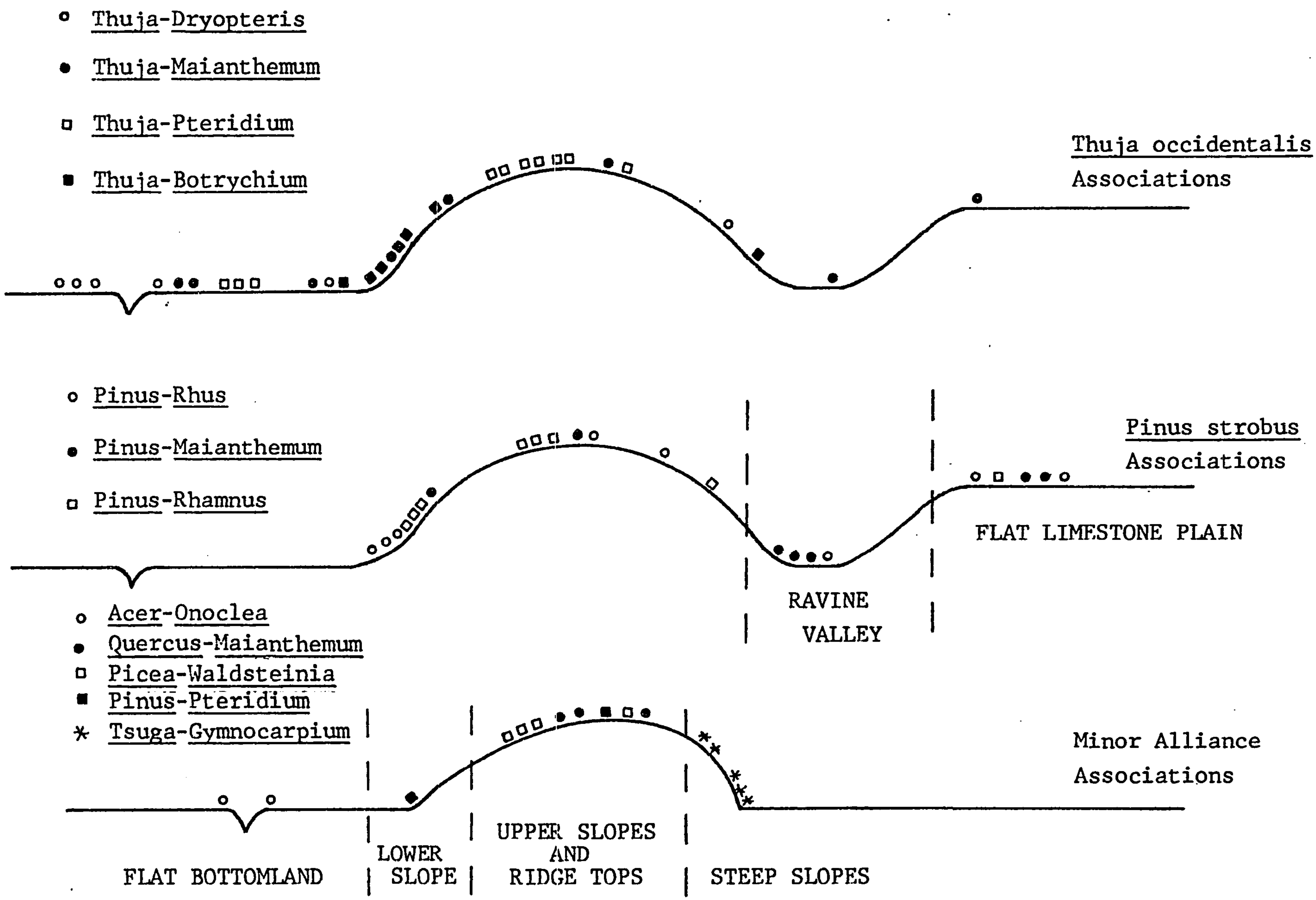
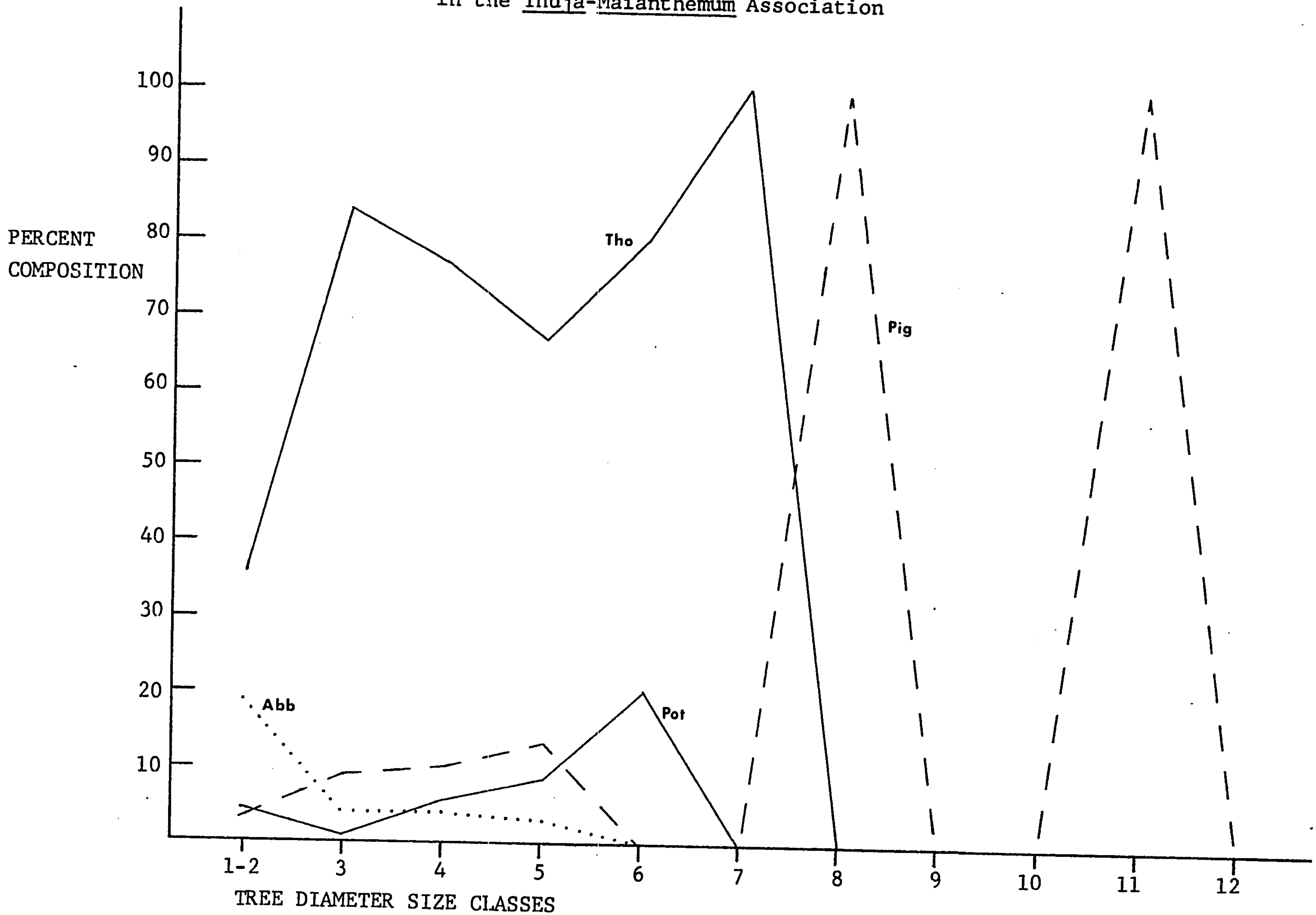


Figure 26. Relative Topographic Positions of the Thuja occidentalis, Pinus strobus, and Minor Alliance Associations

16 fern and forb species create a mean coverage of 42%.

The typical tree composition of the association (Figure 27) shows the importance of Thuja occidentalis up to size class 7. Picea glauca has a relatively stable population through to size class 5 and occurs as occasional individuals of much larger size, although sometimes seedlings-saplings are absent (Appendix Table B.5.3). Abies balsamea normally occurs as dense thickets of saplings less than .5 decimeters in diameter, although occasionally individuals may attain size class 5. Populus tremuloides occurs in this association as scattered, old individuals with generally little reproduction. The average total stand basal area is 48 m2/ha (Table 9). Thuja occidentalis is maintaining a vigorous and expanding dominance in these communities. Populus tremuloides and Picea glauca will slowly be eliminated by their inability to reproduce successfully in the dense shade of the canopy. Abies balsamea, a shade tolerant species, will

Figure 27. Percent Composition of the Major Tree Species in the _Thuja-Maianthemum_ Association



remain for a longer time but will eventually diminish in importance as the *Thuja* progresses. Assuming no external disturbance, the *Thuja*-*Maianthemum* association will slowly change to a *Thuja*-*Pteridium* association.

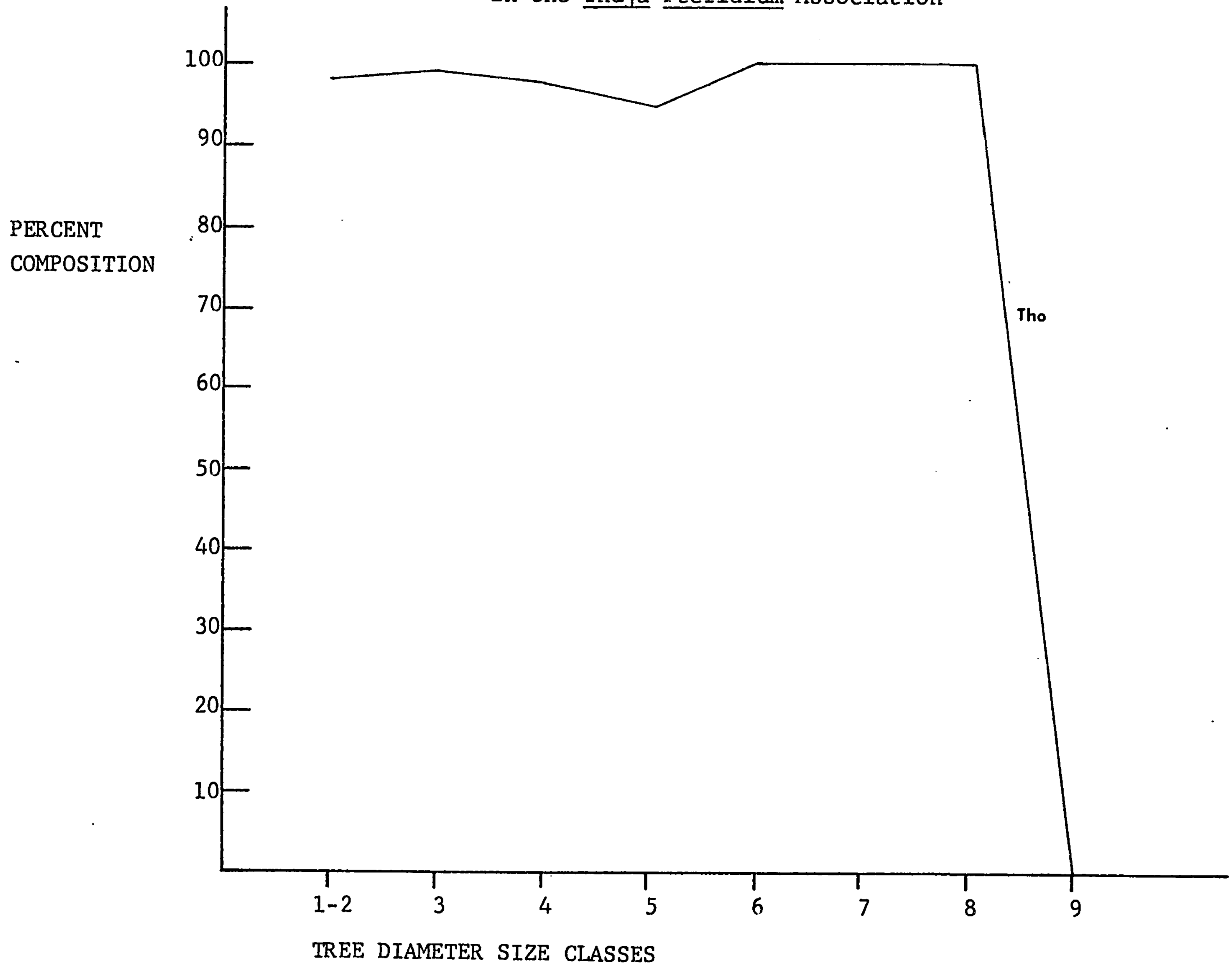
The *Thuja*-*Maianthemum* association occupies a broad range of moisture conditions with a tendency to develop more often on mesic or dry-mesic sites (Table 9). The association is restricted to a medium-textured, sandy loam soil overlying shallow limestone bedrock. These soils are high in calcium and magnesium and basic in soil reaction (Hills *et al*., 1944). Soil samples collected from the association sites show the soils to be medium-textured sandy loams with an organic matter content averaging 8% and an mean pH of 7.2 (Table 10). Six stands of the association occur on the flat, limestone, upland plains southwest of Ottawa while the two others occur on wet sites in flat, bottomland situations (Figure 26).

3. Thuja occidentalis-Pteridium aquilinum Association

The overstory of this association is distinguished from all others within the alliance by the presence of almost pure populations of Thuja occidentalis. Occasionally, Larix laricina is found in small numbers (Table 17 b). A sparse shrub stratum of Rhamnus Frangula and/or Cornus stolonifera is sometimes present. The understory has a diverse fern flora of which Pteridium aquilinum is the most distinctive member (Table 18). The sparse understory is generally composed of about 13 species with a mean coverage of 20%. The almost pure Thuja occidentalis canopy allows very little light to penetrate to the forest floor, and the heavy shade appears to be a major factor in restricting understory development.

The size class distribution of Thuja occidentalis in a typical stand of the association is shown in Figure 28. This association is unusual in the sense that one tree species, Thuja occidentalis, dominates all size classes. Further

Figure 28. Percent Composition of the Major Tree Species in the _Thuja_-_Pteridium_ Association



more, this species dominates every size class to such an extent that the association is unique in being the closest approximation to a pure, mono-specific, natural community in the Ottawa area. There are no conspicuous gaps in the population continuity above size class 3 with the occasional absence or low representation of cedar seedlings. This may be the result of differences in flowering and fruiting phenology of particular stands and particular moisture microfeatures within the stands. Different numbers of seedlings are the result of cyclic rhythms of the trees/habitat/weather interaction and consistent, regular seedling establishment is not to be expected as a normal state of affairs. This conclusion is supported by the observation that in some stands, a veritable carpet of cedar reproduction is found while in other apparently similar communities, not a single seedling can be seen (Appendix Table B.5.3). The Thuja-Pteridium association has an average total stand basal area of 74 m2/ha with lower values on drier sites.

Assuming no external disturbances, the *Thuja-Pteridium* association will persist with its present species complement into the foreseeable future. It appears to be the most stable association in the Ottawa Region since only a major disturbance such as fire or logging could displace the *Thuja* and create conditions suitable for other species to invade.

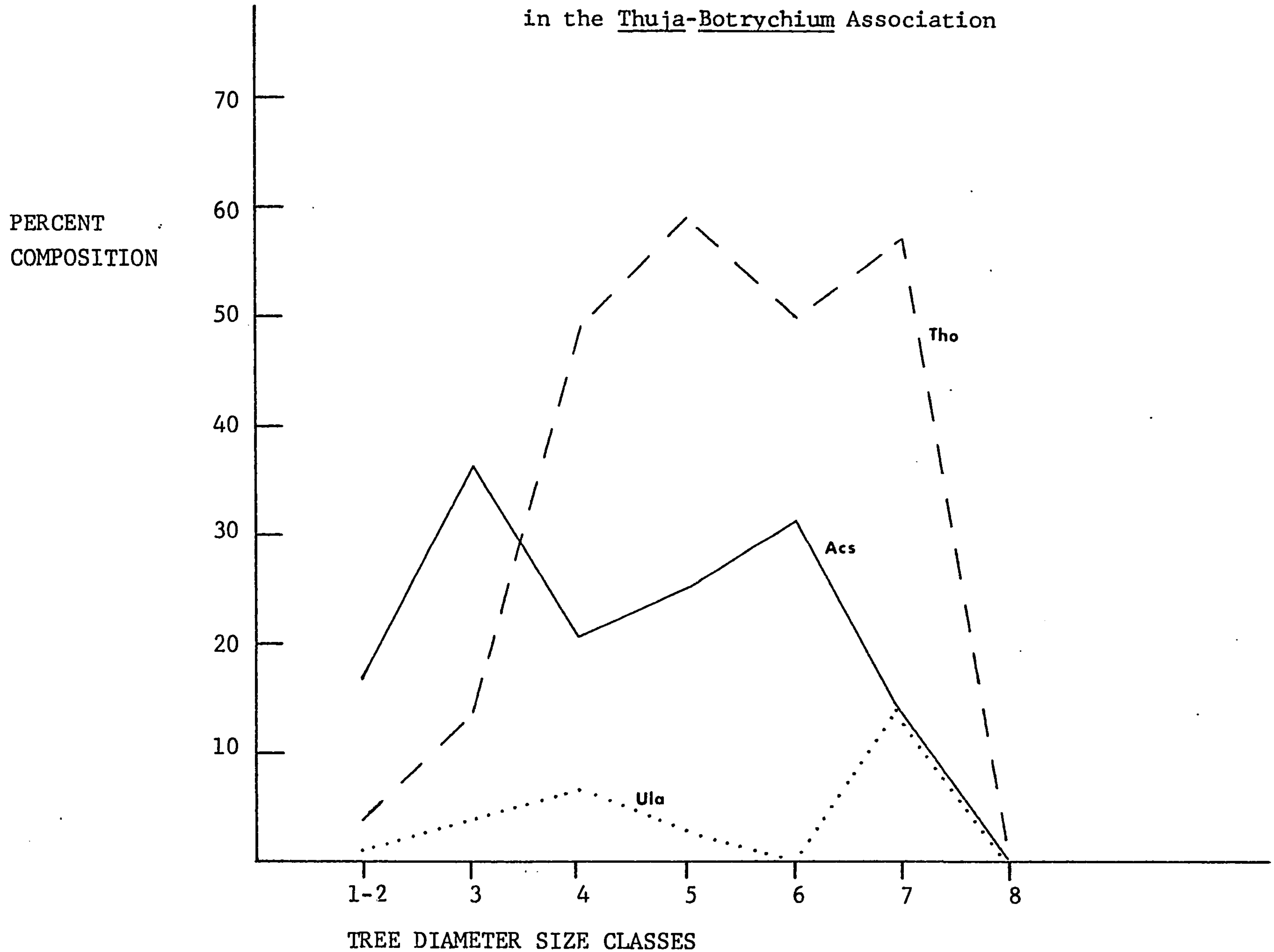
The *Thuja-Pteridium* association develops most often on dry-mesic sites (Table 9). Topographically, it is found most often on excessively drained ridge or upland plains sites, although some stands occur on lower slopes or in moist lowlands (Figure 26). Samples collected from these communities show the soils to be either organic or basic fine-textured, silt loams of high organic matter content (Table 10). The soils map of Carleton County (Hills *et al.*, 1944) shows that substrates underlying the association are predominantly shallow, basic, limestone soils of excessive drainage or, more rarely, poorly-drained, acidic organic mucks with precambrian bedrock close to the surface.

4. *Thuja occidentalis-Botrychium virginianum* Association

The overstory of the *Thuja-Botrychium* association contains many species of moderate importance. *Thuja occidentalis* is normally dominant and *Acer saccharum* is consistently present in smaller quantities. *Ulmus americana*, *Fraxinus americana*, *F. nigra*, *Tilia americana*, *Tsuga canadensis* and/or *Juglans cinerea* are occasionally found as associated species (Table 17 b). The shrub layer is greatly reduced in species numbers and quantities. Similarly, the depauperate understory is essentially restricted to *Botrychium virginianum*, *Dryopteris austriaca*, *Maianthemum canadense*, and various species of *Viola* and *Carex* (Table 18). In general, the understory is composed of 14 species with a mean coverage of about 26%.

The typical size class composition of the three major tree species in the association is shown in Figure 29. Trees of any species do not exceed size class 7. *Thuja occidentalis*, the

Figure 29. Percent Composition of the Major Tree Species in the _Thuja_-_Botrychium_ Association



normal dominant, shows adequate representation through all size classes, although some breaks in continuity are apparent, particularly in seedling-sapling sizes (Appendix Table B.5.3). *Acer saccharum* exhibits a more stable population with only a single gap in continuity in one community and generally, more abundant, consistent representation as seedlings. *Ulmus americana* exists here as individual, mid-sized trees with rarely any seedlings or saplings present. The association has an average stand basal area of 42 m2/ha with maximum development occurring on mesic and dry-mesic sites (Table 9). *Thuja occidentalis* appears to be having difficulty in maintaining seedling and sapling populations. Simultaneously, *Acer saccharum* has become established at some time in the past and is now actively invading and displacing the dominant *Thuja*. These communities were probably disturbed by cutting or grazing because normally, *Acer saccharum* has little opportunity to invade a *Thuja* dominated forest due to the poor light conditions. The opening of the canopy or the import of seeds would create favourable conditions for establishment of *Acer* seedlings. Once established, *A. saccharum* is well-adapted to grow in the shade of the *Thuja* canopy and, in time, will grow taller and produce more abundant seeds than *Thuja*. Ultimately, the *Thuja-Botrychium* association will lead toward an *Acer-Parthenocissus* association as the *Thuja occidentalis* is slowly replaced by *Acer saccharum*.

The *Thuja-Botrychium* association occupies, in the main, mid to lower slope topographic positions (Figure 26) where drainage ranges from wet to dry with the average condition being mesic (Table 9). Samples collected from within these communities show the soil to be medium-textured sandy or silty loams with a moderate organic matter content of about 9% and an average pH of 6.3 (Table 10). These habitats have very good forest growing potential. According to the Soil Survey of Carleton County (Hills *et al.*, 1944), the location of these forests coincide with the locations of a variety of medium-textured, fertile soils.

A.6 Pinus strobus Alliance

General Features of the Alliance

Forest communities dominated by Pinus strobus are concentrated in the western portion of the study area. They tend to occur most frequently on either mesic to dry, shallow soils over bedrock or on exposed or eroded, dry ridge locations. The canopy of these communities is characteristically open and often, there is much exposed bedrock or open, needle-covered areas on the forest floor. Member stands of the alliance do not develop well on the extensive, fine-textured clay soils covering much of the eastern part of the region, nor on the shallow, wet soils in both the eastern and southcentral portions of the study area. Small, isolated patches of Pinus strobus forest can be found here and there throughout the study zone, but such stands tend to be too small in area, too young or too disturbed to be considered adequate for sampling. The location and distribution of the 23 selected communities are shown in Figure 30.

The tree stratum is dominated by Pinus strobus with a host of associated species such as Abies balsamea, Picea glauca, Thuja occidentalis, Acer rubrum, Quercus rubra and/or Populus tremuloides. The diverse shrub layer often includes Prunus virginiana, various species of Amelanchier, Cornus stolonifera and Corylus cornuta. Characteristic species of the understory include Rhus radicans, Maianthemum canadense, Aster macrophyllus and Pteridium aquilinum. The general dearth of fern species further distinguishes the understory of this alliance.

The relative dominance and percent constancy values of the tree and shrub species within the alliance are given in Table 19. It shows the existence of three associations within the Pinus strobus alliance, namely; Pinus strobus-Rhus radicans, Pinus strobus-Maianthemum canadense and Pinus strobus-Rhamnus Frangula.

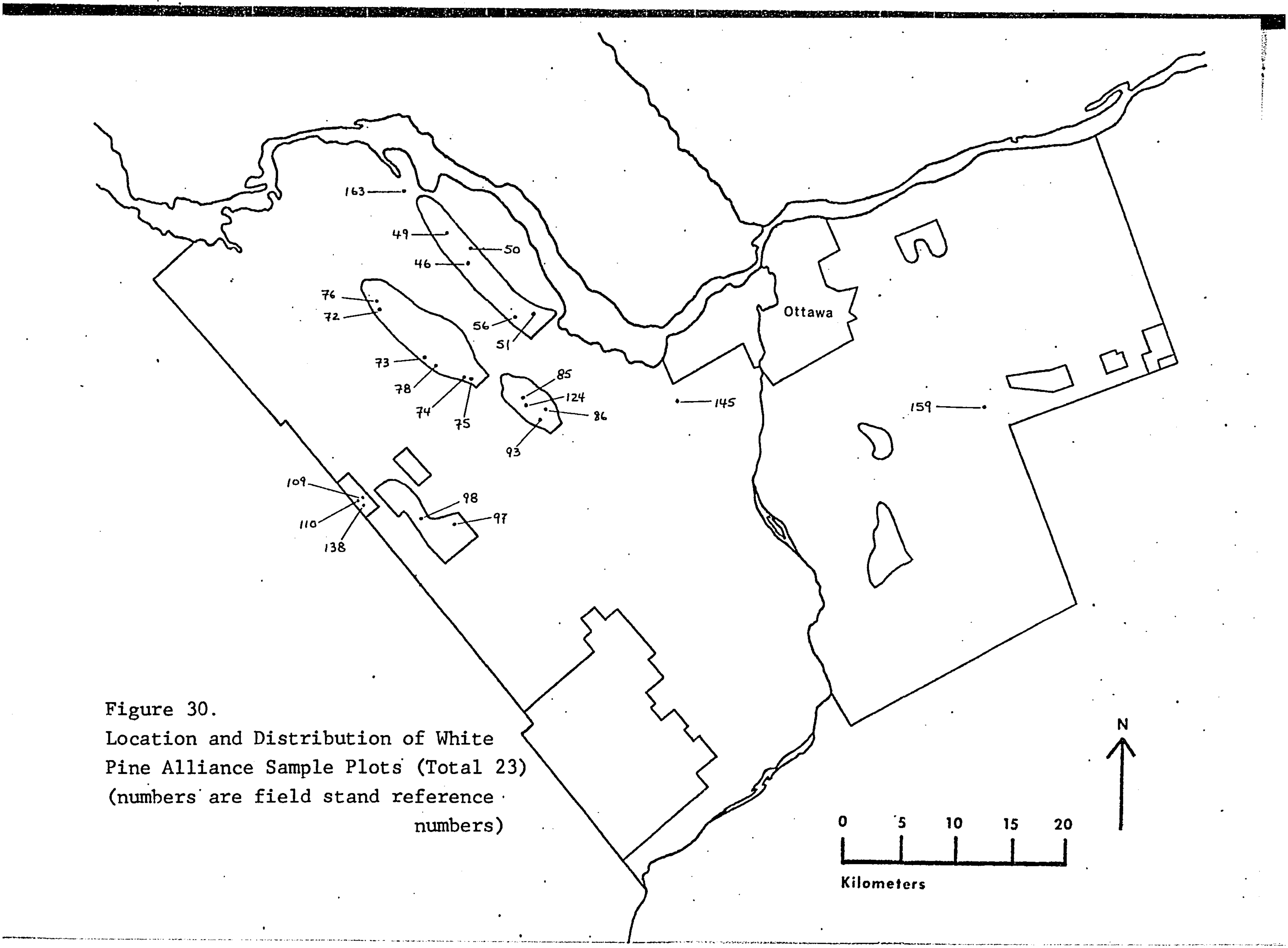


Figure 30.
Location and Distribution of White Pine Alliance Sample Plots (Total 23) (numbers are field stand reference numbers)

Table 19. Relative Dominance and Percent Constancy Values (Pinus strobus Alliance)[1]

Plot #	51	56	50	97	110	46	49	138	109	78	159	93	145	75	124	76	163	98	72	73	74	86	85	Pinus-Rhus Association[3]	Pinus-Maianthemum Association[3]	Pinus-Rhamnus Association[3]
	Pinus strobus Alliance																									
Trees[2]																										
Pis	23	23	32	48	40	25	71	54	67	58	48	75	77	66	96	31	39	61	50	56	68	70	81	40.100	70.100	57.100
Abb	+	17	35	9	50	20	+	13	12		+	+				13	1	+	5	+		7	+	18.100	2.43	3.88
Pig	54	14		32	18	4	6	6								29	19	10	+	2	1	2	+	17.88	.	8.100
Acr	+		2			11	9				20		+	+	3	+	5		5	6	10	5	1	3.50	3.57	4.88
Tho		2	7	+				14	7	9	18	3		23		23						3	5	3.50	9.71	4.38
Qur					+					+			+		+	+	+	+	3	+	10	+	+	+.13	+.43	2.100
Bep		3	24					1			+			4		2		+	1	1	1	2		4.38	+.29	+.75
Fra				+						+		+				+	+	+	2	+	+	+	+	+.13	+.29	+.100
Pot	6	6		7	6	23	9	+	7									3		6	4			7.88	1.14	2.38
Acs		+								+		10	13			+			22	+	+	2	1	+.13	3.43	3.75
Tia		+				11						+							3	5	1		+	1.25	+.14	1.50
Caco										+		+				+			+	+	+		+	.	+.29	+.63
Ula								1		14									+	4	2		7	+.13	2.14	2.50
Pob									2					+				3		+	+			.	+.29	+.38
Pog				1	4	+	4	+																1.63	.	.
Tsc											12	6	4									1		.	3.43	+.13
Shrubs																										
Prv		2			+			+	+	+		+				+	+	4					+	+.38	+.43	+.50
Amel								+	+	+					2		+		+	+	+	4	1	+.13	+.43	+.75
Cos	3	4		3	1			+	4									2		+				1.63	+.14	+.25
Coco	10	5			+	1	+	+										7	+					2.75	.	+.25
Juc		16			16			+		+						+		9	+		+			4.38	+.14	1.50
RhF										4				+					+	12	+	+	2	.	+.29	2.63
Dil	+		+		+		+								+						+			+.50	+.14	+.13
Apa					+															+	+	+		+.13	.	+.38
	Pinus-Rhus Association								Pinus-Maianthemum Association							Pinus-Rhamnus Association										

1 (Table 19 lists only those species showing 15% constancy or greater within the alliance; complete species list is found in Appendix Table B.6.1).
2 (Species abbreviations are defined in Appendix Table C).
3 (Number to left of dot is relative dominance, number to right of dot is percent constancy).

Associations

1. *Pinus strobus-Rhus radicans* Association

The overstory of the *Pinus-Rhus* association is characterized by a mixture of *Pinus strobus*, *Picea glauca* and *Abies balsamea*, with *P. strobus* normally dominant although occasionally, great numbers of small-diameter *Abies balsamea* or *Picea glauca* may contribute significantly to total basal area (Table 19). Other characteristic tree species include *Populus tremuloides* and *P. grandidentata* with the latter occurring almost always on the drier sites. The shrub stratum is diverse with the most constant members being *Cornus stolonifera* and *Corylus cornuta*. *Juniperus communis*, when present, may cover considerable areas. Consistent and abundant understory species include *Rhus radicans*, *Maianthemum canadense*, *Fragaria virginianum*, *Waldsteinia fragarioides* with the occasional presence of various species of *Rosa* and *Viola* (Table 20). On the average, the association has 14 understory species creating a mean coverage of about 56%.

Table 20. Understory Species in the Pinus strobus Associations[1]

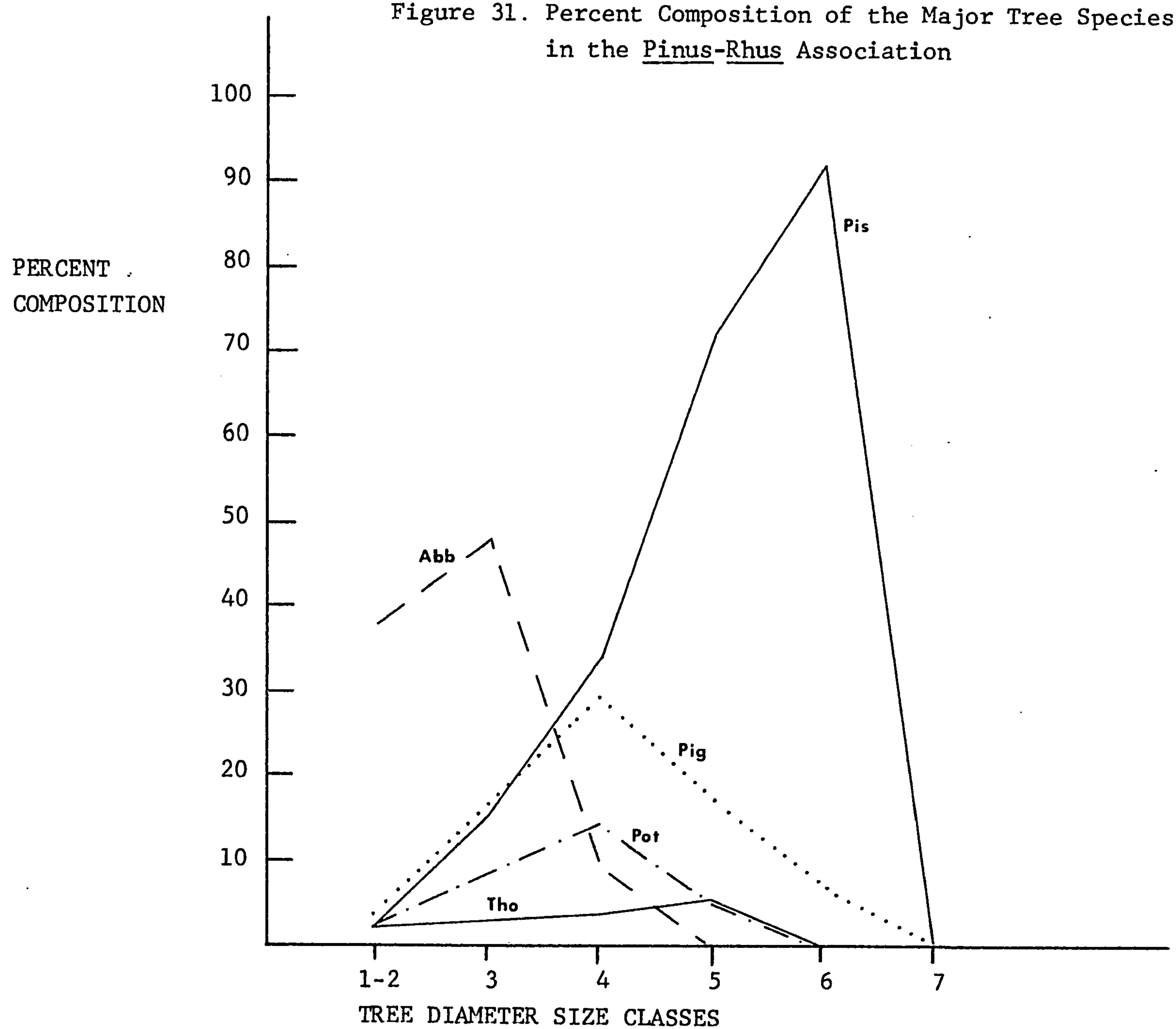
Forbs	Pinus-Rhus Ass'n[2]	Pinus-Maianthemum Ass'n[2]	Pinus-Rhamnus Ass'n[2]
Maianthemum canadense	5.100	1.86	8.100
Carex spp.	3.88	5.57	3.75
Rhus radicans	18.100	3.43	5.50
Aster macrophyllus	9.50	3.29	2.75
Fragaria virginiana	+.75	+.14	1.63
Aralia nudicaulis	2.63	1.29	2.63
Viola spp.	1.63	+.14	+.50
Waldsteinia fragarioides	5.63	2.29	4.25
Galium triflorum	+.25	+.43	1.50
Trientalis borealis	+.38	+.29	+.38
Epipactis helleborine	+.25	+.43	+.25
Hieracium spp.	+.38	.	+.50
Ribes spp.	+.13	+.43	+.38
Pyrola elliptica	+.38	+.29	+.13
Rubus spp.	+.25	.	+.38
Aster spp.	+.25	+.14	+.25
Rosa spp.	1.50	+.14	.
Cypripedium acaule	+.13	+.29	+.25
Mitchella repens	.	+.29	+.38
Ranunculus acris	.	+.14	+.38
Linnaea borealis	+.38	+.14	.
Aquilegia canadensis	+.13	+.14	+.25
Ferns and Allies			
Pteridium aquilinum	4.63	3.43	3.75
Dryopteris austriaca	.	+.43	+.63
Understory Characteristics			
Mean Understory Coverage (%)	55.8	22.7	36.0
Mean Number of Species	14.4	12.6	19.6
Mean Number of Species With Coverage Greater Than 1%	7.6	3.3	5.5

1 (Table 20 lists only those species showing 15% constancy or greater within the alliance; complete species list is found in Appendix Table B.6.2).

2 (Number to left of dot is percent coverage, number to right of dot is percent constancy).

The typical composition of each size class within the association is shown for the five major tree species in Figure 31. According to the figure, *Pinus strobus* has little representation as seedlings but steadily increases to maximum importance in size class 6. *Thuja occidentalis* shows a similar trend (at much lower percentages) to maximum importance in size class 5. The other three major species, *Abies balsamea*, *Picea glauca* and *Populus tremuloides*, exhibit maximum importance at some intermediate size class (3 for *Abies*, 4 for *Picea* and *Populus*) each diminishing towards both higher and lower classes. Seedlings and saplings are dominantly *Abies balsamea*, although both *Pinus strobus* and *Picea glauca* gradually increase and dominate in size class 4. *P. strobus* increasingly dominates the larger size classes while *P. glauca* declines in importance. The small maximum size classes exhibited here indicate either unfavourable growing conditions limiting the maximal diameters obtainable, or more probably, a young forest not yet fully developed and still able to show an increase in

Figure 31. Percent Composition of the Major Tree Species in the <u>Pinus</u>-<u>Rhus</u> Association



the maximum diameters of its largest trees. The association has an average total basal area of 31 m2/ha with maximum development on the dry sites (Table 9).

The Pinus-Rhus association is a seral community which may develop in two directions. On all sites but one, Pinus strobus is not reproducing well and will probably slowly be eliminated, barring future disturbance. On the more mesic sites, P. strobus regeneration is particularly perilous and the consistent, uninterrupted populations of Abies balsamea and Picea glauca indicate a future trend towards a Picea-Waldsteinia association. On the dry sites, Pinus strobus reproduction is more significant although it still exhibits gaps and is completely absent in some stands. Here, young populations of Acer rubrum, Quercus rubra, Populus tremuloides and P. grandidentata appear better able to invade among the resident Abies balsamea and Picea glauca. The great stature and longevity of Pinus strobus ensures its continued presence for a long time, although new associated species (many of them deciduous) will increase under the pine canopy. As a result, the Pinus-Rhus association now present on dry sites may slowly be transformed into a Pinus strobus-Rhamnus Frangula association.

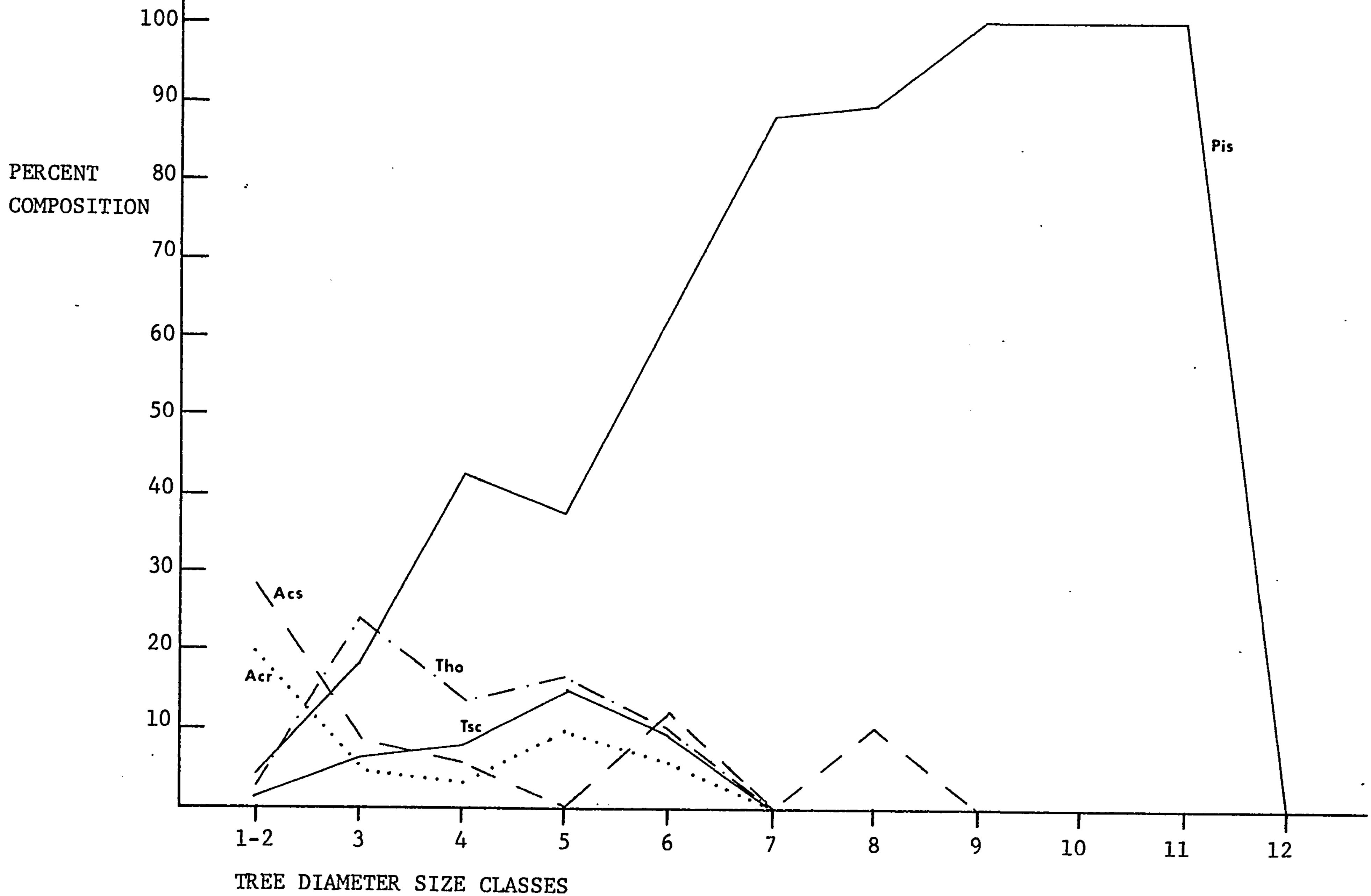
The Pinus-Rhus association is found with equal frequency on mesic and dry sites with the average drainage being dry-mesic (Table 9). These communities frequently occupy lower to mid slope positions although some member stands can also be found on flat, upland plains (in particular, the dry, limestone flats in the western part of the study zone) (Figure 26). Samples collected from these communities indicate that the soil is coarse-textured sand with low organic matter content of about 2% and an acidic pH of 4.7 (Table 10). According to the soils map of Carleton County (Hills et al., 1944), this association is located on both acidic, dry, sandy soils of low fertility and more frequently, on basic, shallow, well drained limestone soils.

2. _Pinus strobus-Maianthemum canadense_ Association

The overstory of the _Pinus-Maianthemum_ association is characterized by a high percentage of _Pinus strobus_ with little representation from other trees (Table 19). _Thuja occidentalis_ is a fairly consistent, minor member of the overstory and _Tsuga canadensis_ occurs on the mesic sites with larger total stand basal areas. The shrub stratum here is sparse and diverse and shows no discernible species pattern. The association has an exceedingly sparse understory with _Maianthemum canadense_ being consistently present in low quantities, and various species of _Carex_, when found, being relatively abundant. The absence of _Hieracium_ species (particularly _H. canadense_ and _H. pratense_) and the lack of _Rubus_ species are a better understory indicator (Table 20). The _Pinus-Maianthemum_ association has an average of 13 species of understory plants and a mean total coverage of only 23%.

Figure 32 shows the typical composition of each size class of the

Figure 32. Percent Composition of the Major Tree Species in the *Pinus-Maianthemum* Association



association in terms of the five major tree species. Size class 1-2 is dominated by deciduous species, *Acer rubrum* and *A. saccharum*. In larger size classes, deciduous species tend to diminish in importance although an occasional large individual can be found. *Pinus strobus* unmistakably dominates all size classes from 3 through size class 11. *Thuja occidentalis* is a minor component of this association with maximum influence and representation in size classes 3 through 5. *Tsuga canadensis* increases slowly in percent composition and has maximum influence in size classes 5 and 6. *T. canadensis*, *Acer saccharum* and *Thuja occidentalis* appear only on mesic sites. *Acer rubrum* is found on both mesic and dry sites within this association. *Pinus strobus* has diameters above size class 6 only on the mesic sites, although its seedling and sapling population is much more consistent and abundant on the dry locations. The association has an average stand basal area of 55 m2/ha with maximum development on mesic sites (Table 9).

These data suggest two successional directions based on the moisture class of the individual site. On the dry sites, shallow soil and successive fires reduce sub-canopy competition and expose mineral soil for successful *Pinus strobus* regeneration. The association will persist into the foreseeable future without change in species composition on dry sites. On the more mesic sites and on the drier sites as they mature without disturbance, *P. strobus* regeneration is at a disadvantage because of the accumulated surface organic matter and seedling-sapling competition from other species such as *Thuja occidentalis*, *Tsuga canadensis* and *Acer saccharum* which are better adapted for growth in mesic conditions. As a result, on the older mesic sites, *Pinus strobus* appears as a seral population of large sized trees, with young populations of *Thuja occidentalis*, *Acer rubrum*, *A. saccharum* and *Tsuga canadensis* invading under the canopy. The *Pinus-Maianthemum* association on mesic sites will thus slowly develop into a *Tsuga canadensis-Gymnocarpium*

Dryopteris association.

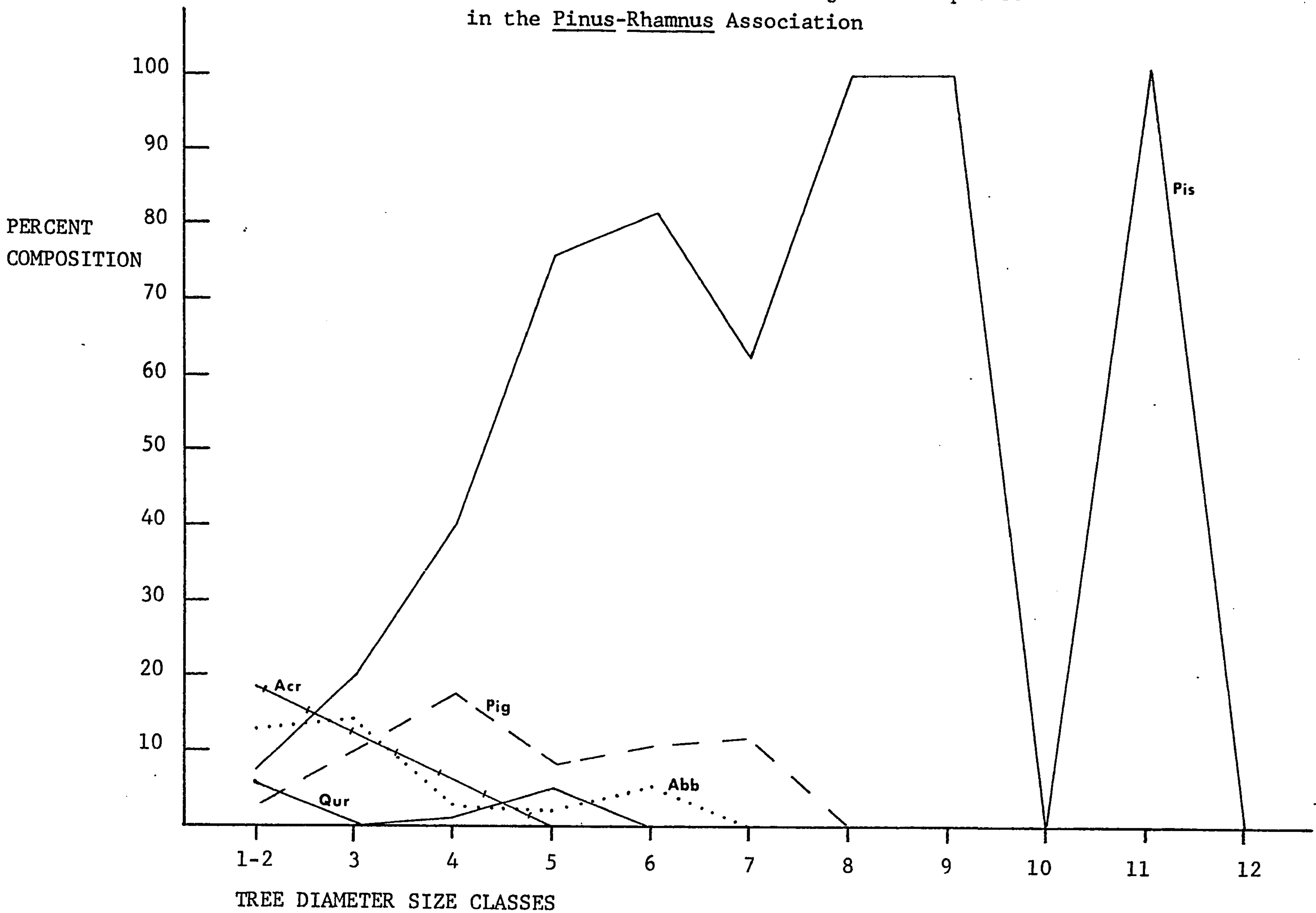
The *Pinus*-*Maianthemum* association is found most frequently on mesic sites, although it does occur on dry sites (Table 9). The association tends to occupy lower and mid slope topographic positions although a variety of locations is possible including ridge tops and flat, upland plateaus (Figure 26). Soil samples collected from within these communities are medium-textured loamy sands of low organic matter content and an average pH of 4.4 (Table 10). According to the soils map of Carleton County (Hills *et al.*, 1944), the association occurs on either shallow, limestone soils, or, more frequently, on acidic sands or loamy sands developed from glacial drift.

3. *Pinus strobus*-*Rhamnus Frangula* Association

The *Pinus*-*Rhamnus* association has an overstory composed of the dominant *Pinus strobus* with a lower, sub-canopy stratum made up of *Picea glauca*, *Abies balsamea* and a host of young deciduous species including Acer rubrum, Quercus rubra, Acer saccharum and Fraxinus americana (Table 19). The distinctive but sparse shrub layer is characterized by the presence of Rhamnus Frangula and various species of Amelanchier particularly on the drier sites. The understory of the association is distinguished by the consistent and abundant presence of Maianthemum canadense, and the occasional presence of Fragaria virginiana, Galium triflorum, Pteridium aquilinum and Dryopteris austriaca. The understory has a mean total coverage of 36% composed of about 20 understory species (Table 20).

The typical composition of the association is shown for the five major tree species in Figure 33. Pinus strobus is clearly dominant in all size classes above 1-2. Abies balsamea and the deciduous members, Acer rubrum and Quercus rubra, show strongest representation in the smaller size classes gradually disappearing from the present population after size class 6. Picea glauca maintains a significant percent composition

Figure 33. Percent Composition of the Major Tree Species in the _Pinus_-_Rhamnus_ Association



through to size class 7. Unfortunately, lack of space in Figure 33 precluded the presentation of the population structures of *Acer saccharum*, *Fraxinus americana* and *Tilia americana* which also contribute to the mixed nature of the community. They essentially follow the same pattern as that of *Acer rubrum* and *Quercus rubra* already outlined. The population structure (Appendix Table B.6.3) shows that *Pinus strobus* has greater regeneration success on dry sites (increased numbers of seedlings and saplings) as opposed to mesic sites. The association exhibits an average total basal area of 49 m2/ha with maximum development occurring on the mesic and dry-mesic sites (Table 9).

These data indicate two future courses of succession depending on the drainage condition of the particular site. On dry sites, *Pinus strobus* reproduces well and will maintain dominance into the foreseeable future although minor population of *Acer rubrum*, *Quercus rubra*, *Abies balsamea* and *Picea glauca* will also remain because of the habitat diversity created by the open *Pinus* canopy. *Quercus rubra* is consistently present in the association and could increase and eventually dominate these sites if *Pinus strobus* regeneration was to decline. It is possible that a *Quercus rubra*-*Maianthemum canadense* association could develop here since these associations are characterized by large, single *Pinus strobus* trees among an otherwise deciduous canopy. On mesic sites, *P. strobus* regeneration shows signs of deterioration and vigorous *Abies balsamea* and *Picea glauca* populations foretell the eventual displacement of *Pinus strobus* and the transition toward a *Picea glauca*-*Waldsteinia fragarioides* association. External disturbance, particularly fire, would have a rejuvenating effect and allow *Pinus strobus* to regain dominance by abundant successful germination of seeds on exposed mineral soil. In the absence of fire, *P. strobus* acts as a long-lived seral species which is eventually replaced by sub-canopy populations of other species.

The *Pinus-Rhamnus* association frequently occupies dry sites (Table 9). Topographically, these sites are located on ridge tops or in upper slope locations (Figure 26). Soils collected from the association show them to be sandy loams with an average organic matter content of approximately 7% and an average pH of 4.8 (Table 10). According to the Carleton County Soils Map (Hills *et al.*, 1944), this association occurs on either slightly acidic, well-drained till soils or, more frequently, on dry, acidic sands of low fertility.

B. Minor Alliances

B.1 *Acer saccharinum* Alliance

General Features of the Alliance

The overstory of this alliance is dominated by *Acer saccharinum*. It occurs in wet areas throughout the study zone but is often too small in area for adequate sampling. The location of the two communities sampled during the present study is shown in Figure 34. The alliance is represented by a single association, namely: *Acer*

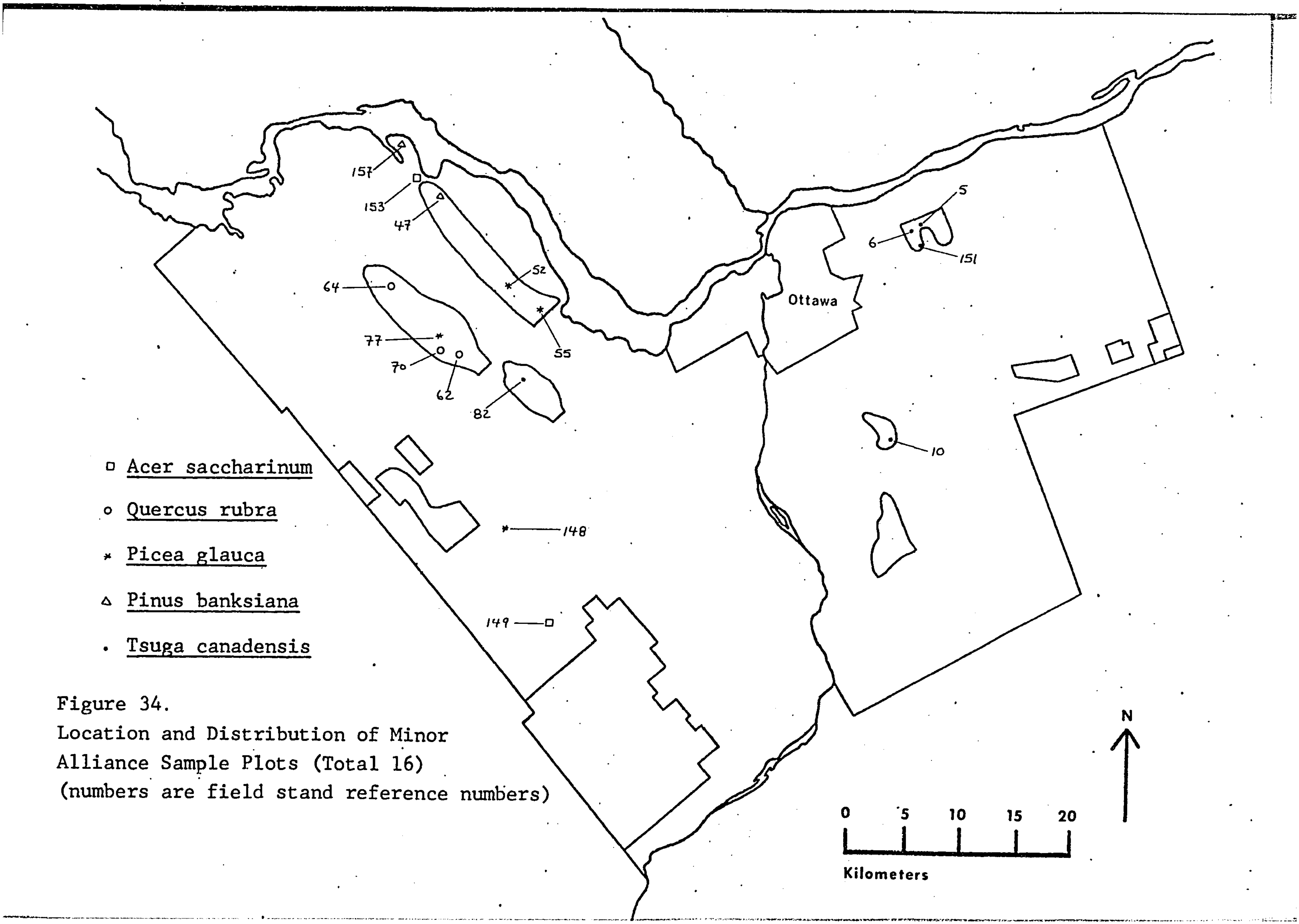


Figure 34.
Location and Distribution of Minor Alliance Sample Plots (Total 16)
(numbers are field stand reference numbers)

saccharinum-Onoclea sensibilis.

Acer saccharinum-Onoclea sensibilis Association

This association is dominated by Acer saccharinum with Fraxinus nigra sometimes present in large quantities, and Acer rubrum and Ulmus americana, occasionally occurring as minor elements (Table 21 a, b). Acer saccharinum and A. rubrum are known to hybridize and produce trees of intermediate character. Most individuals are easily identified as one or the other. Only one shrub species, Ilex verticillata was found in these communities. The lush understory is composed primarily of Onoclea sensibilis with consistent but lesser amounts of Galium boreale, Urtica dioica and various Carex species (Table 22). Other common forbs include Impatiens biflora, Pilea pumila, Lysimachia thyrsiflora and L. Nummularia. On the average, the understory is composed of 20 species with a mean coverage of about 83%.

The typical composition of each size class for the two major tree species (Figure 35) shows that this association is clearly dominated by Acer

Table 21a. Relative Dominance Values (Minor Alliances)[1]

	Acer saccharinum Alliance		Quercus rubra Alliance			Picea glauca Alliance				Pinus banksiana Alliance		Tsuga canadensis Alliance				
Plot #	153	149	70	64	62	148	77	52	55	157	47	82	5	6	10	151
Trees[2]																
Bep				4	+	+	9	12	5			12	18	7		+
Acs			12	8	1	+	+					30	6	4	48	19
Tia		+		2	+		19				2	+	8	23		2
Acr		4	2	22	23		8			+	55	+	16			
Qur			45	26	46		+			+	3	8				+
Abb				1	3	30		35	13		+	5				
Pig				1	+	55	61	21	45		9					
Fra			7	4	12	2	+				+	+				
Pis			19	14	1	1					5	12				
Pot			1	1	2			18	9	1						
Tsc												11	16	23	49	69
Bea		+											31	43	1	9
Tho						5			21		+	2				
Osv			10	8	+										2	
Pob						+	+						+			
Pog						4		4		11						
Ula		2		1								+				
Acsi	69	92														
Pib										74	24					
Frn	31	2														
Qum			+		+											
Caco												+				
Fag													6			
Caca													+			
Shrubs																
Prv				+		2	+	+		+	+	2				
Cos			+	+	+	1		3	7				+			
Amel			3	2	9	+	+			+						
Vib			+	1	+	+	+									
RhF			+	+			+									
Coco						+		6								
Sal							+			5						
Loc						+			+							
Dil						+										
Apa										+						
Ilv	+															
Acp													+			
Prp										8						
Dip															+	
Shc									+							
Rha										+						

1 (Table 21 is a complete list of trees and shrubs in these alliances).
2 (Species abbreviations are defined in Appendix Table C).

Table 21b. Relative Dominance and Percent Constancy Value Summary (Minor Alliances)[1]

	Acer saccharinum Alliance[3]	*Quercus rubra* Alliance[3]	*Picea glauca* Alliance[3]	*Pinus banksiana* Alliance[3]	*Tsuga canadensis* Alliance[3]
Trees[2]					
Bep	.	1.67	7.100	.	7.80
Acs	.	7.100	+.50	.	21.100
Tia	+.50	+.67	5.25	1.50	7.80
Acr	2.50	16.100	2.25	28.100	3.40
Qur	.	39.100	+.25	2.100	2.40
Abb	.	1.67	20.75	+.50	1.20
Pig	.	+.67	46.100	5.50	.
Fra	.	8.100	+.50	+.50	+.20
Pis	.	11.100	+.25	3.50	2.20
Pot	.	1.100	7.50	+.50	.
Tsc	.	.	.	.	34.100
Bea	+.50	.	.	.	17.80
Tho	.	.	7.50	+.50	+.20
Osv	.	6.100	.	.	+.20
Pob	.	.	+.50	.	+.20
Pog	.	.	2.50	6.50	.
Ula	1.50	+.33	.	.	+.20
Acsi	81.100	.	.	.	.
Pib	.	.	.	49.100	.
Frn	16.100	.	.	.	.
Qum	.	+.67	.	.	.
Caco	.	.	.	.	+.20
Fag	.	.	.	.	1.20
Caca	.	.	.	.	+.20
Shrubs					
Prv	.	+.33	+.75	+.100	+.20
Cos	.	+.100	3.75	.	+.20
Amel	.	5.100	+.50	+.50	.
Vib	.	+.100	+.50	.	.
RhF	.	+.67	+.25	.	.
Coco	.	.	2.50	.	.
Sal	.	.	+.25	3.50	.
Loc	.	.	+.50	.	.
Dil	.	.	+.25	.	.
Apa	.	.	.	+.50	.
Ilv	+.50	.	.	.	.
Acp	.	.	.	.	+.20
Prp	.	.	.	4.50	.
Dip	.	.	.	.	+.20
Shc	.	.	+.25	.	.
Rha	.	.	.	+.50	.

1 (Table 21 is a complete list of trees and shrubs in these alliances).
2 (Species abbreviations are defined in Appendix Table C).
3 (Number to left of dot is relative dominance, number to right of dot is percent constancy).

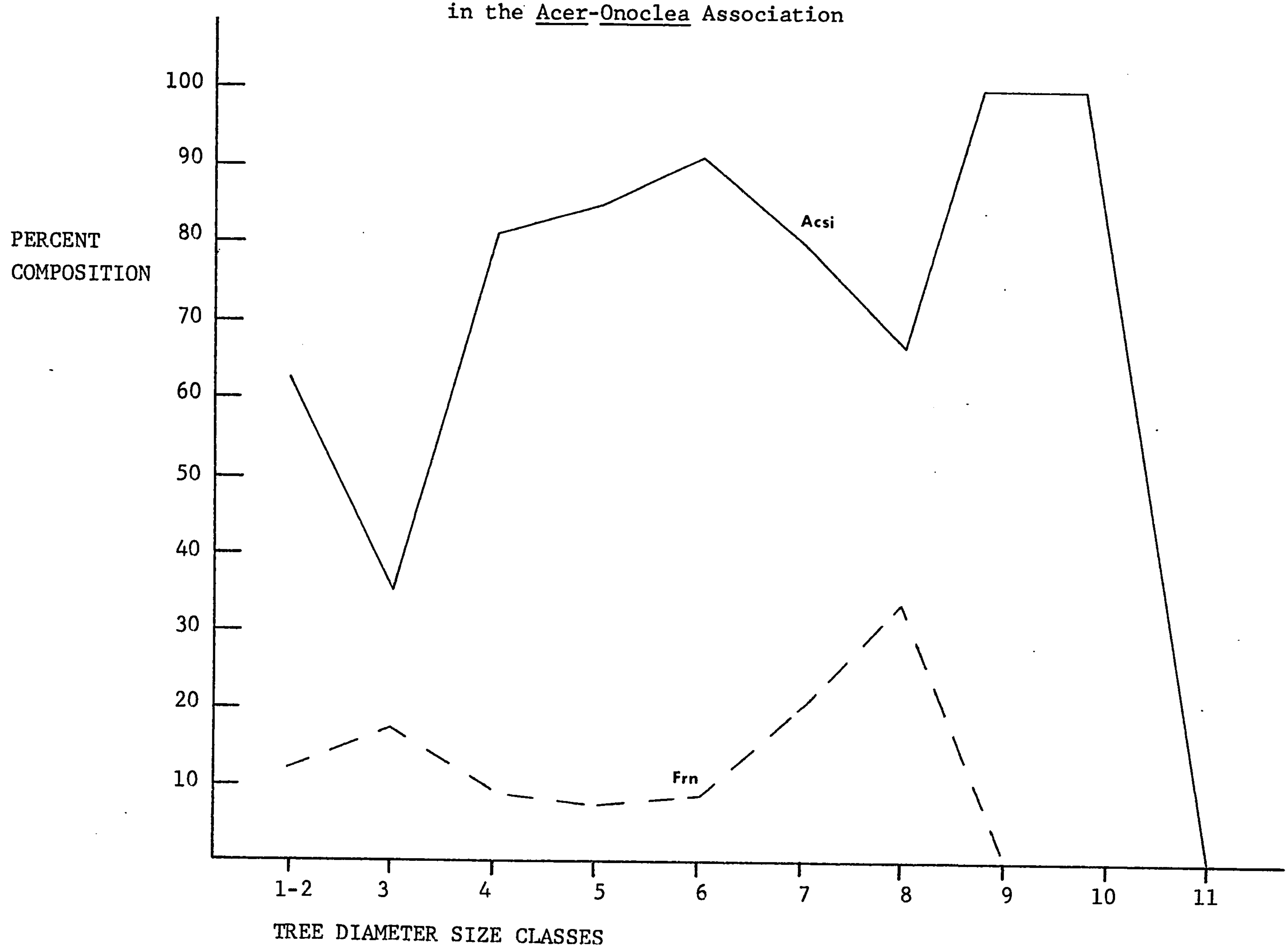
Table 22. Understory Species in the Minor Alliances[1]

Forbs	A. saccharinum Alliance[2]	Q. rubra Alliance[2]	P. glauca Alliance[2]	P. banksiana Alliance[2]	T. canadensis Alliance[2]
Maianthemum canadense	.	11.100	6.100	+.50	+.100
Carex spp.	2.100	2.67	6.50	2.50	5.80
Rhus radicans	.	2.67	11.100	16.100	.
Rubus spp.	+.50	.	+.75	3.50	.
Trillium grandiflorum	.	+.67	1.50	.	1.60
Smilacina stellata	.	.	+.25	+.50	+.60
Aster macrophyllus	.	5.100	9.75	.	2.20
Aralia nudicaulis	.	8.100	7.75	.	+.20
Waldsteinia fragarioides	.	.	10.100	.	.
Epipactis helleborine	.	.	+.50	.	+.20
Pyrola elliptica	.	+.33	+.50	.	+.20
Fragaria virginiana	.	.	+.25	2.100	.
Viola spp.	.	+.33	1.75	.	.
Trientalis borealis	.	.	+.25	.	+.40
Actaea alba	.	.	+.25	.	+.40
Galium triflorum	.	.	+.25	1.50	.
Hieracium spp.	.	.	+.25	3.50	.
Aster spp.	.	.	+.25	+.50	.
Rosa carolina	.	.	+.25	+.50	.
Mitchella repens	.	2.67	+.25	.	+.20
Galium boreale	5.100	.	.	.	.
Urtica dioica	1.100	.	.	.	.
Ferns and Allies					
Pteridium aquilinum	.	1.100	4.100	13.100	+.60
Dryopteris austriaca	+.50	+.67	+.25	.	+.80
Thelypteris noveboracensis	.	.	.	.	1.60
Gymnocarpium dryopteris	.	.	.	.	5.60
Equisetum scirpoides	.	.	.	.	3.60
Polystichum acrostichoides	.	.	.	.	+.60
Onoclea sensibilis	50.100	.	.	.	.
Understory Characteristics					
Mean Understory Coverage (%)	83.1	44.1	66.3	60.0	24.7
Mean Number of Species	20.0	17.3	16.0	12.5	16.6
Mean Number of Species With Greater Than 1% Coverage	8.5	7.0	8.8	6.5	6.4

1 (Table 22 lists only those species showing 15% constancy or greater within the alliance; complete species list is found in Appendix Table B.7.1).

2 (Number to left of dot is percent coverage, number to right of dot is percent constancy).

Figure 35. Percent Composition of the Major Tree Species in the *Acer-Onoclea* Association



saccharinum throughout all size classes, with *Fraxinus nigra* usually maintaining a smaller but stable population. The association has an average stand basal area of 63 m2/ha (Table 9).

These data indicate that the *Acer saccharinum*-*Onoclea sensibilis* association is a stable community. The two major species are both reproducing and growing well and no invading species are apparent.

The association occupies wet, bottomland sites which are flooded regularly each spring and maintain high water tables all year round (Figure 26, Table 9). A soil sample collected from the association was a fine-textured loam of high organic matter content and pH of 5.1 (Table 10). The soils map of Carleton County (Hills *et al.*, 1944), indicates that the association is located on acidic, stratified sand and gravel. In general, the soil characteristics are an acidic, wet, fine-textured loams of high organic matter content that is regularly replenished by flooding.

B.2 Quercus rubra Alliance

General Features of the Alliance

The overstory of this alliance is dominated by *Quercus rubra* with a variety of associated species such as *Acer rubrum*, *Fraxinus americana* and *Pinus strobus*. It occurs in the study area as mesic to dry stands on precambrian rock in the Carp Hills. The location of the three communities sampled is shown in Figure 34. The alliance is represented by a single association, namely; *Quercus rubra-Maianthemum canadense*.

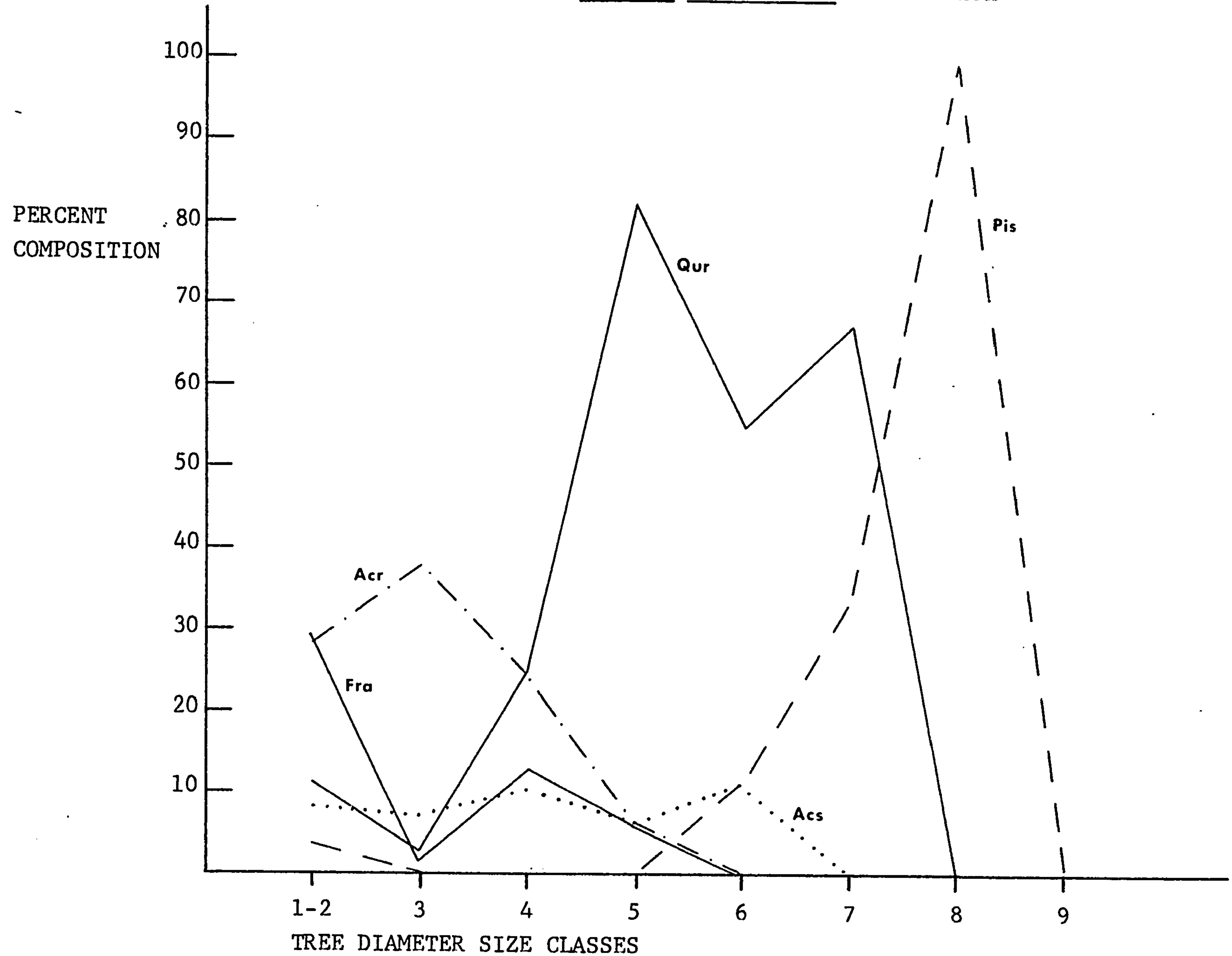
Quercus rubra-Maianthemum canadense Association

In addition to the dominant *Quercus rubra*, the overstory of the *Quercus-Maianthemum* association may be composed of *Acer rubrum*, *A. saccharum*, *Ostrya virginiana*, *Fraxinus americana* and *Pinus strobus*, often in large quantities (Table 21 b). The moderate shrub stratum is characterized by consistent presence of *Cornus stolonifera* and the abundance of various species of *Amelanchier*. The understory is distinguished by the abundance of *Maianthemum canadense*, *Aster macrophyllus*, *Aralia nudicaulis* and Pteridium aquilinum (Table 22). On the average, the association maintains 17 understory species with a mean coverage of approximately 44%.

The tree composition of a typical member of the Quercus-Maianthemum association in terms of the five major species is given in Figure 36. Quercus rubra presently has a large number of seedlings and larger sized trees although the critical growth stage from seedlings to saplings is not always successful. Acer rubrum, Fraxinus americana and to a lesser extent, Acer saccharum, have large numbers of seedlings and fairly continuous population patterns up to size class 6 (Appendix Table B.7.3). Pinus strobus maintains a few seedlings and then exhibits a large gap in population structure until size class 6 and above where a few, large, old trees remain. Presently, the association attains an average stand basal area of 39 m2/ha (Table 9).

These data indicate that the Quercus-Maianthemum association is not stable. It

Figure 36. Percent Composition of the Major Tree Species in the _Quercus_-_Maianthemum_ Association



developed on sites where *Pinus strobus* was formerly a dominant tree but eventually will be entirely eliminated due to lack of regeneration. *Quercus rubra* invaded the old *Pinus* community (perhaps after fire or perhaps after natural decrease of *Pinus strobus*) and is now itself showing signs of failing reproduction. *Q. rubra* will remain as a major constituent of this association for many years because of its many smaller to mid-sized trees which will grow through to maturity. Just as the *Quercus* entered the *Pinus* community, now *Acer rubrum*, *A. saccharum* and *Fraxinus americana* are invading the *Quercus* association. Eventually, *Acer saccharum* will dominate these sites, probably as an *Acer saccharum*-*Parthenocissus quinquefolia* association.

The *Quercus*-*Maianthemum* association occurs on mesic and dry sites (Table 9). Topographically, these are ridge top and upper slope positions (Figure 26). Unfortunately, no soil samples were collected from this association, although according to the Carleton County Soil Survey

(Hills *et al.*, 1944), these communities are located on shallow, acidic sand derived from thin glacial till over precambrian bedrock.

B.3 *Picea glauca* Alliance

General Features of the Alliance

The overstory of the *Picea glauca* alliance is normally dominated by *Picea glauca* with *Abies balsamsea* as a co-dominant species. Members of this alliance appear restricted to rocky slopes and are thus not common in the southern and eastern parts of the study zone. The location of the four sampled communities is shown in Figure 34. The alliance is composed of a single association, namely: *Picea glauca-Waldsteinia fragarioides*.

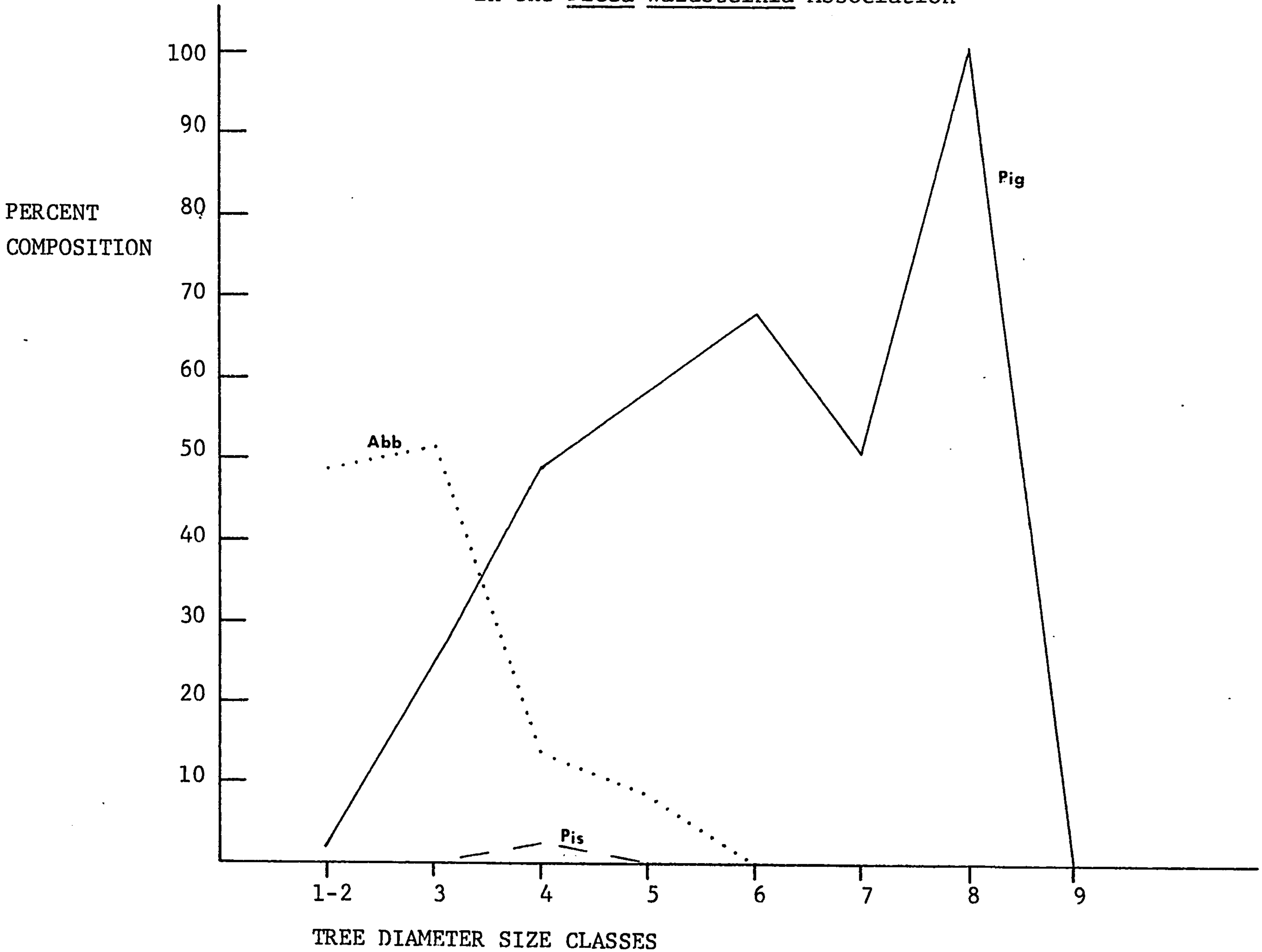
Picea glauca-Waldsteinia fragarioides Association

The *Picea-Waldsteinia* association is normally dominated by *Picea glauca* with *Abies balsamea* as a co-dominant species, although rarely, this order may be reversed (Table 21 a, b). *Betula papyrifera* is consistently present, often with some representation from various species of *Populus* (*P. tremuloides* on dry sites. P. balsamifera on mesic sites and P. grandidentata appearing indifferent to drainage class in this association). Thuja occidentalis occasionally occurs as a minor member. Cornus stolonifera is the most consistent component of the diverse shrub stratum.

The association has a consistent, abundant assemblage of Rhus radicans, Waldsteinia fragarioides, Maianthemum canadense and Pteridium aquilinum (Table 22). A large number of other forbs are often present including Aster macrophyllus, Aralia nudicaulis and various species of Rubus and Viola. Generally, 16 understory species create a mean coverage of about 66%.

The typical tree composition of the Picea-Waldsteinia association (Figure 37) shows that these communities are presently dominated by Picea glauca in all size classes above 3 while the seedling/sapling group (size class 1-2) is dominated by Abies balsamea. Pinus strobus is rare and Populus tremuloides, Thuja occidentalis

Figure 37. Percent Composition of the Major Tree Species in the *Picea-Waldsteinia* Association



and *Tilia americana* are occasionally seen as large individual trees. This association has an average stand basal area of 42 m2/ha (Table 9).

These data show that the present population structure of both *Picea glauca* and *Abies balsamea* is self-reproducing and dominant, and further that no new invading species are likely to enter the communities barring unforeseen disturbance. The *Picea-Waldsteinia* association is thus a stable community which will persist without major species changes in the foreseeable future.

This association occurs with equal frequency on mesic or drier sites (Table 9). In terms of topographic position, it appears restricted to ridge tops or upper slope plateaus (Figure 26). Soil samples collected from these communities show that it occurs on either acidic, organic soils or fine-textured silt loams of high organic matter content and an average ph of 5.7 (Table 10). According to the Carleton County Soil Survey (Hills *et al.*, 1944), this association frequently occurs on substrates classified as fine-textured limestone soils and, more rarely, on acidic, glacial sands.

B.4 *Pinus banksiana* Alliance

General Features of the Alliance

The overstory of this alliance is exclusively dominated by *Pinus banksiana* with various subcanopy species such as *Acer rubrum*, *Picea glauca*, *Quercus rubra* and *Populus grandidentata* sometimes present. The occurrence of natural members of this alliance is restricted to dry, alluvial sand deposits in the Ottawa area. The location of the two communities sampled during this study is shown in Figure 34. The alliance has a single association, namely: *Pinus banksiana*-*Pteridium aquilinum*.

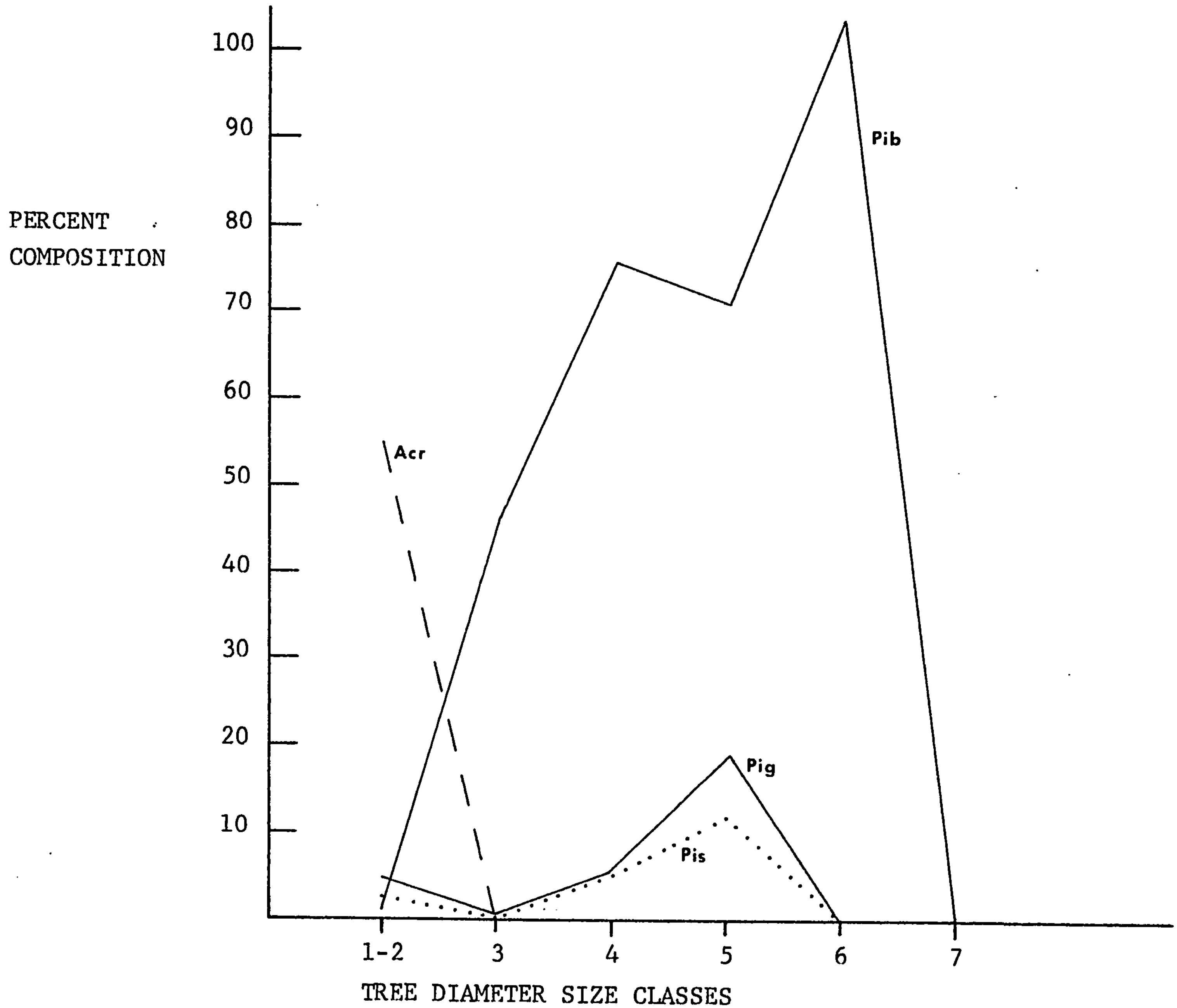
Pinus banksiana-*Pteridium aquilinum* Association

The *Pinus*-*Pteridium* association is dominated by *Pinus banksiana*, normally with a minor complement of *Picea glauca*, *Quercus rubra*, *Populus grandidentata* and often with a significant number of *Acer rubrum* seedlings under the mature pines (Table 21 a, b). It has a characteristic shrub stratum of Prunus virginiana with various Salix species often present. The understory is distinguished by the abundance of Rhus radicans, Pteridium aquilinum and Fragaria virginiana (Table 22). In general, the association has 13 understory species with a mean coverage of 60%.

The tree composition of a typical member of the association is shown in Figure 38. Pinus banksiana clearly dominates all size classes above seedlings (1-2). P. strobus and Picea glauca maintain fragmented populations up to size class 5 while Abies balsamea and Acer rubrum generally maintain large populations of seedlings. The association presently has an average stand basal area of 45 m2/ha (Table 9).

There are insufficient numbers of these communities to discern clearly their successional trends. Most literature sources indicate that Pinus banksiana is a seral species that requires frequent, moderate fires to maintain its dominance.

Figure 38. Percent Composition of the Major Tree Species in the _Pinus_-_Pteridium_ Association



In the absence of fires, *Pinus banksiana* slowly dies out of the community and is replaced by other species. Assuming quick suppression of fires in the Ottawa region, it is expected that the naturally-seeded *Pinus banksiana* communities will be replaced by a mixed coniferous-deciduous association probably composed of, at least, *Pinus strobus*, *Abies balsamea* and *Acer rubrum*. The trend may be towards a *Pinus strobus*-*Rhus radicans* association.

Presently, the *Pinus banksiana*-*Pteridium aquilinum* association occupies dry and dry-mesic sand dunes or flats (Figure 26). Soil samples from these stands consistently show a coarse-textured sand of low organic matter content and a average pH of 5.1 (Table 10). According to the Soil Survey of Carleton County (Hills *et al*., 1944), these substrates are of deltaic origin and often exhibit drifting and dune formation. Such deposits are particularly prevalent in the northwest portion of the study zone on the Constance Bay peninsula.

B.5 *Tsuga canadensis* Alliance

General Features of the Alliance

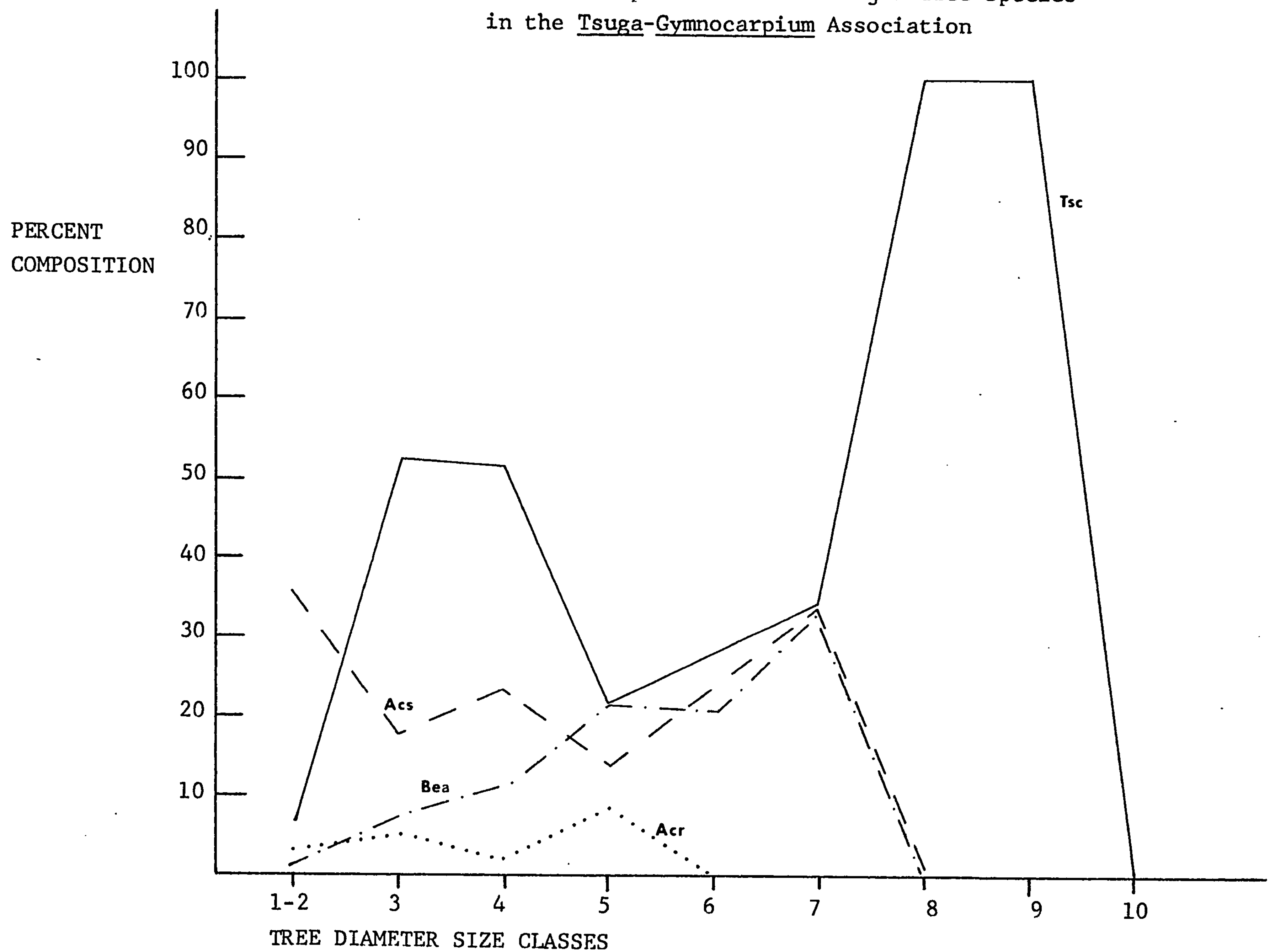
The overstory of this alliance is dominated by *Tsuga canadensis* in association with *Acer saccharum* and *Betula alleghaniensis*. It often occurs on relatively steep, northwesterly-facing slopes. The locations of the five communities sampled in the present study are given in Figure 34. This alliance is composed of a single association, namely: *Tsuga canadensis-Gymnocarpium Dryopteris*.

Tsuga canadensis-Gymnocarpium Dryopteris Association

The *Tsuga-Gymnocarpium* association is dominated by *Tsuga canadensis* associated with *Acer saccharum* and *Betula alleghaniensis*. Usually, small numbers of *Betula papyrifera*, *Tilia americana*, *Acer rubrum* and *Quercus rubra* are also present (Table 21). The shrub stratum is characteristically depauperate in species numbers and abundance. The understory is characterized by the sparse but consistent presence of *Maianthemum canadense* plus a rich fern flora composed of Dryopteris austriaca Thelypteris noveboracensis, Gymnocarpium Dryopteris, Polystichum acrostichoides, and the fern ally Equisetum scirpoides (Table 22). On the average, the association has 17 understory species with a mean coverage of about 25%.

The typical tree composition of this association (Figure 39) shows the relatively even mixture of Tsuga canadensis, Acer saccharum and Betula alleghaniensis in the mature size classes 5, 6, and 7. The only species to grow larger at the present time is Tsuga canadensis which dominates size classes 8 and 9. Seedlings (size class 1-2) are dominated by Acer saccharum while T. canadensis is seen to have no seedlings in certain stands and good regeneration in others (Appendix Table B.7.2). Its reproductive pattern appears to be cyclic or at least, triggered by something other than annual seasonal changes (perhaps, precipitation during the year). Good fruit and seedling production, like that of Thuja occidentalis, is not to be expected in every Tsuga canadensis

Figure 39. Percent Composition of the Major Tree Species in the _Tsuga-Gymnocarpium_ Association



community in every year. Size classes 3 and 4 are mixed but dominated by Tsuga canadensis. Acer rubrum occasionally maintains a population within this association although generally, it is absent. The Tsuga-Gymnocarpium association has an average stand basal area of 43 m2/ha (Table 9).

These data indicate that the two major tree species will continue to co-exist into the foreseeable future. Tsuga canadensis and Acer saccharum show continuous, healthy population structure with neither presently tending to displace the other. Betula alleghaniensis is showing signs of failing reproduction and, will slowly be eliminated in the absence of any future disturbance.

The Tsuga-Gymnocarpium association occupies steep, mesic, northwest-facing slopes (Figure 26). This particular habitat and the correlated vegetation was noted in many small areas within the study zone. This habitat was noticeably cooler and darker (of lower light intensity) than adjacent forests although quantitative microclimatic data were not recorded. Samples collected within the association show the soils to be fine-textured loams of high organic matter content and an average pH of 5.5 (Table 10). According to the Carleton County Soils Map (Hills *et al.*, 1944), these communities are located most frequently on acidic, eroded ravine sites and are not correlated to specific soil types.

C. Key to Present Forest Associations

The following dichotomous key (Table 23) to the presently-occurring forest associations of the Ottawa region is based on the dominance of overstory species. Dominance is defined in terms of basal area of the tree species. In most cases, this is clearly related to a large number of stems of all size classes. In particular, the presence of many, large trees of the same species will indicate the dominant without the need of quantitative sampling. Major tree associates are normally those species consistently present though sometimes in small quantities. Characteristic understory species are those which most clearly distinguish one association from another of the same alliance. A brief habitat description is also given. More detail and slight variations from these typical association features can be seen from the previous description of the appropriate association.

TABLE 23. KEY TO THE PRESENT FOREST ASSOCIATIONS

1a. Community dominated by deciduous tree species

2a. Community dominated by the species of the genus *Acer*

3a. Community dominated by *Acer saccharum*

4a. Associated trees mainly *Ulmus americana* and *Quercus macrocarpa*; *Amelanchier* present; *Parthenocissus quinquefolia* and various species of *Viola* in understory; dry-mesic ridges or plateaus with sandy loam soil:

* *Acer saccharum-Parthenocissus quinquefolia* Association

4b. Major tree associate *Fagus grandifolia*; *Corylus cornuta*, *Trillium grandiflorum*, *Caulophyllum thalictroides* and *Asarum canadense* abundant in understory; mesic, mid-slope topography with sandy loam soil:

* *Acer saccharum-Trillium grandiflorum* Association

3b. Community dominated by *Acer rubrum* or *Acer saccharinum*

5a. Community dominated by *Acer rubrum*

6a. Associated trees mainly *Populus tremuloides* and *Betula papyrifera*; *Corylus cornuta*, *Trientalis borealis*, *Clintonia borealis* and *Cornus canadensis* common in understory; mesic, flat bottomlands with sandy loam soil:

* *Acer rubrum-Trientalis borealis* Association

6b. Tree associates mainly *Fraxinus nigra* and *Ulmus americana*; *Prunus virginiana*, *Onoclea sensibilis* and *Galium triflorum* present in understory; wet-mesic, flat, bottomlands with loamy sand soils:

* *Acer rubrum-Galium triflorum* Association

Table 23 ...cont'd

5b. Community dominated by Acer saccharinum; major tree associate Fraxinus nigra; Ilex verticillata sometimes present; Onoclea sensibilis, Galium boreale and Urtica dioica consistently present in understory; wet, bottomland sites of loam soil:

* Acer saccharinum-Onoclea sensibilis Association

2b. Community not dominated by species of the genus Acer

7a. A community dominated by species of the genus Populus

8a. A community dominated by Populus tremuloides and P. grandidentata

9a. Major tree associate Acer rubrum with no coniferous species; major shrubs Corylus cornuta and Prunus virginiana; Pteridium aquilinum and Maianthemum canadense abundant in understory; mesic, lower to mid-slope topography with sandy soils:

* Populus tremuloides-Pteridium aquilinum Association

9b. Major tree associates Abies balsamea, Acer rubrum, Picea glauca and Thuja occidentalis; major shrubs Prunus virginiana and Cornus stolonifera; Aster macrophyllus, Rhus radicans and various species of Carex and Rubus in understory; mesic to dry, ridge and upper slope topography with sandy loam soils;

* Populus tremuloides-Aster macrophyllus Association

8b. Community dominated by Populus balsamifera; major tree associates P. tremuloides and Betula papyrifera; major shrubs Corylus cornuta and Cornus stolonifera; Parthenocissus quinquefolia, Galium triflorum and various Viola and Ribes species in understory; wet-mesic, lowlands on lower slope topography with loam soils:

* Populus balsamifera-Corylus cornuta Association

7b. Community not dominated by species of the genus Populus

10a. A community dominated by Fraxinus nigra

Table 23 ...cont'd

11a. Major tree associates Ulmus americana Acer rubrum; Salix species and Acer spicatum often present; lush understory of Matteuccia Struthiopteris, Onoclea sensibilis, Impatiens biflora and Laportea canadensis; wet lowlands on floodplains with alluvial organic or sandy loam soil:

* Fraxinus nigra-Matteuccia Struthiopteris Association

11b. Major tree associates Ulmus americana, Populus balsamifera and Thuja occidentalis; Cornus stolonifera and Rhamnus Frangula often abundant; lush understory of Onoclea sensibilis, Galium triflorum and Mitella nuda; wet, lowland sites with organic or loam soils:

* Fraxinus nigra-Mitella nuda Association

10b. Community dominated by Quercus rubra; major tree associates Acer rubrum and Pinus strobus; Amelanchier species present; Maianthemum canadense, Aralia nudicaulis, Aster macrophyllus, Pteridium aquilinum in understory; dry-mesic, ridge and upper slope sites with sandy loam:

* Quercus rubra-Maianthemum canadense Association

1b. Community dominated by coniferous tree species

12a. Community dominated by Thuja occidentalis

13a. Abundant shrub layer normally dominated by Cornus stolonifera;

14a. Major tree associates Fraxinus nigra and Ulmus americana; characteristic understory species are Dryopteris austriaca Osmunda cinnamomea, Galium triflorum and abundant Ribes and Rubus species; wet, flat lowlands on floodplains with organic soil:

* Thuja occidentalis-Dryopteris austriaca Association

14b. Major tree associates Picea glauca and Abies balsamea; characteristic understory species are Maianthemum canadense, Galium triflorum plus various species of Viola and Carex; mesic to dry-mesic upland plains or lowlands with sandy loam soil:

* Thuja occidentalis-Maianthemum canadense Association

Table 23 ...cont'd

13b. Sparse shrub layer with no single dominant

15a. Almost pure *Thuja* community with occasional presence of *Larix laricina*; *Pteridium aquilinum* and *Carex* species are the most constant understory species; dry-mesic upland plains with silt loam soil:

* *Thuja occidentalis*-*Pteridium aquilinum* Association

15b. Major tree associate *Acer saccharum*; *Botrychium virginianum*, *Maianthemum canadense* and *Viola* species present in understory; mesic, mid to lower slope sites with sandy loam soil:

* *Thuja occidentalis*-*Botrychium virginianum* Association

12b. Community not dominated by *Thuja occidentalis*

16a. Community dominated by species of the genus *Pinus*

17a. Community dominated by *Pinus strobus*

18a. Community with three or more major tree associates

19a. Major tree associates *Picea glauca*, *Abies balsamea* and *Populus tremuloides*; *Corylus cornuta* and *Cornus stolonifera* normally present; *Rhus radicans*, *Maianthemum canadense*, *Fragaria virginiana* and *Waldsteinia fragarioides* present in understory; dry-mesic slopes with sandy soil:

* *Pinus strobus*-*Rhus radicans* Association

19b. Major tree associates *Picea glauca*, *Acer rubrum* and *Thuja occidentalis*; *Rhamnus Frangula* and *Amelanchier* species present; *Pteridium aquilinum*, *Maianthemum canadense*, *Aster macrophyllus* in understory; dry, upper slopes and ridges with sandy loam soil:

* *Pinus strobus*-*Rhamnus Frangula* Association

Table 23 ...cont'd

18b. Community distinctly dominated by Pinus strobus with Thuja occidentalis often present; Prunus virginiana and Amelanchier species present; sparse understory characterized by Maianthemum canadense; mesic, mid to upper slope sites with loamy sand soil:

* Pinus strobus-Maianthemum canadense Association

17b. Community dominated by Pinus banksiana; major associates Pinus strobus, Picea glauca and Acer rubrum (often only as seedlings/saplings); major shrub Prunus virginiana; Rhus radicans, Pteridium aquilinum and Fragaria virginiana present in understory; dry-mesic sand flats or dune formations:

* Pinus banksiana-Pteridium aquilinum Association

16b. Community dominated either by Picea or Tsuga

20a. A community dominated by Picea glauca; major tree associates Abies balsamea and Betula papyrifera; Cornus stolonifera and Prunus virginiana often present; understory characterized by the presence of Waldsteinia fragarioides, Rhus radicans, Pteridium aquilinum and Maianthemum canadense; mesic to dry ridges and upper slopes with silt loam soil:

* Picea glauca-Waldsteinia fragarioides Association

20b. Community dominated by Tsuga canadensis; major tree associates Acer saccharum and Betula alleghaniensis; sparse scattered shrub layer; characteristic understory species are Gymnocarpium Dryopteris, Maianthemum canadense, Dryopteris austriaca, Equisetum scirpoides and Polystichum acrostichoides; mesic, steep, north-facing slopes with loam soils:

* Tsuga canadensis-Gymnocarpium Dryopteris Association

CHAPTER 5. Potential Forest Vegetation

A. Forest Succession

The 21 described forest associations represent different stages of forest succession. The objective of the present chapter is to relate these recurring forest associations into the best approximation of how they are going to change in species composition and abundance according to exhibited tendencies in overstory composition, regeneration and habitat. The associations are not static vegetation units which will immediately and completely transform into a different, subsequent successional community. The forest associations are convenient species groups which represent valid, recurring noda in the dynamic, continuous process of forest succession. These temporary species associations have been demonstrated to be recognizable in space and time and have their own biotic and abiotic characteristics which recur whenever the habitat, the previous seral community and surrounding species reservoirs permit.

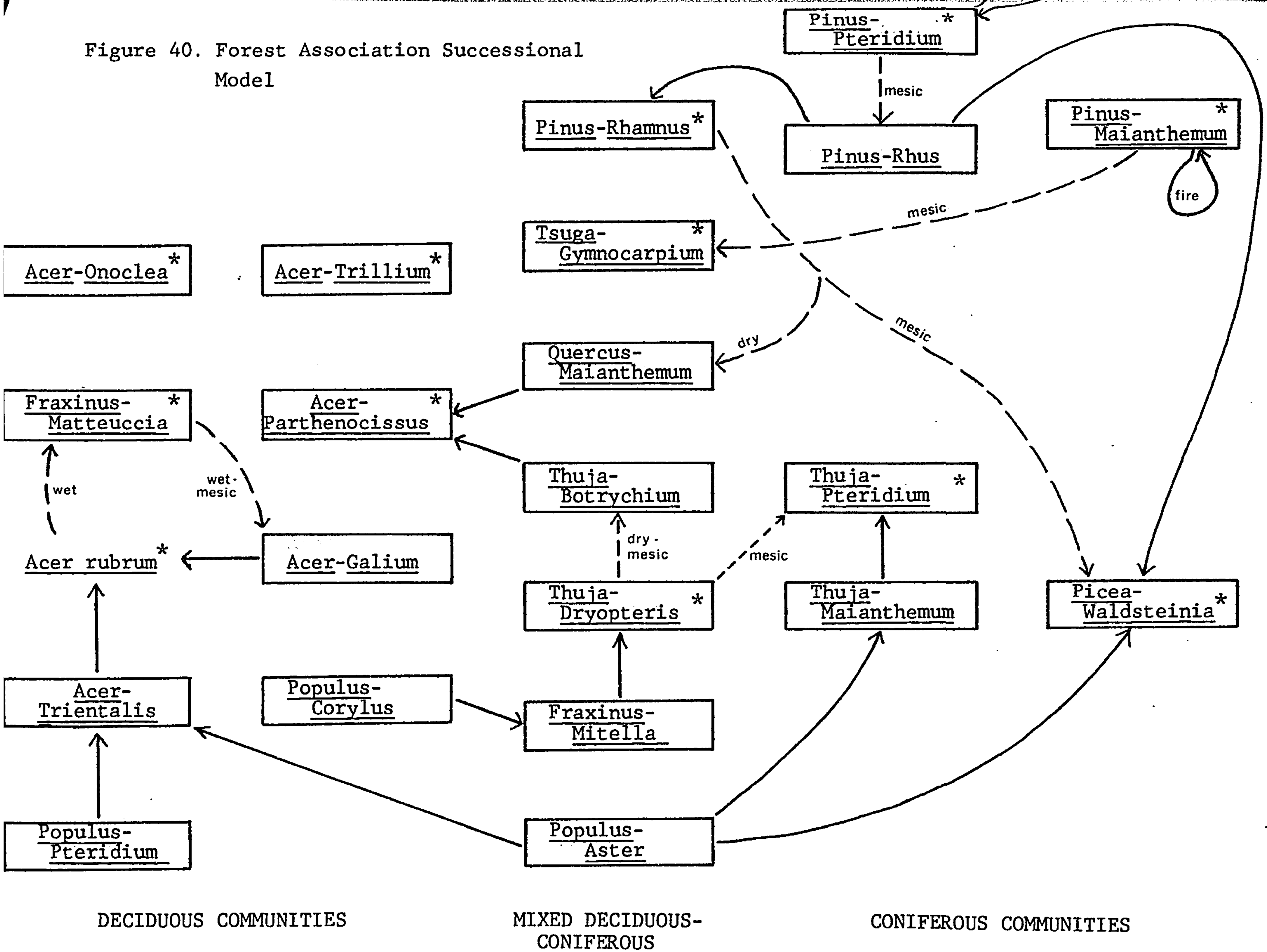
Specific data concerning the rates of change from one association to another are not possible because of the multiplicity of factors involved. Some successional changes, particularly early in forest development or in variable habitats (e.g., lowlands susceptible to rapid, widespread flooding followed by recession), are swift and obvious involving one or two tree generations for relatively complete transformation. Others, in particularly stable habitats or late in succession on most sites, are prolonged competitive struggles between species whose outcomes are rarely obvious. Generally, most transitions from one association to another recognizable association are completed within two tree generations (approximately 100-200 years).

All member stands of a presently-occurring forest association may not respond with common successional trends. Differences in site characteristics, and therefore differential abundance of competitor species, can cause the same present floristic community to display different successional tendencies (most obvious in terms of drainage classes within associations). Disturbances to the forest (e.g., logging, fire, clearing for housing or intensive recreation) could shift, delay, or divert any observed successional trends among the associations.

Figure 40 shows a model representing natural, secondary forest succession in the Ottawa area. The successional trends indicated are for the foreseeable future as evidenced by the population structures, tree ages, understory composition and habitat features present in the existing forest communities. Stable, enduring communities in which further successional change is unclear or presently unpredictable are indicated by stars (*).

The forest successional model (Figure 40) shows the stable associations, of which five are deciduous, four are coniferous and three are mixed deciduous-coniferous communities. Six of these associations show stability over all moisture classes within the association and thus have no successional arrows leading from them. The remaining six associations show stability over most drainage classes but exhibit signs of potential change on certain habitats. The successional model (Figure 40) is presented for each

Figure 40. Forest Association Successional Model



association as a whole, as if each member community would act as indicated. It was apparent that, in some cases, habitat features could modify a species' ability to develop and as a result, different population structures and different successional trends may be observed within one association. Such associations with stable communities on certain habitats and seral tendencies on other habitats have dashed arrows leading from them with a label indicating the drainage condition which appears to create the population instability. The length of the arrow does not imply any corresponding time interval.

All associations within the *Acer saccharum*, *A. saccharinum*, *Picea glauca* and *Tsuga canadensis* alliances are stable communities with no evidence of change in species composition in the foreseeable future.

Associations within the *Fraxinus nigra*, *Thuja occidentalis*, *Pinus strobus* and *P. banksiana* alliances may be stable or seral depending on their habitat and population structure characteristics.

All member associations of the *Populus* and *Quercus rubra* alliances are seral communities. The *Populus* associations may lead to a number of later associations, while the *Quercus rubra* communities appear to lead toward an *Acer-Parthenocissus* association. The two described associations within the *Acer rubrum* alliance are seral, but both show a definite trend toward a stable, homogeneous *A. rubrum* association.

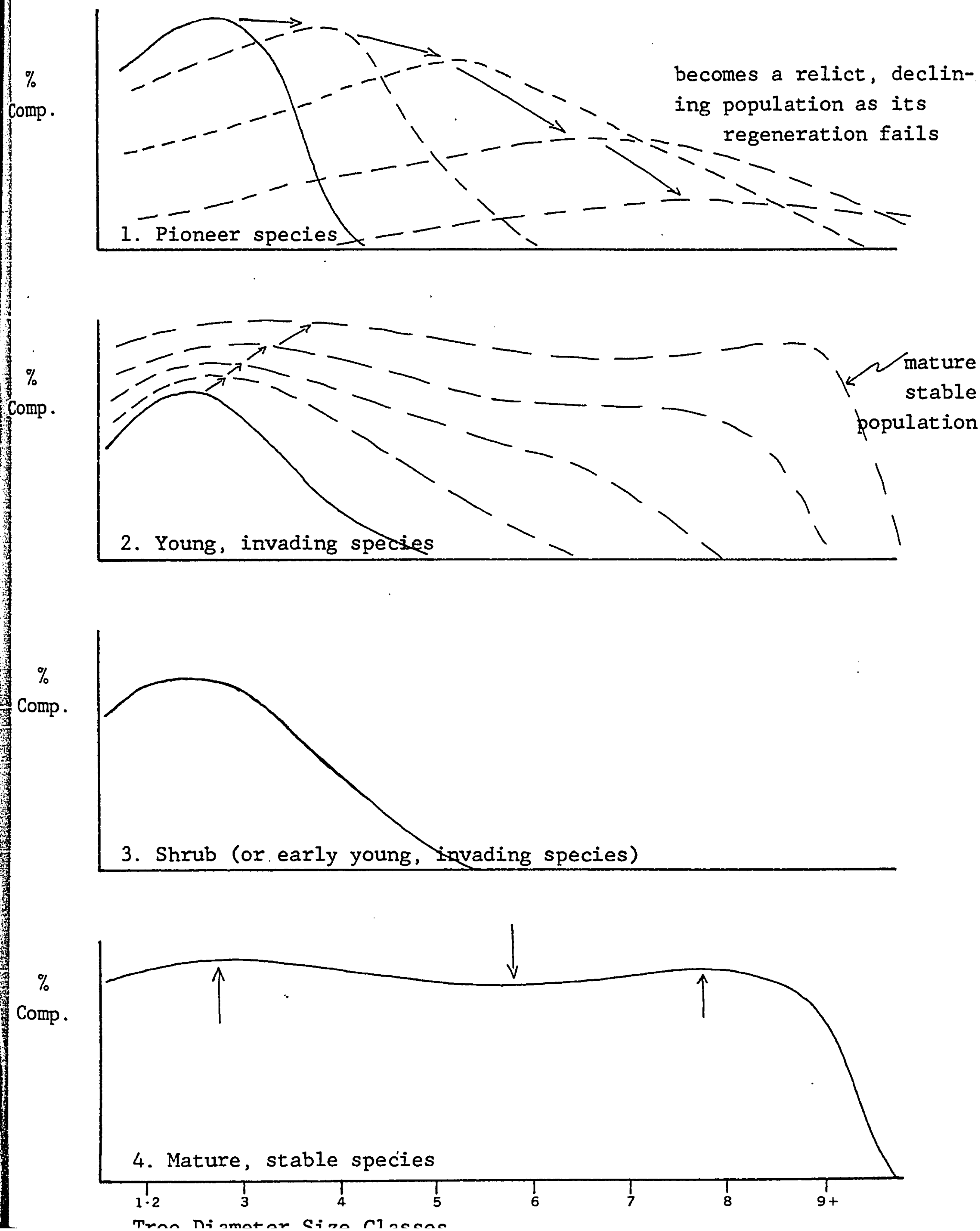
B. Evidence of Forest Succession

The major source of evidence for these successional trends comes from the population structure tables and graphs for each association and the recognized autecology of these species.

It is apparent that changes in the population structure of individual tree species are an important factor controlling the observed successional trends. These changes in tree population structures fall into four major, recognizable patterns (Figure 41).

1. an early successional, pioneer population
2. a young, invading population
3. a mature, stable, enduring population
4. a relict declining population.

Figure 41. Tree Population Patterns



A population is considered to mean all of the recorded stems in all size classes for a particular species in a particular association. The population structure then is the distribution pattern or the number of stems of that species in each size class (increasing size being at least roughly equated to increasing age).

An example of an early pioneer population (trend 1) is found in Table 15 and Figure 22 in which *Populus tremuloides* and *P. grandidentata* in the *Populus-Pteridium* association show strong representation in all size classes. These species occupy the largest size classes present and were probably the two earliest tree species on the site. But, it is also known that species of *Populus* in general are relatively fast-growing, short-lived trees susceptible to many fungus and rot diseases and that they do not reproduce well in the shade of a tree canopy. Their apparent solid dominance on these sites then will slowly deteriorate as *Populus* seedlings and saplings fail to survive (*P. grandidentata* shows signs of this process already). Later species such as the numerous *Acer rubrum* seedlings and saplings will tend to replace the aspens.

The invasion by Acer rubrum in the same association (Table 15, Figure 22) is an example of a young, invading population (trend 2). A. rubrum is present as seedlings even at the height of Populus dominance on these sites. Acer rubrum is well adapted to survive under a tree canopy and will eventually mature and increase its own dominance as the older Populus die out of the community leaving few self-replacements. On the graph of percent composition (Figure 22), the typical shape of a young, invading population (Acer rubrum) is seen as a "lump" or high proportion of stems in the seedling/sapling size classes with few maturing individuals yet expressed above size class 4. This same graphical shape is typical of shrubs and other subordinate species such as Ostrya virginiana indicating the necessity of using autecological information in addition to that of population structure for interpreting succession.

A mature, stable, enduring population (trend 3) is demonstrated by Acer rubrum in the Acer-Trientalis association (Appendix Table B.2.3, Figure 16). In this case, *A. rubrum* occupies the largest size classes present and shows strong representation throughout all size classes. The continuous population structure (i.e., stems present in all sizes) indicates that the *A. rubrum* population will continue its dominance on these sites. There are no other species available here to compete with *A. rubrum* except for declining populations of *Populus tremuloides*, *P. balsamifera* and *Betula papyrifera* which will remain as minor, generally non-regenerating members of the community. The shape of the *Acer rubrum* percent composition line (Figure 16), is typical of an enduring population showing high proportions in seedlings/saplings and the larger size classes with a slight droop in the mid to large sizes where earlier "pioneer" individuals reside until their death.

A declining relict population (trend 4) is clearly shown by *Pinus strobus* (Table 21, Figure 36) in the *Quercus-Maianthemum* association. *Pinus strobus* is represented in size classes larger than those of the dominant trees indicating that it has been on the site for a long time. But, its population structure is severely fractured into diverse, unconnected groups, with particularly low (in many stands, non-existent) seedling representation. These gaps in population continuity and low regeneration representation indicate a population of scattered, old individuals. P. strobus must have been present early in the successional sequence (to achieve the large sizes) but are now slowly being eliminated with the death of each old member. This is the normal course of events for pioneer and seral species and is a natural continuation for species which exhibit trend 1. The shape of the line (Figure 36) for Pinus strobus is typical of such declining populations. These four successional patterns are repeatedly observed in many of the associations described.

Figure 40 showing the presently occurring associations their successional status and the expected seral community towards which they are leading, is based on analysis of the tree population structures. The population structure of the expected, subsequent community was very important in this analysis since it often showed declining, relict populations of the species which were dominant in the earlier seral association.

Additional data from tree core analysis is presented in Table 24. Generally, it is found that the age of representative trees from early successional associations are found to be younger than representative trees from the proposed subsequent association. There are some apparently contradictory age sequences here because the succession model (Figure 40) is based on numerous member stands averaged to create abstract associations of some variability, whereas the age data is recorded for specific trees on specific sites. The early seral associations are all young, although they can remain up to about 60 years on suitable sites. Mid to late successional communities are generally middle-aged and show a great deal of variability. The most advanced, stable associations identified in Figure 40 are, without exception, the oldest communities.

It is expected that habitat features such as drainage, topographic position and soil would also show a correlated progression although such changes

Table 24. Tree Age Data By Forest Associations

Present Forest Association[1]	Plot #	Species[2]	DBH (dm)[3]	Height (m)	Age (years)	Apparent Later Forest Association
Acer-Parthenocissus	141	Acs	5.1	24	120	Acer-Parthenocissus (stable)
	142	Acs	4.6	23	134	
	142	Acs	3.6	24	55	
Acer-Trillium	144	Fag	5.7	24	110	Acer-Trillium (stable)
	144	Acs	3.1	27	88	
Acer-Galium	139	Acr	5.1	25	45	wet-mesic..... Acer rubrum (stable)
	139	Acr	5.0	24	40	
	139	Acr	3.7	22	37	wet..... Fraxinus-Matteuccia
	143	Acr	3.9	24	63	
	143	Acr	3.1	23	60	
Acer-Trientalis	150	Acr	3.2	21	32	Acer rubrum (stable)
	150	Acr	2.8	20	39	
	155	Pot	3.6	20	35	
	155	Acr	2.3	20	35	
	156	Acr	2.7	18	41	
	156	Acr	2.3	18	52	
Fraxinus-Matteuccia	135	Frn	2.4	23	34	wet-mesic..... Acer-Galium
	135	Frn	2.2	21	43	wet..... Fraxinus-Matteuccia (stable)

1 (For full association names, see text and Table 6).

2 (Species abbreviations are defined in Appendix Table C).

3 (Diameter at breast height).

Table 24. continued

Present Forest Association[1]	Plot #	Species[2]	DBH (dm)[3]	Height (m)	Age (years)	Apparent Later Forest Association
Fraxinus-Mitella	146	Frn	3.2	21	65	Thuja-Dryopteris
	146	Ula	5.9	24	58	
	164	Ula	3.4	15	50	
	164	Frn	2.2	15	68	
Populus-Corylus	136	Pob	3.1	23	26	Fraxinus-Mitella
	136	Pot	2.5	23	26	
	147	Ula	2.9	18	55	
Populus-Pteridium	140	Pog	2.2	18	27	Acer-Trientalis
	140	Pot	1.9	17	36	
	158	Pog	2.3	15	29	
	158	Pot	2.4	15	29	
	162	Pog	4.1	18	31	
	162	Pog	2.7	17	40	
Populus-Aster	152	Pog	1.8	20	33	Thuja-Maianthemum or Picea-Waldsteinia
	152	Pot	1.9	20	31	
Thuja-Dryopteris	154	Tho	3.2	20	97	wet..... Thuja-Dryopteris (stable) dry-mesic..... Thuja-Botrychium
	154	Frn	1.9	23	65	
Thuja-Maianthemum	160	Tho	2.7	12	77?	Thuja-Pteridium
	160	Tho	3.2	11	73?	
	161	Pig	2.3	15	33	
	161	Tho	1.8	11	34	
Thuja-Pteridium	137	Tho	4.1	17	61	Thuja-Pteridium (stable)
	137	Tho	2.6	15	62	
Thuja-Botrychium	(young or disturbed stands)					Acer-Parthenocissus
Pinus-Rhus	138	Pig	2.9	22	70	dry..... Pinus-Rhus (stable) mesic..... Picea-Waldsteinia
	138	Tho	2.7	14	73	
	138	Pis	3.6	20	70	

Table 24. continued

Present Forest Association[1]	Plot #	Species[2]	DBH (dm)[3]	Height (m)	Age (years)	Apparent Later Forest Association
Pinus-Maianthemum	93	Pis	5.5	30	95?	
	93	Pis	5.6	30	108	dry(fire)..... Pinus-Maianthemum (stable)
	145	Fag	3.0	24	58	
	145	Pis	5.2	27	110	mesic..... Tsuga-Gymnocarpium
	159	Acr	3.0	18	45	
	159	Pis	6.0	24	83	
	159	Tsc	2.1	15	35	
Pinus-Rhamnus	163	Pis	5.5	27	81	dry..... Pinus-Rhamnus (stable)
	163	Pig	2.9	24	73	dry-mesic..... Picea-Waldsteinia or Quercus-Maianthemum
Acer-Onoclea	149	Acsi	3.8	24	35	
	149	Acsi	2.5	23	30	
	153	Frn	4.5	21	55	Acer-Onoclea (stable)
	153	Acsi	4.2	21	58	
Quercus-Maianthemum	-	-	-	-	-	Acer-Parthenocissus
Picea-Waldsteinia	148	Pig	4.9	23	60	
	148	Pig	3.6	21	93	Picea-Waldsteinia (stable)
Pinus-Pteridium	-	-	-	-	-	dry(fire)..... Pinus-Pteridium (stable)
						dry-mesic..... Pinus-Rhus
Tsuga-Gymnocarpium	151	Tsc	2.3	21	65	
	151	Tsc	5.4	26	170	Tsuga-Gymnocarpium (stable)

during secondary succession are expectedly minimal. Table 25 displays the habitat data corresponding to the proposed association sequences. Drainage and soil characteristics are extremely variable and the problem of averaged parameters make strict progression sequences impossible. In terms of topographic position, the most advanced successional associations tend to occupy moderate (between upper slope and lower slope) positions or specialized habitats as opposed to earlier communities which exist on a wide range of sites including the harsher or more rigorous, exposed situations.

The range of basal areas for the described associations are provided in order to show the variability involved. The late seral communities usually have greater total basal areas than have earlier ones, although the strictness of the timing of invasion and change of one association to the other is a parameter difficult to quantify and predict on the basis of association averages alone.

Table 25. Moisture Class, Topographic Position, Soil and Basal Area Data By Forest Associations

Forest Association	Average Moisture Class	Common Topographic Position[1]	Soil Texture[2]	Soil pH	Average Total Basal Area (m^2/h)	Range of Basal Area (m^2/h)
Acer-Parthenocissus	3.7	US/LS	SL	5.5	45	11-125
Acer-Trillium	2.9	US/LS	SL	6.0	51	26-132
Acer-Galium:[3]	2.0	FB/LS	LS	5.8	51	35-67
Fraxinus-Matteuccia	1.6	FB	SL	5.9	34	24-47
or Fraxinus-Mitella	1.3	FB	L	7.0	42	33-57
or stable Acer rubrum[4]	(2.6)	(FB/LS)	(SL)	(5.0)	(52+)	-
Acer-Trientalis:	2.5	FB/LS	SL	4.7	46	25-71
stable Acer rubrum[4]	(2.6)	(FB/LS)	(SL)	(5.0)	(52+)	-
Fraxinus-Matteuccia:	1.6	FB	SL	5.9	34	24-47
Acer-Galium	2.0	FB/LS	LS	5.8	51	35-67
Fraxinus-Mitella:	1.3	FB	L	7.0	42	33-57
Thuja-Dryopteris	1.6	FB	O	6.5	56	46-77
Populus-Corylus:	2.0	LS/FB	L	7.0	46	25-72
Fraxinus-Mitella	1.3	FB	L	7.0	42	33-57
Populus-Pteridium:	3.0	US/LS	LS	4.9	38	18-67
Acer-Trientalis	2.5	FB/LS	SL	4.7	46	25-71
Populus-Aster:	3.7	US	LS	5.0	36	20-50
Thuja-Maianthemum	3.4	FB/FP	SL	7.2	48	23-66
or Picea-Waldsteinia	4.0	US/LS	SiL/O	5.7	42	30-53

1 (FB- flat bottomland, FP- floodplain, LS- lower slopes, US- upper slopes or ridges).

2 (L- loam, LS- loamy sand, O- organic, S- sand, SiL- silt loam, SL- sandy loam).

3 (Colon to be read as "appears to be seral to"; e.g., Acer-Galium appears to be seral to Fraxinus-Matteuccia; associations without colons appear to be stable).

4 (No stands recorded in the field; estimated values appear in the table).

Table 25. continued

Forest Association	Average Moisture Class	Common Topographic Position	Soil Texture	Soil pH	Average Total Basal Area (m^2/h)	Range of Basal Area (m^2/h)
Thuja-Dryopteris:	1.6	FB	O	6.5	56	46-77
Thuja-Botrychium	3.3	LS	SL/L	6.3	42	23-62
Thuja-Pteridium	3.5	US/FB	SiL/O	6.8	74	14-150
Thuja-Botrychium:	3.3	LS	SL/L	6.3	42	23-62
Acer-Parthenocissus	3.7	US/LS	SL	5.5	45	11-125
or Thuja-Pteridium	3.5	US/FB	SiL/O	6.8	74	14-150
Thuja-Maianthemum:	3.4	FB/FP	SL	7.2	48	23-66
Thuja-Pteridium	3.5	US/FB	SiL/O	6.8	74	14-150
Pinus-Rhus:	4.0	LS/US/FP	S	4.7	31	12-46
Pinus-Rhamnus	4.6	US/LS	SL	4.8	49	25-94
or Picea-Waldsteinia	4.0	US/LS	SiL/O	5.7	42	30-53
Pinus-Maianthemum:	3.6	LS/US/FP	LS	4.4	55	13-108
Tsuga-Gymnocarpium	3.0	LS/US	SL/L	5.5	43	33-61
Pinus-Rhamnus:	4.6	US/LS	SL	4.8	49	25-94
Picea-Waldsteinia	4.0	US/LS	SiL/O	5.7	42	30-53
or Quercus-Maianthemum	3.7	US	-	-		
Acer-Onoclea	1.5	FB	L	5.1	63	50-75
Quercus-Maianthemum:	3.7	US	-	-		
Acer-Parthenocissus	3.7	US/LS	SL	5.5	45	11-125
Picea-Waldsteinia	4.0	US/LS	SiL/O	5.7	42	30-53
Pinus-Pteridium:	4.5	US/LS	S	5.1	45	31-59
Pinus-Rhus	4.0	US/LS/FP	S	4.7	31	12-46
Tsuga-Gymnocarpium	3.0	US/LS	SL/L	5.5	43	33-61

C. Climax Forest Associations

The climax forest associations of the Ottawa area are those showing no evidence of further changes in species composition. Table 26 lists the 12 associations which meet this criterion. These stable climax associations occupy many different, often specialized habitats within the region and are usually maintained by some identifiable environmental factor.

The *Acer-Trillium* association is the well documented climatic climax forest of the Ottawa-St. Lawrence Lowlands and regularly occurs on deep-soiled, fertile, mid slope situations.

The three edaphic climax forest associations are maintained largely as a result of specific soil characteristics which tend to discourage competing species. The *Thuja-Pteridium* association is particularly well adapted to dry, basic soils and occurs as the stable community on much of the limestone plain southwest of Ottawa. The *Thuja-*

Table 26. Climax Forest Associations of the Ottawa Area

Forest Association	Climax Type	Major Maintenance Factor(s)
Acer saccharum-Trillium grandiflorum	Climatic climax (Great Lakes-St. Lawrence Lowlands)	-time, climate, topography, geology
Thuja occidentalis-Pteridium aquilinum	Edaphic climax	-depth to water table, soil pH
Thuja occidentalis-Dryopteris austriaca	Edaphic climax	-depth to water table, soil pH
Acer saccharinum-Onoclea sensibilis	Edaphic climax	-water table
Fraxinus nigra-Matteuccia Struthiopteris Acer rubrum	Edaphic climax complex	-fluctuating water table
Pinus strobus-Maianthemum canadense	Topo-edaphic climax	-topography, fire
Acer saccharum-Parthenocissus quinquefolia	Topo-edaphic climax	-topograhpy, soil depth
Tsuga canadensis-Gymnocarpium Dryopteris	Topo-edaphic climax	-topography, microclimate
Pinus strobus-Rhamnus Frangula	Disclimax	-fire suppression
Picea glauca-Waldsteinia fragarioides	Disclimax	-fire suppression
Pinus banksiana-Pteridium aquilinum	Serclimax (fire climax)	-repeated fires

Dryopteris and the *Acer-Onoclea* associations are adapted to very wet, organic soils where the high water table inhibits the establishment of competitors. An edaphic climax complex is also present involving the stable association *Fraxinus-Matteuccia* and a homogeneous *Acer rubrum* association. These communities occupy wet-mesic lowland sites, often having a fluctuating water table due to beavers, man or seasonal variation in precipitation and ground water. Fine-textured mineral soils and organic mucks are common. On the wet-mesic sites or with a prolonged lowering of the water table, *A. rubrum* exhibits greater numbers of seedlings/saplings and often is the dominant species in the stand although *Fraxinus nigra* is present. On wet sites or with a raised water table, *F. nigra* has a competitive advantage and often dominates the community although *Acer rubrum* is present.

Because of the vulnerability of such sites to a variety of water table variations, and because each association can exhibit stability under non-fluctuating habitat conditions, these deciduous wetland communities are best considered together as an edaphic climax complex.

Two disclimax associations, the Pinus-Rhamnus and Picea-Waldsteinia associations, are stable communities because of the intervention of man. Both of these disclimaxes are the result of the suppression of major forest fires in the Ottawa area. Man has thus allowed secondary succession to continue without the periodic rejuvenation of the ecosystem by fire.

Three topo-edaphic climax forest associations, Acer-Parthenocissus, Pinus-Maianthemum and Tsuga-Gymnocarpium stable as a result of the combined effects of specialized topography and soils. In the case of the Acer-Parthenocissus association, the principal maintenance factors seem to be the shallowness of the soil and the flat, rocky ridge top locations. The Pinus-Maianthemum association is a stable community on rocky ridge locations where soil development is extremely slow and surface organic matter accumulation is minimal. Fire may also be a factor in creating exposed mineral soil. The *Tsuga-Gymnocarpium* association is characteristic of the Northern Hardwoods Region and occurs in the Ottawa area on on steep, northwest facing slopes.

A serclimax or fire climax, the *Pinus banksiana-Pteridium aquilinum* association, is a stable community if recurring fires are allowed to take their course. With the increasing tendency of rapid fire suppression by man, this serclimax association is probably going to slowly change into a later seral association and thus, will be eliminated as a climax association of the area.

As a group, these 12 climax associations make up the most advanced, stable vegetation of the Ottawa Region.

CHAPTER 6. Association Descriptions and Other Workers

There is a certain amount of subjectivity in any forest sampling procedure. The 149 sampled stands are, for the most part, easily classifiable into distinct floristic associations. There is some variation within the described associations due primarily to the component stands representing different histories of disturbance and length of development time. The forests of the Ottawa area have been divided into six major recurring, and five locally distributed, forest alliances. Recognition of each alliance was based on detailed sample plots which were placed at different representative sites in order to characterize the alliance in a quantitative fashion. The data were then tabulated in such a way as to accentuate the similarities between member stands and thus lead to the recognition of associations (similar species groupings) within the alliance. As a basis for mapping, conveying information and understanding the forest cover of an area, this reduction of the natural complexity to comprehensible, typical pieces serves a useful purpose. This study is the first attempt to document, classify and integrate the forests of the Ottawa, Ontario area into an ecologically meaningful pattern.

Previous work on forest ecology in the Ottawa area has been on a general, regional descriptive level with little attempt at integrative, ecosystem based interpretation. Source and background material for the present study came from the earlier works of many authors. These fall into four groups:

1. Literature of national or international scope which deals with the study area only in the sense that it is included within the area covered by the regional description. This type of document include some important and comprehensive articles on wide ranging forest cover types with explanations and hypotheses concerning the distribution of large vegetative formations (Macoun, 1894; Nichols, 1935; Marie-Victorin, 1938; Braun, 1972; Rowe, 1972; Maycock and Curtis, 1960; Taylor and Ludwig, 1966), as well as various descriptive, regional, technical or popular floras or monographic works on species or species

groups which occur in the Ottawa study zone (Muenscher, 1944; Hitchcock, 1950; Fernald, 1950; Hultén, 1958; Preston, 1961; Hosie, 1961; Gleason and Cronquist, 1963; Marie-Victorin, 1964, Boivin, 1966; Gillett, 1968; Maini and Cayford, 1968; Dore, 1969; Savile, 1973; Bassett, 1973; and Argus, 1975, among others). Among these are some of the "classics" of eastern North American forest ecology which most researchers read and absorb as basic, "state-of-the-art" material early in their work, and constantly refer to for verification and explanation.

2. Information of a regional or provincial nature in which the forests of the study area are included and discussed, at least, in a cursory way. This group includes several extensive, internationally known works (Dansereau, 1944, 1959a, 1959b; Hills, 1960, 1961; Grandtner, 1966) which specifically attempt to develop acceptable, regional forest system classifications. In addition, works on specific stages of the successional process or specific successional species groups present within

the Ottawa area are included here (Dansereau, 1943; Lemieux, 1964; Daly, 1965; Davies, 1968; Warder, 1970; and Gagnon and Grandtner, 1973). Monographs, regional and provincial checklists and other field manuals to aid identification are available for species and assemblages occurring in the study area (Zavitz, 1959; Pringle, 1967, 1970; Montgomery and Switzer, 1967; Haavisto, 1974; Argus and White, 1975).

3. Articles concerning the forests and flora of areas bordering the Ottawa area, but not including it. These papers include some excellent examples of both classification and ordination approaches as applied to forest ecosystems (Maycock, 1956, 1963; Martin, 1959; MacHattie and McCormack, 1961; Beschel and Webber, 1962; Beschel, Webber and Tippett, 1962; Grandtner, 1966; Lafond and Ladouceur, 1968; Bouchard, 1970; McIntosh, 1972; Lopoukhine, 1974); some are devoted to the phytogeography and present distribution patterns of plant species which often extend into the Ottawa area (Moore, 1964; Rousseau, 1968, 1974;

Lafontaine and Brunton, 1972; Reznicek, 1972b; Woods, 1973; Lafontaine, 1973a; Brunton, 1973; St. Lawrence Islands National Park, 1974; Brunton and Lafontaine, 1974; and Cody, 1975), or are floras or checklists of plants occurring in selected areas surrounding the Ottawa district (Baldwin, 1958; Brayshaw, 1959; Moore, 1967; Pringle, 1969; Beschel, 1970; Moore, 1972; Reznicek, 1972a; Shchepanek, 1973; Brunton and Dickson, 1973; Brunton, 1974a; Dickson and Brunton, 1974; and Williams and Brunton, 1974).

4. Articles expressly concerned with the vegetation and resource base of the Ottawa area or parts of it. A great deal of this local material has appeared in the last 10 years thanks to a very active field-naturalists' club in Ottawa. Normally, one would expect the quantity of useful literature to decrease as attention is progressively focussed down to a particular region. In the Ottawa area, the opposite seems true; there is a large amount of material written on the flora of the Ottawa district. I have here chosen only the

most inclusive papers to report. Many articles deal with the distribution and description of specific plant taxa or groups (Cody, 1956, 1967; Gillett, 1958, 1973; Brodo, 1967; Greenwood, 1967; Dugal, 1971; Hanes, 1971; Hegmann, 1972; Lafontaine, 1973b; Muhle, 1973; Brunton, 1974b; Lafontaine and White, 1974; White, 1975a, 1975b), while others report additions to the flora and range extensions within the area (Calder, 1948; Dore, 1954; 1962a, 1962b, 1968; Frankton, 1954; Erskine, 1955). Some investigators took a different tack in that they describe and emphasize the entirety of the vegetation of a restricted locality within the study zone (Groh, 1955; Breitung, 1957; Gillett, 1967; Joyal, 1969, 1970, 1972; Cameron and Lambert, 1973; Frankton, 1973; Ottawa Field Naturalists' Club, 1973; National Capital Commission, 1974; Reed, 1974) while in other reports, information on vegetation and forests is only incidentally or inferentially obtained, the author's primary purpose being to communicate something unrelated or at least not specifically related to forest ecology (Savile, 1951; Munro, 1967;

Hoffman, 1971; Harrington, 1971; Watson, 1972; Dadswell, 1974; Getz, 1974; Stephenson, 1974; Ouellet, 1975; Romanelli, 1975; Geo-analysis, 1976; Black and Stewart, 1976).

Very little has been written concerning forest ecology and the forest associations of the region and what has been written applies only to small, specific habitats (Jeglum, Bik and Salm, 1974; Reed, 1974). The only integrative attempts to synthesize all of the well-documented floristic data into a forest association scheme was started by Dr. Robert Reed and his students at the University of Ottawa (Reed, 1974, 1975a, 1975b, 1976; Reed, Billington and Johannsen, 1976; Billington, 1976) culminating in the present study. As Dr. Small (in the National Capital Commission, 1974) says, the Ottawa region (he speaks of the Mer Bleue in particular) has received a great deal of attention over the last century because of the concentration of botanists in Ottawa. For this reason, and because of the active Field-Naturalists' Club, the study zone has been very well botanized in terms of floristics (much more than most other areas of comparable size in Canada). One perennial problem with such an arrangement is that botanists tend to have "specialities", and so we know the distribution, life history and ecology of the ferns or the orchids or the rare plants from among the more than 1500 individual vascular plant species, with no common threads, no conceptual or actual patterns of overall vegetation into which these species fit. This is one of the major objectives of the present study; to provide an integrative framework of forest associations (i.e., a puzzle of 21 pieces instead of 1500) on which to hang our autecological knowledge of species distributions, tolerances and successional status.

Another useful sort of material which often adds supportive evidence to the time continuum of forest development is an impression of what the forests of the area were like in the past. Knowing the present situation and predicting the future is much safer if the past seems also to have lead smoothly and explicably to the present. There are four sources of information on the past forest composition of the Ottawa area. General textbooks and specific monographs on the soils or physiography of the region often give general, qualitative indications of what the vegetation looked like before intensive clearing (Hills, Richards and Morwick, 1944; Wicklund and Richards, 1962; Chapman and Putnam, 1966); early land records were often made with the aid of vegetational markers (large, living trees) and early surveyors often gave adequate forest descriptions to help locate themselves (these sources have not been searched during the present study); regional historical texts or atlases, and old newspapers often contain much information on previous forest conditions and previous forest disturbances (although the quality and verity of these reports tends to vary with the reporter and his memory rather than with the situation reported) (Belden, 1879; Guillet, 1947; Ottawa Citizen, 1955; Greening, 1961; McGiffin, 1963; Burns _et al_., 1972 Langdon, 1972); the last source of information on past forest conditions comes from the study of plant pollen preserved in the mud of lake and bog sediments as revealed through core sampling (Potzger, 1953; Wright, 1964; Terasmae and Mott, 1964; Camfield, 1969; Webb, 1973). This of course gives a much longer hindsight view of forests and is very useful in developing post-glacial forest histories, although the techniques are fraught with uncertainties if applied too strictly in time or space.

My intent in the remainder of this section is to compare the forest associations described in this study with those of the major previous regional investigators. Both Braun (1950) and Rowe (1959, 1972) classify the vegetation of the study area in much the same way, since both are largely based on the original treatment by Halliday (1937). The study area lies in Rowe's L.2 Upper St. Lawrence Section of the Great Lakes-St. Lawrence Forest Region and in Braun's Laurentian Upland Section of the Great Lakes-St. Lawrence Division of her Hemlock-White Pine-Northern Hardwoods Region. Both workers emphasize the transitional nature of the forests with dominantly broadleaved associations of <u>Acer saccharum</u>, <u>Fagus grandifolia</u>, <u>Tilia americana</u> and various mixtures of associated species such as *Betula alleghaniensis*, *Ulmus americana* and *Acer rubrum*. An abundance of secondary successional species such as *Populus tremuloides*, *P. balsamifera*, *Betula papyrifera* and *B. populifolia* are also mentioned. In addition, both Braun and Rowe recognize the abundance of coniferous communities composed of *Pinus strobus*, *P. resinosa*, *P. banksiana*, *Thuja occidentalis*, *Picea glauca* and *Abies balsamea*, and the occurence of stable, mixed communities of *Tsuga canadensis* and the northern hardwoods. Table 27, showing the composition and drainage classes of the eight deciduous, six coniferous and seven mixed coniferous-deciduous forest associations revealed by the present study, substantiates the mixed and variable character of the forest cover. Table 28 lists the 21 forest associations described in the present study with the comparable associations as described by eight previous workers in regions around or including the Ottawa area.

Dansereau (1959) has produced an extensive, preliminary description of the 171 principal plant

Table 27. General Character and Average Moisture Class of the Forest Associations of the Ottawa Area

Moisture Classes	Forest Association	Average Moisture Class	General Character of the Association[1]	
Wet (1-1.5)	Fraxinus-Mitella	1.3	M	
	Acer-Onoclea	1.5	D	
Wet-Mesic (1.6-2.5)	Fraxinus-Matteuccia	1.6	D	
	Thuja-Dryopteris	1.6	M	
	Populus-Corylus	2.0	D	
	Acer-Galium	2.0	D	
	Acer-Trientalis	2.5	D	Deciduous and Mixed deciduous-coniferous
Mesic (2.6-3.5)	Acer-Trillium	2.9	D	
	Populus-Pteridium	3.0	D	
	Tsuga-Gymnocarpium	3.0	M	
	Thuja-Botrychium	3.3	M	
	Thuja-Maianthemum	3.4	C	
	Thuja-Pteridium	3.5	C	
Dry-Mesic (3.6-4.5)	Pinus-Maianthemum	3.6	C	
	Populus-Aster	3.7	M	
	Quercus-Maianthemum	3.7	M	
	Acer-Parthenocissus	3.7	D	Coniferous and Mixed deciduous-coniferous
	Pinus-Rhus	4.0	C	
	Picea-Waldsteinia	4.0	C	
	Pinus-Pteridium	4.5	C	
Dry (4.6+)	Pinus-Rhamnus	4.6	M	

1 (C- coniferous, D- deciduous, M- mixed coniferous and deciduous).

Table 28. Comparative Forest Associations (Present Study and Previous Authors)

Present Study	Dansereau (1959)	Lafond and Ladouceur (1968)	Loupoukhine (1974)	Hills (1960)	Jeglum, Bik and Salm (1974)	Lemieux (1964)	Grandtner (1966)	Gagnon and Grandtner (1973)
Acer-Parthenocissus	Aceretum saccharophori ulmosum	1.5 1.8	MBA-X	x		1c Osv-Acs? 1d Tia-Acs?	Erablière a orme	
Acer-Trillium	Aceretum saccharophori laurentianum	1.4 1.5	MBB-MBB	x	Fagr-Acsa	1b Fag-Acs	Erablière laurentienne	
Acer-Galium	Acereto-ulmetum laurentianum	1.8	EA-EA		Acru-Ulam			
Acer-Trientalis	Aceretum rubri?* Betuletum papyriferae?	1.9.4 5.4?	EA-EA MAB-others	x	Acru Acru-Pot			4.31
Fraxinus-Matteuccia	Fraxinetum riparium	2.2	EA-EA	x		3b Ula-Frn		
Fraxinus-Mitella	Acereto-ulmetum laurentianum	2.1?	SC-EA			3a Bel-Frn		
Populus-Corylus	Populetum boreale?*	6.1	AB-others		Acru-Potr			4.333?

? (indicates differences in composition of reported association as compared to that of present study).

* (indicates difference in successional status compared to that reported in the present study).

Table 28. continued

Present Study	Dansereau (1959)	Lafond and Ladouceur (1968)	Loupoukhine (1974)	Hills (1960)	Jeglum, Bik and Salm (1974)	Lemieux (1964)	Grandtner (1966)	Gagnon and Grandtner (1973)
<u>Populus-Pteridium</u>	Populetum tremuloidis	5.4	MAB-MAB		Potr-Acru Pogr-Acru			4.331?
<u>Populus-Aster</u>	Betuletum papyriferae	4.5? 9.2.2 10.1	AB-SHP		Abb-Acru			4.333?
<u>Thuja-Dryopteris</u>	Acereto-ulmetum laurentianum	14.1?	SCL-EA	x				
<u>Thuja-Maianthemum</u>	Thujetum occidentalis	9.2.2? 14.3 13.4	SC-X	x				
<u>Thuja-Pteridium</u>	Thujetum occidentalis?*	14.1	SC-SC	x	Thoc			
<u>Thuja-Botrychium</u>	Thujetum occidentalis	14.2	MAB-Z	x				
<u>Pinus-Rhus</u>	Pinetum strobi	11.2 11.2.1	WP-SF	x				
<u>Pinus-Maianthemum</u>	Pinetum strobi?*	11.1 11.4	P-P	x	Pist			

Table 28. continued

Present Study	Dansereau (1959)	Lafond and Ladouceur (1968)	Loupoukhine (1974)	Hills (1960)	Jeglum, Bik and Salm (1974)	Lemieux (1964)	Grandtner (1966)	Gagnon and Grandtner (1973)
Pinus-Rhamnus	Pinetum strobi?*	10.3 11.6.1?	WP-others	x				
Acer-Onoclea	Acereto-ulmetum laurentianum ?*	1.6	misc. hdwd.					
Quercus-Maianthemum	Quercetum boreale Aceretum saccharophori quercosum	1.9.1	MAB-IO	x			Chênaie boréale Erablière a chêne boréale	
Picea-Waldsteinia	Piceetum glaucae?*	9.2.3?	SF-SF	x				
Pinus-Pteridium	Pinetum banksianae?*	11.8	misc. stwd.					
Tsuga-Gymnocarpium	Aceretum saccharophori tsugosum	1.3 1.9 15.1	MBB-eH	x	Tsca	1a Bel-Acs? 2a Abb-Bel?	Erablière laurentienne?*	

associations of the St. Lawrence Valley, based on their dominants, physiognomy and ecological (successional) position. Dansereau's plant association descriptions are not confined to forests, and include grasslands, meadows, degraded forests, bogs, railway right-of-ways and riparian thickets. Differences in species composition and order of abundance between Dansereau's associations and those of the present study are relatively minor, with sometimes one having more or finer subdivisions than the other where sufficient stand variation seemed to merit it. The major cause of disagreement is on the basis of the successional status of the common associations. Dansereau gives subclimax status (indicating further compositional changes) to six associations which were found in the present study to show either clear evidence of long-term stability or at least, minimal or unclear evidence of future vegetation change. The difficulty here is a question of generalization. Dansereau's PINETUM STROBI and THUJETUM OCCIDENTALIS associations, for example, are each the most comparable in terms of species composition to three separate associations as described in the present study. Thus, PINETUM STROBI is comparable to the present *Pinus strobus-Maianthemum canadense* in composition but on dry sites in the Ottawa area, this association will persist for long periods without further compositional change and is not a subclimax community but rather it is a serclimax in the terminology of Dansereau (1959) (Table 28). Similar difficulties of generalization and terminology are seen in Table 28. Sometimes, more than one of Dansereau's specific associations are listed as being comparable to one of the Ottawa area associations, or one of Dansereau's associations may be the most comparable to two or three of the present associations. Generally, Dansereau has described the forest alliances of the Ottawa area, although local variations in species groups and orders of species abundance in some associations have been sacrificed in order to provide an overview of the entire St. Lawrence Valley vegetation.

Grandtner (1966) provided a classification of forest associations limited to the upland deciduous forest communities of southern Quebec using Braun-Blanquet terminology and methods. Once again, the question of differential lumping and splitting makes some of the comparable associations look forced together but essentially, comparable species groups are clearly present exhibiting a common dynamic trend.

Lafond and Ladouceur (1968) studied the forests of the Quebec side of the Ottawa River basin. Their biogeographic region VIII (the Ottawa, Gatineau and the Lièvre Valleys region) is the same structural region (geology, geomorphology, physiography) as that of the study zone. Lafond and Ladouceur extend Dansereau's Laurentian sugar maple climax area up into the Gatineau Valley and up the Ottawa River to Allumette Island (where consistent precambrian outcrop starts). Using largely qualitative, descriptive methods, they identified numerous forest associations of deciduous, coniferous and mixed deciduous-coniferous nature which appear very similar to many of the associations identified in the present project (although those of Lafond and Ladouceur are not described in detail). In general, they split species assemblages more than in the present study resulting in many of their associations being represented as subassociations in the present classification. They have included all of the major associations described in the present study, with minor differences in species composition as noted in Table 28.

Gagnon and Grandtner (1973), in a very thorough study of the Populus tremuloides associations of Rowe's (1959) L.4a Laurentian Section of the Great Lakes-St. Lawrence Forest Region (in Quebec, north of the St. Lawrence River on the Canadian Shield, approximately from Ste. Agathe to Quebec City), split assemblages more than in the present study, resulting in comparable groups that differ mainly in the relative composition and order of abundance of member species. The dynamics, habitat features and successional trends of these pioneer communities are in accord in both studies. Gagnon and Grandtner list, in addition, several mixed associations, particularly various assemblages of Populus tremuloides with Abies balsamea, Pinus strobus, Picea glauca and Thuja occidentalis, which are rare in the Ottawa area but which are apparently more common as one approaches the boreal forest.

Lemieux (1964), working in the Quebec northern hardwoods, described eight stable forest associations. Many of these are related most closely to subassociations within the present study. Part of the disparity here is due to the degree of variability allowed in classification and some reflects the changing nature of the forest cover to the north and east. Five of Lemieux' associations correspond well to the various described associations and subassociations in the Ottawa area. Two others, the *Betula lutea-Fraxinus nigra* and *Abies balsamea-Betula lutea* associations appear to be northern variations of the present *Fraxinus nigra* and *Tsuga canadensis* alliances respectively. The eighth, his *Ulmus americana-Acer saccharum* association, is a wet, lowland community dominated by *Acer saccharum* with no extensively recurring counterpart in the present study area.

Hills (1960, 1961) devised a classification of Ontario forests based on the site regions (under the influence of regional landform and macroclimatic factors) and physiographic site classes (under the influence of more local or microclimatic factors such as drainage and local temperature regimes). By subdividing Ontario into 13 site regions, he has produced a table listing the commonly occurring forest species associations for each of the nine physiographic site classes within each site region. The present study zone lies in Hills (1961) 6E Lakes Simcoe-Rideau Site Region with his reported forest groups simply checked off in Table 28 if they appear to match those of the present study. Without specific information on his associations (which was not Hills' intention), it seems that the majority of Ottawa area associations can be envisioned within his general scheme. Hills leaves out some of the transitional associations (notably of the present Populus alliance) as well as two of the minor alliances, Pinus banksiana and Acer saccharinum, but in general, provides an adequate overview of the general forest cover.

Lopoukhine (1974) produced a classification of forest types in Gatineau Park (immediately north of the study zone on the Canadian Shield), the majority of which lies in Rowe's L.4c Middle Ottawa Section although the most southerly portion lies within the L.2 Upper St. Lawrence Section as does the study area. Lopoukhine's classification is based on general species composition (hardwood, softwood or mixed wood) and on site moisture conditions (dry, moist or wet). Starting from these nine broad forest types, he proceeded to differentiate 132 forest subtypes by recognizing particular combinations of named species or species groups. Thus, it can be assumed that Lopoukhine is a classificatory splitter who allows little variability among stands before creating a new subtype to handle it. The subtypes most closely comparable to those presently-described for the Ottawa area are listed in Table 28.

The only specific forest ecology and classification project previously done within the study zone is that of Jeglum, Bik and Salm (1974) in the small Central Research Forest bordering the Mer Bleue Bog east of Ottawa. The most comparable of their "cover type" units to the present associations are listed in Table 28. Because of the restricted size of their forest study area and because of the heavy, past disturbance to those forests, many of the associations which are found in the Ottawa area as a whole, are not found in the Central Research Forest. In addition, their cover types are based on decreasing order of dominance and they describe numerous species combinations which would be considered members of the same association in the present study. They recognize and map, for example, 24 combinations of _Acer rubrum_, _Populus tremuloides_, _P. grandidentata_, _Betula papyrifera_, _B. populifolia_, _B. alleghaniensis_, _Ulmus americana_, _Thuja occidentalis_, _Pinus strobus_ and _Tsuga canadensis_ which fall, in the present classification, into four associations.

One major conclusion from this section is an appreciation of the variety of approaches one can use to classify the forest communities according to your objectives. Some workers are splitters (Lafond and Ladouceur, 1968; Lopoukhine, 1974; Jeglum, Bik and Salm, 1974) who try to describe as much of the variation as accurately as possible by erecting new classification units, and in so doing, create an accurate but complex model of the forest. The ultimate result of splitting is to name each stand as a separate vegetation type or unit and proceed by ordination techniques to evaluate the forest composition. Lumpers (Hills, 1961; Lemieux, 1964; Gagnon and Grandtner, 1973; Grandtner, 1966; Dansereau, 1959 and the present study) tend to define larger units of typical forest vegetation and describe in words or show in tables some of the variations to be expected. This approach seems more useful in understanding, at least preliminarily, the composition and successional trends of forest communities.

CHAPTER 7. Forest Ecology Theory and Terminology

As many previous workers have pointed out (Cottam and Curtis, 1956; Daubenmire, 1966; McIntosh, 1967; Moore et al, 1970; and Mueller-Dombois and Ellenberg, 1974; among others), there are two, essentially antithetical conceptual approaches presently used as a framework model in forest ecology work. These two schools of thought, in the simplest terms called "the classification school" and "the individualistic (or continuum) school", have each attracted a significant following. Most students of both schools would agree that vegetation is a continuously changing and intergrading mixture of species which respond as individuals to changes or gradients in habitat paremeters (i.e., light, moisture, nutrients). There is considerable agreement on processes of forest development; most workers in both schools believe that vegetation change and continuous, directional, terrestrial succession is a common, underlying principle. The crux of the division of thought lies not in the fundamental, natural forest processes, but in the degree of acceptable variability of species and species quantities in different abstract communities. Classification supporters maintain that, despite the individual species variance according to its tolerance of environmental gradients, certain species, because of mutual microenvironmental requirements and processes, often grow together and sufficiently modify the environment to form a repetitive, recognizable vegetational community (Anderson, 1965; Daubenmire, 1966).

Conversely, individualistic supporters argue that no two vegetational communities are strictly identical but that communities show continuous variation in their detailed species composition and can only be artificially and arbitrarily delimited as clear-cut, repeatable units (Vogl, 1966; Cottam and McIntosh, 1966; McIntosh, 1967).

This difference in basic theoretical format has lead to different methodologies for both collecting data in the field and subsequent processing/analyzing it in the lab (Cottam and Curtis, 1956; Whittaker, 1962, 1967; Yarranton, 1966; McIntosh, 1967; Moore et al., 1970; and Grigal and Ohmann, 1975). Vegetational classification involves the arrangement of communities (or more precisely, abstractions from stand data) into classes with the members of any class having common attributes which distinguish them from members of any other class (Anderson, 1965). This suggests that there are discontinuities in species composition or abundance between actual field samples of vegetation as well as the conceptual units abstracted from the field data. The field methods normally involve the placing of some type of relevé or plot on the ground in which an intensive sample is taken from a representative segment of the community and then used with other samples in building a picture of the typical composition of that association.

Supporters of the individualistic concept would not recognize such discontinuities of species composition or abundance in natural vegetation "... except where there may be discontinuities in the physical environment..." (Anderson, p. 552, 1965). The field methods of the continuum supporters usually involve plotless samples, or some variation of rapidly acquired, distance measurements (Cottam and Curtis, 1956) in lieu of plot samples. In the lab, the data is subjected to ordination, a process attempting to separate or portray the individuality of each sampled stand by demonstrating the similarity or dissimilarity of all stands to one another in the form of geometric models (Anderson, 1965).

Recently, there has been several progressive articles (Mueller-Dombois and Ellenberg, 1974; Anderson, 1965; Rowe, 1960; McIntosh, 1967; Moore et al., 1970; Ivmey-Cook and Proctor, 1966; among others) which, instead of holding one or the other concepts up as the definitive approach, attempt to seek the common ground, the favourable features of each theory and blend them or utilize only the bits and pieces of either or none which seem best suited to particular forest situations and practical purposes. Anderson (1965) argues that "... there is no a priori reason why vegetation structure should be such that either classification or ordination can be accepted as an inherently correct technique for the reduction of natural complexity to comprehensible order." Daubenmire (1966) showed that the same data can be treated in different analytical ways to arrive at evidence supportive of either point of view. Further, some authors indicate that the concepts are not mutually exclusive but are in fact complementary. Strict classification is valid if used as a convenient vehicle for mapping and information storage for practical ends or specific purposes (McIntosh, 1967). The description and classification of forest communities supplies the first order of information (Mueller-Dombois and Ellenberg, 1974) by displaying the compositional differences between abstracted, recurring community patterns. These can be envisioned as convenient, yet real repetitive stations along an environmental gradient or floristic continuum. The continuum approach supplies the second order of information by displaying the fine structure and variation within and between vegetation samples. Some authors further note that communities sampled for the purpose of classification can be subjected to ordination, while initial ordination can indicate the possibility of classification (provided that the samples are floristically complete).

It is obvious, and acknowledged by everyone that no two communities are exactly alike. It is also obvious, from a search of ecological literature, that there exist regular, recurring, community types over broad parts of the earth's surface. It is obvious too, that species compositions grade in all directions in response to Anderson's (1965) "... multifarious selective mechanisms..." (moisture gradients, competitive stress, light regimes, temperature regimes, length of the growing season, ad infinitum).

Both the classification and ordination approaches to forest ecology are directed toward obtaining a thorough description of existing vegetation cover and each can be effectively utilized according to the purpose at hand. Mueller-Dombois and Ellenberg (1974) see the basic difference in approach related to "... the degree of entitation and the sample distribution." The continuum approach maintains a broader degree of entitation. The distribution of samples traverses a broad vegetation entity without regard for pre-determined classification types (e.g., the Northern Hardwood Forest, the Boreal Conifer-Hardwood Forest, the

Deciduous Forest). This results in member stands which expectedly differ by more or less continuous increments of similarity. The classification (relevé or plot) approach requires a finer degree of entitation and samples distributed in smaller, normally pre-determined vegetation entities. This approach expectedly results in member stands showing a high degree of similarity more clearly clustered into recurring noda or community types.

The classification approach was used in this study for two major reasons:

1. the field work was supported by the Regional Municipality of Ottawa-Carleton which required an inventory of the existing and potential forest vegetation resources of the area. Thus, for mapping and information storage, classification based on recurring associations with descriptions of the typical species composition, habitat features and any unique or sensitive elements (rare plants, animal abundance or geological/geographical phenomena) was considered the most suitable method. The continuum approach and related sampling techniques does not ordinarily provide the detail required for such an assignment;

2. my purpose was to predict the potential forest vegetation which could be expected from the variety of young, transitional communities making up the present forest cover. I therefore required the detailed population structures of the forest communities and the most efficient way to obtain them, in fact,

> fulfill both purposes at the same time, was to make plot studies as described by Daubenmire (1968).

One other hindrance to effective progressive communication (beside insulation within one's own conceptual school) is the inflated and growing list of forest ecological terms and specific vocabulary. Many workers devised their own systems of terminology as they progressed (Clements, 1916; Du Rietz, 1921; Braun-Blanquet, 1965) and many used the same or similar terms to mean different things. In this study, I have attempted to consistently use the Braun-Blanquet (1965) nomenclature in order to alleviate the difficulty of multiple interpretations. With minor variations as noted below, the description of the present and potential forest vegetation of the Ottawa area is presented in terms of broad alliances (Table 6). Each alliance describes a basic division of the forest based on the dominance of usually one tree species. The alliance may be subdivided into more specific associations which maintain the dominance characteristics of the alliance but have overstory and understory species and habitat characteristics which distinguish them to a finer degree. The associations are subordinate to and are included within the larger alliance unit in a hierarchical sense and are comparable to the species category in taxonomy. In the third hierarchical category, the subassociation, I am forced to divert from Braun-Blanquet's floristic association system and define this unit in terms of habitat, in particular, drainage class. If pressed to give a name to the moisture segments within the described associations, they would be called subassociations.

CHAPTER 8. Succession and Climax Theory

Any type of forest ecosystem analysis must include a discussion of the obvious and potential changes which are occurring in forest composition. No forest vegetation is absolutely permanent and therefore, "... the mere determination of what is present in the forest does not result in a knowledge of the forest. To know the forest, we must recognize and understand significant vegetational features, the evidence of stability or of change, of forest development, the re-actions of vegetation and their effects on forest environments and community continuance, the forest environment itself, and finally, the factors determining and limiting forest regions." (Braun, 1950, p. 10). This leads to a consideration of the concept of forest development or terrestrial succession. Ecological succession is one of the major underlying principles of modern ecology. Within the reference frame of the present study, it is defined as the gradual replacement of species and groups of species on a particular site through the cumulative or individual effects of <u>both</u> autogenic and allogenic factors.

Contemporary successional theory is based on a complex, rapidly enlarging and sometimes contradictory body of empirical knowledge (Drury and Nisbet, 1973; Vitousek and Reiners, 1975). A basic division is often made between community controlled, undisturbed successions (called autogenic succession) and geochemical, unpredictable successions influenced by factors outside of the community (called allogenic succession). Autogenic succession (which often loosely passes for contemporary successional theory) may be summarized as a reasonably directional, predictable, orderly process of community development involving changes in species structure and community processes through community controlled modification of the physical environment culminating in a stablized ecosystem of maximum biomass and species interdependance per unit of available energy flow (Odum, 1971, p. 251). Such a statement is too restrictive as a generally acceptable word model of succession in modern forests, for two reasons. Firstly, after working intensively with Ottawa area forests, it seems that allogenic factors are as important, and, in the future, will be increasingly more important as community-controlled, autogenic factors in determining the successional trends and the stability of all terrestrial communities. After reviewing much of the successional literature, it appears that undisturbed, pristine vegetation anywhere in North America is presently so rare that a general succession theory is obliged to include external disturbance as an integral and important impetus to forest change. Indeed, there is considerable evidence that repeated, external disturbance (in the form of wind storms, climatic change, disease and particularly fire) has been the rule rather than the exception in many terrestrial successions even before the arrival of European settlers in North America (Woods, 1953; Flaccus, 1959; Raup, 1964; Kayll, 1968; Loucks, 1970; Mutch, 1970; Methven, 1973; Taylor, 1973; Wright, 1974; Henry and Swan, 1974; Sprugel, 1976). Secondly, although succession is directional, it is not necessarily unidirectional. The same forest association (e.g., the *Populus tremuloides-Aster macrophyllus* association in the Ottawa area) may evolve into two or more different, subsequent communities depending on the duration, frequency, kind and intensity of autogenic or allogenic forces working in a particular habitat. Here lies the crux of the matter. Any successional theory must be general enough to cover the range of observed variation, but in so doing, it loses a part of its specific applicability to any particular successional sequence. Contemporary successional theory (Odum, 1971) is a broad-based generalization which does account for most observed autogenic vegetation sequences in a general way, although many apparent exceptions are known (Drury and Nisbet, 1973). Succession as defined in the present study and Figure 40 are broad-based generalizations which account for the majority of forest sequences seen or proposed for the Ottawa area, although closer examination of population structure tables, tree age correlations and habitat data of particular member stands may reveal some variation from these trends. For this reason, forest succession must be viewed as a very flexible process controlled largely by the autecology of the species, species competitive interactions (autogenic) and various external disturbances (allogenic). It is not a strict, methodical species by species (and, by extension, community by community) replacement with sharp temporal or spatial boundaries. Each species individually, and each member of each species, reacts within the framework of its genetic capabilities to the existing environment, and if stresses from whatever sources become too great, the individual plants respond by thriving, just surviving or dying. The disappearance of individuals of differential adaptive capability eventually (if the stress is long and intense enough) leads to the disappearance of species and thus, to changes in community composition. It is the overlapping of species tolerances to environmental factors that provides the concentrations of species in recurring groups and allow forest community classifications to be made.

The autecological, autogenic and allogenic factors which cause successional changes are very different in themselves but they all have one effect in common - each improves or interferes with the ability of particular plant species to survive and reproduce efficiently. Different species (and different members of the same species) have different acceptable ranges of requirements in terms of nutrition, light, water and other environmentally-provided life support parameters. The autecological capacity of a species to endure in a given habitat will depend on the constellation of environmental factors and factor interactions either falling inside or outside the tolerance range of the individual. Of course, many plants do not have such exacting requirements that they die in marginally suitable habitats but they can persist as occasional or vegetatively-propogating members of the community if opportunity to establish themselves and low competitive pressure allow them to remain (Poore, 1964).

Some of the most basic and critical factors involved are species tolerance to shade, to habitat heterogeneity (topography, moisture, soil nutrients) and to competition for growing space as exhibited by autecological characteristics such as differing phenological behaviours, longevities, ecological amplitudes, seed dispersal, storage and germination techniques, vegetative propogative abilities (Baker, 1949; Billings, 1952; Kozlowski, 1955, 1958; Ahlgren, 1957; Whittaker, 1965; Townsend and Roberts, 1973;

Marquis, 1975; Schier and Campbell, 1976), and more recently investigated autecological properties involving chemical exudates and leaf geometry patterns (Blum and Rice, 1969; Whittaker in Sondheimer and Simeoen, 1970; Rice and Pancholy, 1972; Horn, 1975).

The genetic-based tolerance ranges of the species often gives rise to ecotypes which have been defined as members of the same taxonomic species which exhibit distinct behavioural, physiological and even morphological variations in different habitats (McMillan, 1960, 1969). Ecotypic differentiation (the process of ecotype development) has been documented for a number of genera of both trees and forbs known to occur in the Ottawa area including *Pinus*, *Acer*, *Thuja*, *Tsuga*, *Fraxinus*, *Picea*, *Betula*, *Ulmus*, *Populus*, *Achillea*, *Potentilla*, *Viola*, *Geranium*, *Plantago*, *Solidago*, *Helianthus* and *Eupatorium* (McMillan, 1960), and is considered to be an evolutionary mechanism which allows vegetation to adjust to its habitat. Within the study zone, it is apparent that some species (e.g., *Ulmus americana*, *Acer rubrum* and *Thuja occidentalis*) are able to dominate equally well at opposite ends of the moisture gradient (Table 9). Such flexibility in moisture tolerance as exhibited by the previous species and others, allows these species to survive under varying conditions at the expense of less adaptable neighbouring species.

Autogenic succession proceeds according to interacting trends as outlined by Odum (1971, p. 252). Gross production tends to equal community respiration (i.e., low net increase in biomass) in late successional communities; total biomass (roughly equivalent or at least proportional to the total stand basal area figures) increases from pioneer to later seral communities; stratification of the community becomes increasingly better-organized in later stages; species diversity (number of species) initially increases and then levels off during mid to late seral stages; nutrient cycles become more closed and conservative from early pioneer communities to mid successional stages after which nutrient retention is no greater than in pioneer stands (Vitousek and Reiners, 1975); and communities increasingly stabilize (in terms of rapid, further allogenic succession). With these progressions, species becomes increasingly intimate, and interactions with neighbours (and intensive competition for environmental resources) become more important in determining species survival than strict autecological, individual responses.

Various allogenic factors often intervene to further complicate forest development. In particular, grazing by domestic animals (Steinbrenner, 1951; Schuster, 1964; Adams, 1975), water table disruptions by either natural or man-induced causes (Green, 1947; McDermott, 1954; Hosner, 1958; McNeel, 1964; Vogl, 1969), unpredictable, widespread devastations such as disease and particularly fire (Ahlgren and Ahlgren, 1960; Cayford, 1963; Kayll, 1968; Mutch, 1970; Van Wagner, 1970, 1971; Methven, 1973; Taylor, 1973; Leak, 1974; Wright, 1974; Methven et al, 1975; Simard, 1975; Sprugel, 1976), and various, direct and indirect actions of man such as logging, clearing for agriculture, thinning and other woodlot management techniques, snowmobiling and air pollution (Sauer and Struik, 1964; Maini and Horton, 1966; Behrand and Patric, 1969; Siccama, 1971; Neumann and Merriam, 1972; Sidhu, 1973a, 1973b, 1974; Roberge, 1975; Carpenter, 1976), can and have influenced the present and potential forest succession within the Ottawa area. Particular examples may be cited for the Ottawa forests. Fluctuations in water table level is a major factor regulating the successional trends in the deciduous lowland communities (Figure 40). In presently wet situations (often on floodplain or margins of beaver ponds) the Fraxinus nigra-Matteuccia Struthiopteris association is often present. If the water table lowers and sites dry somewhat to perhaps a wet-mesic condition, the Acer rubrum-Galium triflorum association tends to appear, presumably because Acer rubrum can better survive and reproduce on slightly more mesic sites. The Fraxinus nigra and Ulmus americana still exist as co-dominant members but such sites are not their optimal habitat. With continued lowering of the water table (or raising of the land surface through organic matter accumulation), the community tends to develop towards a pure Acer rubrum forest with the consequential loss of Fraxinus nigra and Ulmus americana as important community members. If, on the other hand, the water table remains stable or reverts back to wetter conditions through continued allogenic processes, the Acer rubrum tends to disappear and the

Fraxinus-Matteuccia association persists. Severe or prolonged inundation may result in the destruction of the present forest cover and a sort of reverse succession takes place in which the previous forest is reduced to a stumped marsh of willow/alder vegetation or open water. Such situations exist in many areas of the regional forests where beavers or road construction have impounded water and restricted natural drainage causing the devastation of previous forest communities (e.g., *Thuja-Dryopteris* associations in the Waterfowl Area, Manion Corners Marsh and the Regional Forest, and *Fraxinus-Matteuccia* associations in the Carp Hills, the Osgoode Bog and Corkery Swamp). Examples are also found in the literature of retrogressive or diverted succession caused by obstructions of natural drainage (Green, 1947; Savile, 1951; Knudsen, 1962; Vogl, 1969). In addition, factor interaction also plays a role in determining the survival of species under stress by flooding. Mortality rates were found to be much higher in suppressed, sub-canopy trees than in larger trees (Johnson and Bell, 1976) indicating that occasional floods tend to eliminate the early starters of later successional stages (normally the seedlings/saplings and immature trees) and thereby preserve the presently dominant species in a stable (regularly disturbed) community. This situation is called a serclimax by Dansèreau (1959).

Logging for lumber and poles is a form of "artificial" selection, in that particular species (notably Pinus strobus, Thuja occidentalis, Acer saccharum and Betula alleghaniensis) are extracted from the community independently of the other species, except in the special case of sugar bush management in which all other species are extirpated or severely controlled in order to increase the abundance and growth of Acer saccharum. Removal of mature trees normally allows the influx of weedy species or species characteristic of an earlier successional stage by the increased light intensity on the forest floor and the introduction of seeds on machines and clothes. Grazing has a similar effect, particularly on the understory, in that many species of plants not usually found in forest ecosystems can penetrate via their bovine hosts and establish themselves (however temporarily). Cattle are known to drastically reduce the number of tree seedlings on the forest floor and, if grazing is allowed for long periods, this can result in succession of the previously closed forest towards an open, park-like environment with little tree regeneration and abundant field weed species scattered between the trunks.

Periodic forest fires have been a feature of most forest ecosystems since early after glaciation, and may in fact, be necessary agents for the perpetuation of certain species and therefore, certain ecosystems (Kayll, 1968; Mutch, 1970; Van Wagner, 1970; Methven, 1973; Wright, 1974; Marks, 1974; Simard, 1975). The dry pine associations in the Ottawa area (*Pinus strobus*-*Maianthemum canadense* and *Pinus banksiana*-*Pteridium aquilinum*) seem to be well adapted to repeated, moderate burns which expose mineral soil for seedling germination and help (particularly in *Pinus banksiana*) to release the seeds from the cone structure. Without these rejuvenating fires, both of these species and, as a result, their present associations are destined to further succession, whereas they would otherwise be considered serclimaxes under the influence of occasional forest fires. Even now, protection from major fires has allowed continued succession within these open-canopied forests. The *Pinus*-*Maianthemum* association appears to be heading towards a *Tsuga*-*Gymnocarpium* association on the older, mesic sites; the *Pinus banksiana* association is presently showing a trend towards communities similar to those of the *Pinus strobus*-*Rhus radicans* association. Within a few tree generations, these two dry pine associations are expected to be much less prominent in the area. With increasing forest fire protection in North America, it appears that extensive *Pinus strobus*, *P. resinosa* and *P. banksiana* communities are destined to extinction with the species surviving as relicts on exposed or disturbed sites where competition is reduced and mineral soil is available via other means than fire. It seems likely too, that ecological diversity will be reduced in areas of forest fire protection since the array of plant and animal species of mid-successional (post-fire) stages will be eliminated along with the fires (Taylor, 1973). From the memories of living people, old newspaper accounts, charcoal layers at various depths within soil samples and drastically alternating tree species-grass species pollen records, it is evident that fires have been a regular disturbance in the Ottawa area in the past and a major contributing factor to the variety and variability of the present forests.

Vegetation succession and soil changes are another aspect which must be considered. It is generally agreed that "improvement" of soil conditions is a concomitant process with that of the vegetation changes occurring above the soil surface. Particular forest soils of the Ottawa area and other places (Daubenmire and Daubenmire, 1968; Braun-Blanquet, 1965; Drury and Nisbet, 1973) are not necessarily in as direct a conjunction with the maturity of the vegetation as theoretically suggested for sites undergoing primary succession. Both Braun-Blanquet and Drury and Nisbet, among others, recognize that soil processes and maturation of a soil profile is an extremely long-term proposition and that the state of maturity of soils generally lags behind the relatively rapid state of equilibrium achieved by the vegetation (just as vegetation change lags behind climatic change through inertia and the longevity of trees). Soil characteristics change over short distances (even within the same spade slice) so that valid, general characteristics of the soil under each forest association are difficult to obtain. Zinke (1962) demonstrated that concentric rings of soil gradient characteristics radiate and interfere (like physical sound and light wave phenomena) from each tree trunk. Goodlet (1954) observed that wind-throw and falling trees has greatly disturbed soil profiles in Pennsylvania and Lutz and Griswold (1939) state that "... all soils which bear, or in the past have borne, forest stands have been more or less disturbed." In the Ottawa area, many of the forests studied exhibit a pronounced, hummocky appearance where old trees have fallen, uprooting and overturning the soil profiles. It is apparent that forest soils are generally disturbed, inverted or modified and that they have not been mellowing in situ since glaciation. In addition, Stone (1944) and Wilde and Leaf (1955) met with only limited success in attempting to correlate plant species distribution and soil parameters (pH, degree of podzolization) even with forbs and smaller plants which are considered more sensitive to environmental conditions than the larger, more tolerant trees. Daubenmire and Daubenmire (1968), although agreeing that soil conditions vary between forest types, state that it is difficult to specifically demonstrate because plant roots re-act to moisture, solutes and temperature, whereas soil classification is based on ecologically, non-functional characters sensitive to the human eye such as colour, texture, depth and horizon sequences.

Any discussion of succession invariably brings us to a consideration of successional endpoints and climax theory. Like succession theory, climax theory is an old, familiar and popularly established idea among plant ecologists, but a perusal of the literature reveals numerous points of view, points of departure and divergent definitions as to just what climax vegetation is (Clements, 1928; Whittaker, 1953; Selleck, 1960). There are two basic conceptual approaches to the climax idea based mainly on differences in the time scale of the investigator involved. Clements (1916, 1928) very early suggested the monoclimax approach which stated that climax vegetation developed through successional sequences ending in a highest, or most stable, formation determined by regional climate. Such a theory is based on the geological time scale and the eventual creation of a terrestrial peneplain through erosion and geological transport mechanisms. Clements recognized existing vegetation types which did not conform to his climax specifications as subclimaxes which he labelled disclimax, preclimax or postclimax depending on the agent which seemed to be retarding development toward the real, climatic climax. Tansley (1920, 1935) introduced the polyclimax approach by stating that the subclimaxes of Clements are in fact specific, stable, lasting climaxes in their own right maintained, not by the regional climatic factors (although these provide the framework within which vegetation develops), but by specific environmental or historical factors such as soil characteristics (edaphic climax), topographic features (topographic climax), human interference (anthropeic climax) and others. Thus, two central ideas monoclimax (one proposed climax vegetation determined by climate on a geological time scale), and polyclimax (the recognition of various forms of climax vegetations determined by more specific, local agents such as soils, moisture, microclimate) - form the basis against which subsequent discussions and proposals were tested. As more and more students studied the vegetation of different areas of the world, the terminology and nuances of definition flourished (not to mention the considerable vocabulary contributions of the earlier workers themselves), leading to a presently monumental morass of "climaxology".

Many leading ecologists (Daubenmire, 1952, 1968; Dansereau, 1957, 1959; Braun, 1950; Whittaker, 1953) are proponents of the polyclimax approach (or its variations). They recognize that while climatic climaxes presently exist in medium situations (i.e., mid-slope, well-drained, deep soil), the assumption that entire vegetation regions can, or ever will, attain equilibrium and homogeneous, uniform distribution with climate as the controlling factor is largely unproven (Graham, 1941; Watt, 1947; Sprugel, 1976). Such a widespread, homogeneous climax forest is so rarely observed and therefore, academic, that it cannot usefully be employed as the cornerstone of a practical theory. Instead, polyclimax supporters agree that enduring, stable communities in different, specific habitats can and will persist as is, without proceeding towards the "highest" type because of some environmental arrestation. Daubenmire (1952) recognizes six types of climax vegetation including edaphic climax (maintained because of some stable but peculiar soil condition), topographic climax (maintained by occupation of sites of excessive exposure to or protection from direct solar radiation or wind) and fire climaxes (maintained by a particular intensity or frequency of burning) among others, In addition, Daubenmire distinguishes climax from seral (transitional) forests on the basis of observed population structures. Interrupted age-gradients in species populations indicate that at least some of the species are temporary members only and therefore the community is not in a climax state. Climax vegetation (in the sense of polyclimax theory) appears to be self-regenerating and shows no concrete evidence of being followed by different, subsequent communities. Daubenmire (1952, 1968) makes a "reasonable and useful" division between autogenic succession (demonstrable and predictable) and allogenic succession (caused by unforeseeable events and therefore unpredictable). This is similar to Braun's (1950) method of recognizing climax vegetation in which she used essential accordance of overstory and sub-canopy layers (i.e., same species) as an indication of climax status. Dansereau (1957, 1959) using more general terminology, recognizes more generally-defined climaxes such as the disclimax (associations owing their durability to repetitive interferences by man), serclimax (associations maintained by regularly recurring physical factors) and proclimax (relict associations persisting from previous periods of different climatic regimes), as well as recognizing and mapping the climatic climax vegetation regions of the St. Lawrence Valley based on stands from medium-slope, mature sites.

In the Ottawa area, it is obvious that there are many types of advanced vegetation. According to Daubenmire's criteria, the starred endpoints (Figure 40) appear to be self-regenerating with no obvious and clear indications of future, foreseeable changes. These associations are listed in Table 26. The major determining factors in the stability of these climax associations are soil moisture, soil chemistry, topography, time of development, fire and other disturbance history. The degree of man's influence on forest development becomes more apparent too, when you consider his ability and increasing tendency to alter these factors determining forest stability such as modifications of soil moisture, curtailment of development time and increased suppression of fire, as well as various artificial selection pressures such as logging and intensive recreation. Normally, man's interference in forest development results in a setback in succession. A comparison of pre- and post-settlement forests shows obvious shifts in the abundance of various species, although the number and total composition tends to remain the same. Normally, increasing numbers of early successional species such as _Populus_, _Ostrya_, _Betula_ and huge increases in the proportion of open field weed species are seen after arrival of settlers (Siccama, 1971; Webb, 1973).

Indeed, it is only in the short term that we can define "climax" vegetation because even presently-stable communities will change as global climate patterns shift, where large-scale natural disturbances occur regularly and where modern man becomes increasingly prominent in the world's forests. "Since existing vegetation is moulded by the interaction of climate and the numerous factors of the habitat, all of which are continuously changing; since the time lag of vegetation behind climate and environment is surely to increase with the longevity of the species; and since capacity for immigration and evolution of the species and the history of the area are all important factors to be considered, the prediction of a climax vegetation or reference to vegetation as having attained an endpoint appears to be presumptuous" (Selleck, 1960, p.542). Literature examples show that where old, apparently virgin climax forests are preserved from allogenic disturbances, the observed effect is not to maintain the status quo, but to witness further, slow but perceptible differences in species composition over time (Leak, 1974; Phillips, 1976).

The present and potential forest vegetation of the Ottawa area has been described in terms of its exhibited tendency to change within the foreseeable future as a practical and useful baseline for regional planners and scientists. Thus, some forest associations are very transitory, others resist change for long periods but finally change while still others appear to be stable and self-perpetuating under present climatic and disturbance conditions. It is fruitless to predict succession beyond stability since such potential changes are subject to the vagaries of atmospheric disruptions, man-controlled disturbances and unpredictable celestial events.

CHAPTER 9. Summary

The forest vegetation of the Ottawa area is classified into 11 alliances based on the basal area dominance of the major tree species. Twenty one distinct associations are found within the alliances based on combinations of named species, each with characteristic overstory, understory and habitat features. The forest vegetation is of a transitional nature with eight deciduous, six coniferous and seven mixed deciduous-coniferous associations making up the forest cover.

Each association was examined in terms of tree population structure, tree ages and habitat features in order to predict the future community which could be expected. A successional model showing the potential trends of the present associations was constructed and the stable, most advanced forest associations of the region were identified.

Previous forest ecology workers in eastern North America, and particularly in the eastern Ontario-western Québec region, have attempted classifications of these forests (or parts of them). In general, these systems agree with the present work, although the degree of splitting and lumping of different associations by different investigators make individual comparison difficult. This study provides the first, detailed and integrated classification of the forest vegetation of the Ottawa, Ontario area.

Differences in conceptual approach, methodology, terminology and regional vegetations have lead to confusing and apparently contradictory reports in the literature. A discussion of these matters and the flexible, ecosystem-based approach used in the present study is provided.

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Table A.1.
RECONNAISSANCE DATA SHEET

Location: Stand No.__________

__________ Nearest named point on map

__________ Direction and Distance

__________ County, Prov.

Topographic Position:

Altitude: Site; Reference; Corrected Aspect:________ %Slope:________

Drainage:__________ Other:__________

Data by:__________ Date: __________

TREES	COVER	GRAMINOIDS	COVER
		FERNS + FERN ALLIES	
		FORBS	
SHRUBS			

General notes of interest (e.g. boundaries, areal extent, tree height, layers, soil conditions, signs of disturbance, etc.):

arest Named Point on Map ______ Direction and Distance ______ Province County ______ Stand #

timeter (site) ______ Altimeter (Ref. Point) ______ Altimeter (Site-corrected) ______ % Slope ______ Aspect

Table A.2.

ta by ______ Date ______

nsity of Trees by Size Classes:

pecies	1	2	3	4	5	6	7	8	9	10	11	12	13
	<0.5 dm												
	<1 m tall	>1 m tall	>0.5 dm	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10+

Stand #   Date

TAXA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	F%	C%

Table A.2. ..., cont'd

Location ________ Table A.2. ...cont'd Stand Number________

% SLOPE

ASPECT:

TERRAIN DESCRIPTION:

Heights of Layers:
- Tree
- Shrub
- Ground Layer

Range of Tree Diameters:

HUMAN ACTIVITY:

ANIMAL ACTIVITY:

Notes on Tree Reproduction:

SPECIAL FEATURES:

OTHER DISTURBANCES:
- Insect or Disease
- Beaver Activity
- Windthrow
- Fire
- Cutting
- Other

SOIL SAMPLE:

(1) LITTER TYPE-

(2) DEPTH

(3) LOWER LEVEL DESCRIPTION-

(on bag = date, location, stand number, forest type, drainage)

DRAINAGE:	1	2	3	4	5
	W	WM	M	DM	D

Table B.1.1. Relative Dominance Values for the Remainder of the Tree and Shrub Species (<u>Acer saccharum</u> Alliance)*

Plot #	15	11	13	142	71	116	89	130	141	9	12	8	91	14	20	2	80	4	92	16	88	125	90	87	144	54	126	53
Trees																												
Caca														+													+	
Acsi		9														4												
Pog																		32										
Acni																										+		
Shrubs																												
Acsp				+						+		+																
Acp					+																							+
Tac					+																		+					
Prp							+				1																	
Apa								+															+					
Spl																			+									
Ces																									+			
Alr										+																		
Sac				+																								

<u>Acer</u>-<u>Parthenocissus</u> Association (plots 15–14) — <u>Acer</u>-<u>Trillium</u> Association (plots 20–53)

* (Table B.1.1. lists those species showing less than 15% constancy within the alliance). (Species abbreviations are defined in Appendix Table C).

Table B.1.2. Remainder of the Understory Species
(*Acer saccharum* Alliance)*

Forbs	*Acer*-*Parthenocissus* Association	*Acer*-*Trillium* Association
Aralia nudicaulis	+.21	+.07
Aster spp.	+.14	+.14
Circaea quadrisulcata	+.21	+.07
Hepatica acutiloba	+.21	+.07
Tiarella cordifolia	+.21	+.07
Cypripedium acaule	+.29	.
Solanum dulcamara	+.14	+.07
Osmorhiza Claytoni	+.21	.
Uvularia grandiflora	+.07	+.14
Rhus radicans	+.14	+.07
Veronica officinalis	+.14	+.07
Sanguinaria canadensis	+.07	+.14
Eupatorium maculatum	+.14	.
Mitella nuda	+.07	+.07
Phryma leptostachya	+.14	.
Medeola virginiana	+.14	.
Prenanthes spp.	+.07	+.07
Oxalis stricta	+.07	+.07
Smilacina stellata	.	+.14
Actaea rubra	.	+.14
Allium tricoccum	.	+.14
Erythronium americanum	.	1.14
Plantago major	+.07	+.07
Aster macrophyllus	+.07	+.07
Goodyera repens	+.07	.
Typhus latifolia	+.07	.
Laportea canadensis	+.07	.
Impatiens biflora	+.07	.
Boehmeria cylindrica	+.07	.
Urtica dioica	+.07	.
Mitella diphylla	+.07	.
Sanicula marilandica	+.07	.
Leonurus cardiaca	+.07	.
Antennaria spp.	+.07	.
Ranunculus acris	.	+.07
Pyrola rotundifolia	.	+.07
Clintonia borealis	.	+.07
Habenaria spp.	.	+.07
Trifolium repens	.	+.07
Eupatorium perfoliatum	.	+.07
Fragaria virginiana	.	+.07
Melilotus alba	.	+.07
Potentilla recta	.	+.07
Phlox divaricata	.	+.07
Senecio pauperculus	.	+.07
Verbena hastata	.	+.07
Artemisia vulgaris	.	+.07
Pyrola spp.	.	+.07

*(Table B.1.2. lists those species showing less than 15% constancy).
(Number to left of dot is percent coverage, that to right is percent constancy)

Table B.1.2. ...cont'd

Forbs	Acer-Parthenocissus Association	Acer-Trillium Association
Dicentra Cucullaria	.	+.07
Dentaria diphylla	.	+.07
Silene Cucubalus	+.07	.
Rubus spp.	+.07	.
Linnaea borealis	+.07	.
Achillea Millefolium	+.07	.
Amphicarpa bracteata	.	+.07
Grasses		
Carex plantaginea	+.07	.
Ferns and Allies		
Botrychium dissectum	+.21	+.07
Botrychium spp.	+.14	+.14
Matteuccia Struthiopteris	+.07	+.14
Onoclea sensibilis	+.07	+.14
Thelypteris noveboracensis	+.07	+.07
Gymnocarpium Dryopteris	+.07	+.07
Equisetum hyemale	.	+.14
Dryopteris cristata	+.14	.
Dryopteris marginalis	.	+.07
Cystopteris bulbifera	+.07	.
Adiantum pedatum	+.07	.
Lycopodium spp.	.	+.07
Equisetum arvense	.	+.07
Polypodium virginianum	.	+.07

Table B.1.3. Acer saccharum Alliance Population Structure* and Habitat Data

	Acer-Parthenocissus Association														Acer-Trillium Association													
Plot #	15	11	13	71	142	116	89	130	141	9	12	8	91	14	20	2	80	4	92	16	88	125	90	87	144	54	126	53
Acer saccharum																												
(1-2)	96	12	61	181	673	145	4045	6195	855	5	198	164	114	25	24	112	37	23	7	534	486	546	1008	350	712	276	6050	5607
(3)	1	9	18	7	3	25	10	17	1		49		34	2	2	4	6	9	9	11	24	18	4	7	18		1	
(4)	3	6	18	7	6	13	20	13			21	3	11	9	5	10	5	5	15	4	15		8	19	6	6	3	5
(5)	1		5	1	5	1	10	3	6		1		1	11	7	3	5	1	2	1			2	1	2	5	1	3
(6)	1		1	4	4		1		2			2	1	1	3	1	2	3	1	3	1		2	1	3	2	1	2
(7)					1				2			1		1					2			1	1			3	3	
(8)	1											2																
(9)								1																		2		
(10)								1																				
Fraxinus americana																												
(1-2)			15	103	33	266	20	100	38	48	2	85	5	33		35	12		2		47		5	23	284	46		285
(3)			13						3	6		8					1		2		3							
(4)			9						2			2	2								2			6				
(5)												11	1								1							
(6)												3					2							1				
Tilia americana																												
(1-2)	1	13	12	8	1			6		7					2	11					4		1	4	166	45	65	83
(3)		3	2					1		1		1				5					1						1	
(4)	1	2										1	2			2												
(5)													1				1											
(6)	3																1											
(7)				2													1							2				
(8)	1																		1					1				
Ostrya virginiana																												
(1-2)			4	1		78	7	38	201			11			1	42					104	3	29	165	490	36		
(3)						32	1	9	2			4				9					1	4		1				
(4)						11	1	3	1			1	1	1	2	1			4	1	1	1						
(5)															2										1	2		

Tree Diameter Size Classes

* (Data plotted in the table is the number of stems).

Table B.1.3. ...cont'd

Plot #	15	11	13	71	142	116	89	130	141	6	12	8	91	14
					Ulmus americana									
(1-2)		12	2	3,	108		21			4		4	19	1
(3)		3					2						1	
(4)	1	3					4			2			5	1
(5)				1			1			4			1	3
(6)				1			4						1	
(7)				2			1							
(8)														
(9)														
	Other Species													
(1-2)	34	14		164,	212	3	8	27,	423	21		8	27	9
(3)	1	10		1				1		1				1
(4)	3	4		3			3							
(5)	1			2	2	1	1	3					2	1
! (6)														
(8)				1					1					
(9)														
(10)						1								
(11)						1								
Habitat Data														
Percent Slope	1	1	2	0	2	2	1	5	3	10	3	15	2	4
Aspect	NE	S	NE	-	NW	NE	NW	NE	NE	NE	SE	E	W	W
Total Stand Basal Area (m2/ha)	32	11	27	53	40	54,	101,	125	50	14	20	32	33	38
Soil Type[1]	Lg	F	F	Rs	A	M	Ns	F	Kg	F	Lg	F	A	Gr-b

Plot #	20	2	80	4	92	16	88	125	90	87	144	54	126	53
					Fagus grandifolia									
(1-2)	18	60	6		9	1	18	78	45	11	29	59	34	108
(3)	1	7	1	2			1	2	3		5			2
(4)	1	7		3	1		2	1	3		6			2
(5)	1		1	2		3			3					2
(6)	1			1		2	1	4	2	2	2			5
(7)							1	1			1	2		3
(8)								1						
(9)												2		
	Other Species													
(1-2)	36	44	39	1		2	74	3	12,	259,	319,	163,	151,	42
(3)	1			2									6	
(4)		4		8	2		3				1		4	
(5)	1	1		5										
! (6)	1			1										
(8)														
(9)														1
(10)														
(11)														
Habitat Data														
Percent Slope	4	35	0	0	0	9	3	1	4	2	1	5	0	7
Aspect	NW	S	-	-	-	SE	S	NE	NW	SW	NE	S	-	W
Total Stand Basal Area (m2/ha)	33	26	31	31	32	35	35	39	42	53	56	70	105	132
Soil Type[1]	F	Bc-s	A	Er	Rc	Lg	A	Rc-s	Ns	A	F	F	Gr-1	Fc

! (Indicates that no stems occurred in the missing size class).
1 (Soil type according to Hills <u>et. al</u>., 1944).

Table B.2.1. Relative Dominance Values for the Remainder of the Tree and Shrub Species (<u>Acer rubrum</u> Alliance)*

Plot #	143	127	41	43	139	42	3	68	156	129	128	1	37	150	44	38	63	155
Trees																		
Acs								2		3				+			2	
Tia	+			+			+										+	
Pis							+		+	+							+	
Pig			2						+						+	+		
Bea										+	+			+				+
Tho			+	7	+													
Osv													22		+		3	
Qur								+					8				6	
Fag																		+
Shrubs																		
Alr				+				+			+							+
Ilv		+							+	+								+
Acp										+			+					
Vir	+										+	+						
Spl								+			+							
Dip												+				+		
Sap	+													+				
Apa		+																
Prp												12						
Clv					+													
	Acer-Galium Association							Acer-Trientalis Association										

* (Table B.2.1. lists those species showing less than 25% constancy within the alliance). (Species abbreviations are defined in Appendix Table C).

Table B.2.2. Remainder of the Understory Species
(*Acer rubrum* Alliance)*

Forbs	*Acer-Galium* Association	*Acer-Trientalis* Association
Medeola virginiana	+.29	+.27
Arisaema triphyllum	+.43	+.18
Lactuca spp.	+.14	+.27
Solidago spp.	.	+.36
Vaccinium angustifolium	.	+.36
Tiarella cordifolia	+.14	+.27
Impatiens biflora	6.57	.
Mitchella repens	.	+.36
Aster macrophyllus	+.14	+.18
Asarum canadense	2.43	.
Actaea spp.	+.29	+.09
Circaea quadrisulcata	+.29	+.09
Prenanthes spp.	+.14	+.18
Gaultheria procumbens	.	+.27
Mitella nuda	1.29	+.09
Urtica dioica	7.43	.
Solanum dulcamara	+.29	+.09
Polygonatum biflorum	+.14	+.18
Smilacina racemosa	+.14	+.09
Osmorhiza Claytoni	+.29	.
Achillea Millefolium	+.14	+.09
Streptopus roseus	.	+.18
Iris versicolor	.	+.18
Smilacina stellata	.	+.18
Coptis trifolia	.	+.18
Ranunculus abortivus	+.29	.
Boehmeria cylindrica	+.29	.
Eupatorium rugosum	+.14	+.09
Desmodium glutinosum	.	+.09
Epipactis helleborine	+.14	.
Linaria vulgaris	+.14	.
Epigaea repens	.	+.09
Pyrola virens	.	+.09
Thalictrum dioicum	+.14	.
Oxalis stricta	+.14	.
Hieracium spp.	+.14	.
Taraxacum spp.	+.14	.
Sanicula marilandica	+.14	.
Rosa carolina	+.14	.
Smilax herbacea	.	+.09
Chelone glabra	.	+.09
Fagopyrum esculentum	.	+.09
Mitella diphylla	+.14	.
Phryma leptostachya	+.14	.
Lithospermum officinale	+.14	.
Pilea pumila	+.14	.
Hackelia virginiana	+.14	.

* (Table B.2.2. lists those species showing less than 30% constancy). (Number to left of dot is percent coverage; that to right is percent constancy).

Table B.2.2. ...cont'd

Forbs	Acer-Galium Association	Acer-Trientalis Association
Erigeron spp.	.	+.09
Krigia app.	.	+.09
Amphicarpa bracteata	.	+.09
Agrimonia spp.	.	+.09
Cirsium arvense	.	+.09
Cicuta maculata	.	+.09
Inula Helenium	.	+.09
Trifolium repens	.	+.09
Chrysanthemum leucanthemum	.	+.09
Aralia racemosa	.	+.09
Habenaria psycodes	.	+.09
Grasses		
Brachyelytrum erectum	.	+.18
Calamagrostis canadensis	.	+.18
Carex tenera	.	+.09
Carex intumescens	.	+.09
Oryzopsis spp.	.	+.09
Ferns and Allies		
Gymnocarpium Dryopteris	+.28	+.09
Osmunda Claytoniana	+.14	+.18
Dryopteris cristata	+.14	+.18
Botrychium virginianum	+.28	.
Matteuccia Struthiopteris	3.28	.
Cystopteris bulbifera	+.28	.
Dryopteris marginalis	+.14	.
Botrychium multifidum	.	+.09
Lycopodium lucidulum	.	+.09
Thelypteris noveboracensis	+.14	.
Athyrium thelypteroides	.	+.09
Lycopodium clavatum	.	+.09
Lycopodium complanatum	.	+.09
Cystopteris fragilis	.	+.09

Table B.2.3. Acer rubrum Alliance Population Structure* and Habitat Data

Plot #	143	127	41	43	139	42	3	68	156	129	128	1	37	150	44	38	63	155
Acer rubrum																		
(1-2)	75	55	96	80	518	951	245	196	884	466	422	27	257	158	522	1203		1245
(3)	1	1	14	11	4	2	32	25	23	22	42	9	9	7	3	8		23
(4)	3	5	15	14	3	3	11	12	27	21	47	28	5	8	2	9		26
(5)	2	4	15	5	14	2		5	9	8	6	3		6	5	2		7
(6)	4	1		2	3	2			1				2	3	2	2		4
(7)	2	2			3	2							2	2				
(8)	1				1	2												
(9)	1					3												
Populus tremuloides																		
(1-2)				12				4	2	11	27		52		18	33		
(3)								9	1							1		
(4)								2		3	2		2		3	1		4
(5)				3					1	1					1	2		1
(6)								1					1			2		2
(7)				2														
Ulmus americana																		
(1-2)	69	5	3		101	33	10											
(3)		2	3				14											
(4)				2			5											
(5)				5														
(6)	1			2														
(7)	1																	
(8)	1																	
(9)	1																	
Fraxinus nigra / **Betula papyrifera**																		
(1-2)	124	52	96	17	377	87	10	8										
(3)					1		6	2		1					2	2		1
(4)	2		2	2	4	3	11	1	1	4	2	1	2	2	3	2		1
(5)					1		2	2			1							

Acer-Galium Association (plots 143–3) — Acer-Trientalis Association (plots 68–155)

* (Data plotted is the actual number of stems).

Table B.2.3. ...cont'd

	143	127	41	43	139	42	3	68	156	129	128	1	37	150	44	38	63	155
Other Species																		
(1-2)	2		22	60	18	6	530	166	55	22	17	6	49	250	251	5		13
(3)				5				2		2	1		2	2	3			1
(4)	1		1	4	10		3	5		2	2		2		2			2
(5)					3			2	1	3	2		2					3
(6)			1		2			3										2
Habitat Data																		
Percent Slope	1	0	0	0	3	0	2	4	0	0	6	0	0	1	0	2	4	1
Aspect	N	-	-	-	N	-	SE	NE	-	-	NW	-	-	NW	-	W	W	W
Total Stand Basal Area (m2/ha)	65	36	36	53	66	67	35	44	48	51	57	25	33	36	40	50	58	71
Soil Type[1]	Rs	M	M	M	Us	M	Bc-s	A	(Rfs-Sfs)		Gs	Rs	Us	Us	Us	Us	A	Bfsl

1 (Soil type according to Hills et al., 1944).

Table B.3.1. Relative Dominance Values for the Remainder of the Tree and Shrub Species (<u>Fraxinus nigra</u> Alliance) *

	Fraxinus-Matteuccia Association								Fraxinus-Mitella Association							
Plot #	30	135	79	81	29	27	132	103	31	45	104	95	146	164	133	108
Trees																
Fra						+			37							
Juc					3	+										
Bea				6		+										
Osv				+								2				
Qum									2	+						
Acs			+													
Caca									+							
Acsi		+														
Qur																18
Pig				+												
Pis				+												
Shrubs																
Alr														+		5
Coc			+												+	
Dip		+							+							
Vir									+						+	
Clv									+						+	
Crat						+										
Dil										+						
Rhar																+

* (Table B.3.1. lists those species showing less than 15% constancy within the alliance).
(Species abbreviations are defined in Appendix Table C).

Table B.3.2. Remainder of the Understory Species
(*Fraxinus nigra* Alliance)*

Forbs	Fraxinus-Matteuccia Association	Fraxinus-Mitella Association
Laportea canadensis	6.38	.
Eupartorium spp.	+.13	+.25
Geum canadense	+.25	+.13
Trillium grandiflorum	+.25	+.13
Prenanthes spp.	+.13	+.25
Ranunculus acris	+.13	+.25
Arisaema triphyllum	+.38	.
Potentilla spp.	+.13	+.13
Dalibarda repens	+.13	+.13
Mitella diphylla	.	+.25
Trientalis borealis	.	+.25
Bidens cernua	+.13	+.13
Chrysanthemum leucanthemum	.	+.25
Lactuca spp.	.	+.25
Pyrola secunda	.	+.25
Aster macrophyllus	.	+.13
Achillea Millefolium	.	+.13
Oxalis stricta	.	+.13
Myrica Gale	+.13	.
Lysimachia thyrsiflora	+.13	.
Cirsium spp.	.	+.13
Erigeron philadelphicus	.	+.13
Rumex spp.	.	+.13
Polygonum amphibium	.	+.13
Epipactis helleborine	.	+.13
Lithospermum officinale	.	+.13
Trifolium spp.	.	+.13
Glecoma hederacea	+.13	.
Actaea alba	.	+.13
Fragaria vesca	.	2.13
Clintonia borealis	.	+.13
Scutellaria lateriflora	.	+.13
Gentiana Andrewsii	.	+.13
Cornus canadensis	.	+.13
Anemone canadensis	.	+.13
Streptopus roseus	.	+.13
Chelone glabra	.	+.13
Grasses		
Carex retrorsa	.	+.13
Elymus virginicus	.	+.13
Calamagrostis canadensis	.	+.13

* (Table B.3.2. lists those species showing less than 20% constancy).
(Number to left of dot is percent coverage, that to right is percent constancy).

Table B.3.2. ...cont'd

Ferns and Allies	*Fraxinus-Matteuccia* Association	*Fraxinus-Mitella* Association
Osmunda cinnamomea	+.13	1.25
Gymnocarpium Dryopteris	+.13	+.25
Dryopteris marginalis	+.25	+.13
Athyrium thelypteroides	+.25	.
Cystopteris bulbifera	+.13	+.13
Equisetum arvense	.	+.25
Osmunda regalis	.	+.13
Dryopteris Goldiana	.	+.13
Selaginella apoda	.	+.13
Pteridium aquilinum	.	+.13
Lycopodium obscurum	.	+.13
Osmunda Claytoniana	.	+.13

Table B.3.3. Fraxinus nigra Alliance Population Structure* and Habitat Data

Plot #	30	135	79	81	29	27	132	103	31	45	104	95	146	164	133	108
Fraxinus nigra																
(1-2)		102		43	9		21	20	2	400	93	86	82	76	113	39
(3)	3	4	1	5	2		1	39	2		27	35	11	39	5	12
(4)	8	36	7	10	31		17	54	1	5	20	21	17	21	1	32
(5)	1	9	14	3	5		12	3		4		3	6	1		
(6)			3				5						1			
(7)	1															
(8)				1												
Ulmus americana																
(1-2)		11		14	22		21		6		3		2	36	6	
(3)		3	2		2	4	1		15	2	6	5	8		1	
(4)	1	2	5			15	17		3		7	8	9	4	4	3
(5)					1	12	12				3	5	2	2	2	
(6)			1			1	3							3	1	
(7)						1								1	1	
(8)				2												
Populus tremuloides																
(1-2)	1					4			2						6	
(3)									10						2	1
(4)	4								13						1	
(5)	2														5	
(6)												1				
Acer rubrum																
(1-2)	3			34	2		8		87	32	5	120				
(3)	1			5			1		6			1				
(4)	6			5			2		6							
(5)	3			2			2			1						
(6)							1			1						
	Fraxinus-Matteuccia Association								Fraxinus-Mitella Association							

* (Data plotted in the table is the actual number of stems).

Table B.3.3. ...cont'd

Plot #	30	135	79	81	29	27	132	103	31	45	104	95	146	164	133	108
										Thuja occidentalis						
(1-2)										37	50		+	17	2	2
(3)									2	8	14			12		2
(4)										2		45		10		3
(5)												3		1		
										Populus balsamifera						
(1-2)													+	17	43	
(3)														3	8	
(4)											2				1	
(5)											3				2	
(6)														1		
(7)														1		
								Other Species								
(1-2)	9	109	26	115	10	3	310	6	45	60	181	71	84	69	1996	187
(3)	1			3	2	1	3		33	7		1		1		22
(4)				5	1		2	1	23	2		1		2		
(5)					1				1							
(6)					1											
(7)																1
<u>Habitat Data</u>																
Percent Slope	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aspect	-	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Stand Basal Area (m2/ha)	24	34	35	39	28	30	47	36	33	33	35	44	45	57	55	35
Soil Type[1]	M	M	A	A	M	M	Kg	M	Kg	M	M	M	O1	M	M	M

1 (Soil type according to Hills <u>et al</u>., 1944).

Table B.4.1. Relative Dominance Values for the Remainder of the Tree and Shrub Species (<u>Populus</u> Alliance) *

Plot #	24	36	136	147	158	67	162	140	39	7	48	40	102	100	152	25
Trees																
Prs					+		+	+								
Qur							+				+				+	
Qum			+					+							1	
Caco						+	+						+			
Pis											2				+	
Osv						2				4						
Caca										9						+
Bea										4						
Juc																+
Acne			2													
Shrubs																
Clv				+	+			+								
Sal		+					+								+	
Loc			+			+		+								
Vir		+														+
Prp								+								
Crat								+								
Juco															1	
Dip										+						
Apa														+		
Spl					+											
Shc								+								
	<u>Populus</u>-<u>Corylus</u> Association				<u>Populus</u>-<u>Pteridium</u> Association						<u>Populus</u>-<u>Aster</u> Association					

* (Table B.4.1. lists those species showing less than 25% constancy within the alliance).
(Species abbreviations are defined in Appendix Table C).

Table B.4.2. Remainder of the Understory Species (Populus Alliance) *

Forbs	Populus-Corylus Association	Populus-Pteridium Association	Populus-Aster Association
Oxalis stricta	.	+.17	+.17
Pyrola rotundifolia	.	+.33	.
Taraxacum spp.	+.25	.	+.17
Plantago major	+.25	.	+.17
Myrica Gale	+.25	.	+.17
Actaea alba	+.25	.	+.17
Sanicula marilandica	.	+.17	+.17
Mitella nuda	.	.	+.33
Mitchella repens	.	+.33	.
Vaccinium angustifolium	.	+.33	.
Boehmeria cylindrica	.	+.17	+.17
Linnaea borealis	+.25	.	+.17
Lycopus americanus	+.25	+.17	.
Aralia racemosa	.	.	+.33
Actaea rubra	.	+.17	.
Mitella diphylla	.	+.17	.
Agrimonia spp.	.	+.17	.
Monotropa uniflora	.	+.17	.
Hepatica americana	.	.	+.17
Epigaea repens	.	.	+.17
Trifolium spp.	.	.	+.17
Sanguinaria canadensis	.	.	+.17
Urtica dioica	.	.	+.17
Pyrola minor	.	+.17	.
Eupatorium rugosum	+.25	.	.
Lithospermum officinale	+.25	.	.
Thalictrum dioicum	+.25	.	.
Epilobium hirsutum	+.25	.	.
Waldsteinia fragarioides	.	.	2.17
Vicia Cracca	.	.	+.17
Anaphalis margaritacea	.	.	+.17
Rosa carolina	.	.	+.17
Cypripedium reginae	.	.	+.17
Comptonia peregrina	.	.	+.17
Clintonia borealis	.	.	+.17
Monotropa Hypopithys	.	.	+.17
Eupatorium perfoliatum	.	+.17	.
Hieracium spp.	+.25	.	.
Mentha canadensis	+.25	.	.
Prunella vulgaris	+.25	.	.
Fragaria vesca	1.25	.	.
Potentilla norvegicus	+.25	.	.
Chimaphila umbellata	.	+.17	.
Amphicarpa bracteata	2.25	.	.
Cirsium spp.	+.25	.	.
Circaea quadrisulcata	+.25	.	.

* (Table B.4.2. lists those species showing less than 20% constancy). (Number to left of dot is percent coverage, that to right is percent constancy).

Table B.4.2. ...cont'd

Ferns and Allies	Populus-Corylus Association	Populus-Pteridium Association	Populus-Aster Association
Gymnocarpium Dryopteris	.	.	+.33
Dryopteris cristata	+.25	+.17	.
Botrychium multifidum	.	+.17	+.17
Thelypteris noveboracensis	.	+.17	.
Athyrium Filix-femina	.	+.17	.
Botrychium dissectum	.	.	+.17
Dryopteris marginalis	.	+.17	.
Lycopodium lucidulum	.	+.17	.
Equisetum sylvaticum	.	+.17	.

Table B.4.3. Populus Alliance Population Structure* and Habitat Data

Plot #	24	36	136	147	158	67	162	140	39	7	48	40	102	100	152	25
Populus tremuloides																
(1-2)	7	6	7	1	7	2	2	22	31					9	30	5
(3)	2	19	7		8	2	2	15	18	6			2	31	5	13
(4)	2	18	21	2	11	5	3	24	9	17			19	25	13	21
(5)		1	6		3	5	2	4	1	1		1	9		3	5
(6)						5						3				1
(7)						2						1				
	Populus balsamifera				Populus grandidentata											
(1-2)	15	3	20	50			6		2		203		1		11	
(3)	2	15	4	2	1		7	12	11		39			3	12	
(4)	7	12	28	1	10		3	15	2	2	1		4	2	12	
(5)	3	2	5		3	1	1	5		2					2	
(6)				2		1	2									
(7)				4			7									
(8)				3			1									
	Ulmus americana				Acer rubrum											
(1-2)	7	10	21	3	64	90	206	59	37	8	27	92	33	37	824	
(3)	4	3	13	11	1	5	6			3			4		15	
(4)	2	1		4		4	2						1		5	
(5)						1	1									
	Fraxinus nigra				Other Species						Picea glauca					
(1-2)		59		141	175	284	337	527	67	158					4	1
(3)		2		22	28	7	20		1	22	1			1	3	
(4)		3		6		1	11			14					3	
(5)				2		2						1				
	Other Species										Abies balsamea					
(1-2)	136	89	1034	1132							9	10	33	37	79	
(3)	21	8	4	2							4		4		25	
(4)	18			1							9		1		2	
(5)	1											1				
	Populus-Corylus Association				Populus-Pteridium Association						Populus-Aster Association					

* (Data plotted in the table is the actual number of stems).

Table B.4.3. ...cont'd

Plot #	24	36	136	147	158	67	162	140	39	7	48	40	102	100	152	25
											Other Species					
(1-2)											5	96	552	350	17	252
(3)											2	17	7	9	1	12
(4)												5	1	1	2	2
(5)												2				1
(6)												1				
Habitat Data																
Percent Slope	1	0	0	2	2	0	4	7	2	15	0	0	1	1	3	1
Aspect	S	-	-	N	N	-	NW	W	W	NE	-	-	E	E	N	S
Total Stand Basal Area (m2/ha)	25	28	58	72	26	52	67	42	18	24	20	42	50	31	46	28
Soil Type[1]	F	M	M	M	Rfs-Sfs	A	A	Us	F	F	Us	Us	Gr-s	M	Us	F

1 (Soil type according to Hills *et al*., 1944).

Table B.5.1. Relative Dominance Values for the Remainder of the Tree and Shrub Species (<u>Thuja occidentalis</u> Alliance) *

Plot #	112	96	61	154	32	57	105	106	59	160	161	58	111	101	137	99	22	35	84	131	94	134	23	34	107	26	21	83	19	18	17
Trees																															
Bea							10																				8				
Qum													+									+									
Caca																												+			
Fag																					+										
Shrubs																															
Tac				+											+																
Sal																						+						+			
Dip																								+			+				
Soa																											+				
Apa																						+									
Crat																						+									
Zam										+																					
Loc															+																
Rhar		+																													
Shc										+																					
	Thuja-<u>Dryopteris</u> Association					Thuja-<u>Maianthemum</u> Association									Thuja-<u>Pteridium</u> Association											Thuja-<u>Botrychium</u> Association					

* (Table B.5.1. lists those species showing less than 10% constancy within the alliance). (Species abbreviations are defined in Appendix Table C).

Table B.5.2. Remainder of the Understory Species
(*Thuja occidentalis* Alliance) *

Forbs	Thuja-Dryopteris Association	Thuja-Maianthemum Association	Thuja-Pteridium Association	Thuja-Botrychium Association
Trifolium spp.	.	+.33	+.18	.
Linnaea borealis	.	+.33	+.18	.
Polygonatum pubescens	.	.	+.09	+.67
Actaea spp.	.	.	+.18	+.50
Smilacina stellata	+.20	+.22	+.09	+.17
Orchis spp.	+.40	.	+.22	.
Clintonia borealis	+.60	.	+.09	.
Urtica dioica	+.40	.	+.09	2.17
Anemone canadensis	.	+.33	.	+.17
Solidago spp.	.	+.22	+.09	+.17
Impatiens biflora	+.40	.	+.09	.
Mitella diphylla	+.40	.	+.09	.
Solanum dulcamara	+.20	.	+.18	.
Oxalis stricta	+.20	.	+.18	.
Prunella vulgaris	.	+.33	.	.
Rosa carolina	.	+.33	.	.
Pyrola rotundifolia	.	+.22	.	+.17
Pyrola elliptica	.	+.11	+.09	+.17
Ledum groenlandicum	.	+.11	+.18	.
Aster macrophyllus	+.10	3.33	.	.
Aralia racemosa	1.40	.	.	.
Prenanthes spp.	+.40	.	.	.
Coptis trifolia	+.20	.	+.09	.
Achillea Millefolium	+.20	.	+.09	.
Thalictrum dioicum	+.20	.	+.09	.
Cicuta bulbifera	+.20	.	+.09	.
Vaccinium angustifolium	.	+.11	+.09	.
Antennaria neglecta	.	+.11	+.09	.
Arctostaphylos Uva-ursi	.	+.11	+.09	.
Moneses uniflora	.	+.11	+.09	.
Veronica officinalis	.	+.22	.	.
Melilotus alba	.	.	+.18	.
Cypripedium acaule	.	.	+.09	+.17
Mitchella repens	.	.	+.09	+.17
Polygonum spp.	.	.	+.18	.
Asarum canadense	.	.	.	+.33
Trillium grandiflorum	.	.	.	+.33
Laportea canadensis	.	.	.	+.33
Boehmeria cylindrica	2.20	.	.	.
Dalibarda repens	+.20	.	.	.
Tiarella cordifolia	+.20	.	.	.
Ranunculus abortivus	+.20	+.11	.	.
Caltha palustris	+.20	.	.	.
Mimulus ringens	+.20	.	.	.
Sarracenia purpurea	+.20	.	.	.
Vicia Cracca	.	+.11	.	.
Pyrola secunda	.	+.11	.	.

* (Table B.5.2. lists those species showing less than 19% constancy).
(Number to left of dot is percent coverage, that to right of dot is percent constancy).

Table B.5.2. ...cont'd

Forbs	Thuja-Dryopteris Association	Thuja-Maianthemum Association	Thuja-Pteridium Association	Thuja-Botrychium Association
Gaultheria procumbens	.	+.11	.	.
Anaphalis margaritacea	.	+.11	.	.
Mentha spp.	.	+.11	.	.
Aquilegia canadensis	.	+.11	.	.
Spiranthes gracilis	.	+.11	.	.
Monotropa uniflora	.	+.11	.	.
Erigeron philadelphicus	.	+.11	.	.
Dicentra canadensis	.	.	+.09	.
Potentilla spp.	.	.	+.09	.
Malaxis unifolia	.	.	+.09	.
Senecio aureus	.	.	+.09	.
Chrysanthemum leucanthemum	.	.	+.09	.
Hypericum perforatum	.	.	+.09	.
Lactuca spp.	.	.	+.09	.
Streptopus roseus	.	.	+.09	.
Ludwigia palustris	.	.	+.09	.
Geranium Robertianum	.	.	+.09	.
Phryma leptostachya	.	.	.	+.17
Uvularia grandiflora	.	.	.	+.17
Caulophyllum thalictroides	.	.	.	+.17
Osmorhiza Claytoni	.	.	.	+.17
Glecoma hederacea	.	.	.	+.17
Goodyera repens	.	.	.	+.17
Satureja vulgaris	.	.	.	+.17
Ferns and Allies				
Athyrium thelypteroides	+.20	+.11	+.27	.
Lycopodium complanatum	+.20	+.11	+.09	+.17
Lycopodium lucidulum	+.20	+.11	+.09	+.17
Athyrium Filix-femina	+.40	.	+.09	+.17
Gymnocarpium Dryopteris	+.20	.	+.18	.
Thelypteris noveboracensis	2.20	.	+.09	.
Selaginella apoda	.	+.22	.	.
Botrychium multifidum	.	+.11	+.09	.
Lycopodium obscurum	.	.	+.18	.
Thelypteris Phegopteris	.	.	+.09	.
Cystopteris fragilis	.	.	+.09	.
Lycopodium clavatum	.	+.11	.	.
Polypodium vulgare	+.20	.	.	.
Equisetum scirpoides	+.20	.	.	.

Table B.5.3. Thuja occidentalis Alliance Population Structure* and Habitat Data

Plot #	112	96	61	154	32	57	105	106	59	160	161	58	111	101	137	99	22	35	84	131	94	134	23	34	107	26	21	83	19	18	17
	Thuja occidentalis																														
(1-2)	189	33	12	51	9	515	186	3	42	265	293	3	147	201	8		20	100	6	252		252	8	357	128	7	3	11		1	
(3)	60	5		4	35	9	98	48	17	16	53		51	33	22	9	23	87	11	49		156	44	75	74	5	2	3	1	2	
(4)	51	27		21	44	24	72	36	23	14	29	12	45	20	31	39	66	109	43	99	7	48	114		48	11		33	8	11	6
(5)		17	2	3	10	3	5	11	2	7	4		2	12	32	18	13	7	18	31	19	4	12		2		5	11	11	6	7
(6)			3	4					2	4				2					7	8	17						2	2	1	1	2
(7)				1						2									1	3	6						1		3		
(8)			5																		11										
	Ulmus americana					Populus tremuloides									Other Species											Acer saccharum					
(1-2)		71		237		5	9	76	31						395	139		5	163	239	3	167				17	5	53	3	9	5
(3)		6												3			1	1	2	1						6	1	5		12	11
(4)	3	8	3		2					1	2			8	7	4	1	1	3							5	2	6	2	7	7
(5)					1			3	2	1					6	1			2										3		11
(6)					1				2																				2		3
(7)				1																									1		
	Fraxinus nigra					Abies balsamea																				Ulmus americana					
(1-2)	54	12	5	132	4	153	185	148	110	4		54	17	240														3			
(3)	9	3	2	4						1		11		8														1		3	
(4)	17		5	17	2		3							9													1	4	3	1	
(5)			2	1				2																			1	1			
(7)																											1				
	Other Species					Other Species																				Other Species					
(1-2)	317	348	183	212	23	194	304	1	324	48	37	879	3													53	240	95	1	20	
(3)	2	1		3	1	12				1	5	8														16	5	4		20	
(4)	1	7	5		4	15				1	5	2														16	2	4	4	10	
(5)			1		1			1	1	2	1															3		4	1	1	
(6)			6		1																						1	2			
(7)																												1			
						Picea glauca																									
(1-2)						40				59	31	9	2	2																	
(3)						5				9	13	3	5	3																	
(4)						3	3	2	5	6	8		6	3																	
(5)								3	3	1	2																				
(8)										1																					
(11)											1																				
	Thuja-Dryopteris					Thuja-Maianthemum									Thuja-Pteridium											Thuja-Botrychium					

Table B.5.3. ...cont'd

Plot #	112	96	61	154	32	57	105	106	59	160	161	58	111	101	137	99	22	35	84	131	94	134	23	34	107	26	21	83	19	18	17
<u>Habitat Data</u>																															
Percent Slope	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0	0	8	0	4	10	1	2	1	0	0	1	1	2	0	1	6
Aspect	-	-	-	-	-	-	-	-	-	-	W	E	-	-	-	-	SW	-	NW	N	E	N	S	-	-	E	E	E	-	NE	SE
Total Stand Basal Area (m2/ha)	52	54	77	52	46	46	66	52	41	58	59	23	34	50	95	51	52	73	86	130	150	53	76	14	35	23	32	62	53	36	44
Soil Type[1]	F	M	M	M	M	F	F	F	F	F	F	F	F	F	M	M	F	F	A	F	A	F	Gr-b	F	F	Gr-b	F	Ns	F	Gr-b	F

* (Data plotted in the population structure table is the actual number of stems).

! (Indicates that no stems occurred in the missing size classes).

1 (Soil type according to Hills <u>et al</u>., 1944).

Table B.6.1. Relative Dominance Values for the Remainder of the Tree and Shrub Species (<u>Pinus strobus</u> Alliance) *

Plot #	51	56	50	97	110	46	49	138	109	78	159	93	145	75	124	76	163	98	72	73	74	86	85
Trees																							
Fag													3									+	+
Acsi																+			+				
Prs																				+	+		
Lal																							1
Acni												+											
Pir																	35						
Qum														+									
Bea													+										
Osv													+										
Shrubs																							
Sal														2					+			+	
Loc				+				+	+														
Via											+												
Rht																				2	+		
Prp															+					+			
Acsp																	+						
Crat																						+	
Acp													2										
	Pinus-Rhus Association								Pinus-Maianthemum Association							Pinus-Rhamnus Association							

* (Table B.6.1. lists those species showing less than 15% constancy within the alliance). (Species abbreviations are defined in Appendix Table C).

Table B.6.2. Remainder of the Understory Species (*Pinus strobus* Alliance) *

Forbs	Pinus-Rhus Association	Pinus-Maianthemum Association	Pinus-Rhamnus Association
Trillium grandiflorum	+.25	.	+.13
Actaea alba	.	+.29	+.13
Prenanthes spp.	+.13	+.14	+.13
Clintonia borealis	+.13	.	+.25
Arctostaphylos Uva-ursi	+.38	.	.
Cornus canadensis	+.13	.	+.25
Polygonatum pubescens	+.13	+.29	.
Gaultheria procumbens	.	+.29	+.13
Coptis trifolia	.	+.14	+.25
Rumex Acetosella	.	+.14	+.25
Parthenocissus quinquefolia	.	+.14	+.25
Pyrola rotundifolia	+.13	+.14	.
Vaccinium angustifolium	.	7.14	+.13
Pyrola secunda	+.13	.	+.13
Anemone canadensis	+.25	.	.
Chimaphila umbellata	+.13	.	+.13
Hepatica acutiloba	+.13	+.14	.
Malaxis unifolia	+.13	.	+.13
Trifolium spp.	+.13	.	+.13
Cirsium spp.	+.13	.	+.13
Krigia virginica	.	+.14	+.13
Veronica officinalis	.	.	+.25
Asarum canadense	+.13	.	.
Solidago spp.	.	+.14	.
Medeola virginiana	.	+.14	.
Anaphilis margaritacea	+.13	.	.
Cypripedium reginae	+.13	.	.
Echium vulgare	+.13	.	.
Achillea Millefolium	.	.	+.13
Hepatica americana	.	.	+.13
Mitella nuda	.	.	+.13
Aralia racemosa	.	+.14	.
Tiarella cordifolia	.	+.14	.
Monotropa uniflora	.	+.14	.
Sanicula marilandica	+.13	.	.
Prunella vulgaris	+.13	.	.
Caulophyllum thalictroides	+.13	.	.
Polygala paucifolia	+.13	.	.
Melampyrum lineare	+.13	.	.
Antennaria neglecta	.	.	+.13
Satureja vulgaris	.	.	+.13
Cicuta bulbifera	.	.	+.13
Vaccinium spp.	.	.	+.13
Potentilla recta	.	.	+.13
Spiranthes gracilis	.	.	+.13
Stellaria graminea	.	.	+.13
Verbena hastata	.	.	+.13
Capsella bursa-pastoris	.	.	+.13

Table B.6.2. ...cont'd

Forbs	Pinus-Rhus Association	Pinus-Maianthemum Association	Pinus-Rhamnus Association
Circaea quadrisulcata	.	.	+.13
Solanum dulcamara	.	.	+.13
Brassica campestris	.	.	+.13
Phryma leptostachya	.	.	+.13
Orchis spp.	.	+.14	.
Goodyera repens	.	+.14	.
Osmorhiza Claytoni	.	+.14	.
Epifagus virginiana	.	+.14	.
Grasses			
Agrostis stolonifera	.	+.14	.
Ferns and Allies			
Osmunda cinnamomea	.	+.14	+.13
Dryopteris marginalis	.	+.14	+.13
Botrychium multifidum	.	+.14	+.13
Lycopodium obscurum	.	+.14	+.13
Polypodium vulgare	.	+.14	+.13
Thelypteris noveboracensis	.	+.14	.
Gymnocarpium Dryopteris	.	+.14	.
Botrychium virginianum	.	.	+.13
Lycopodium complanatum	.	+.14	.
Cystopteris fragilis	+.13	.	.
Thelypteris palustris	.	.	+.13
Osmunda regalis	.	.	+.13
Osmunda Claytoniana	.	.	+.13
Athyrium Filix-femina	.	.	+.13
Onoclea sensibilis	.	.	+.13
Lycopodium clavatum	.	+.14	.

*(Table B.6.2. lists those species showing less than 15% constancy). (Number to left of dot is percent coverage, that to right is percent constancy).

Table B.6.3. Pinus strobus Alliance Population Structure* and Habitat Data

Plot #	51	56	50	97	110	46	49	138	109	78	159	93	145	75	124	76	163	98	72	73	74	86	85
											Pinus strobus												
(1-2)		3	6			2	56	3		1	5		2	16	38		29	48	55	7	123	14	1
(3)							39	4	2					7	19	1		8	5	6	11		1
(4)	6	5	2	5	2	3	11	12	3	1		1		7	33	2	4	5	6	9	13	1	13
(5)		3	3	9	8	2	5	8	9					4	3		2	3		2	6		16
(6)			2	3		2	3	3	3	2		2	1	4			3	3	2	1		2	5
(7)										1		2	4			1			2	1	1		
(8)										3		4	2				1			1	1	1	
(9)											1		3				2					1	
(10)											1		2										
(11)												2				1							
			Abies balsamea								Acer saccharum							Abies balsamea					
(1-2)	5	270	194	313	119	61	3	139		4		317	174			186	32	11	34	2		174	17
(3)		8	41	14	13	24		32				13	1			9	3		6			4	
(4)			5	3	2	5		1				7				2	1		1				
(5)																1							
(6)													2			1							
(8)													1										
						Thuja occidentalis												Quercus rubra					
(1-2)		27	2	2				49	5		18			14		2	20	2	82	11	66	23	2
(3)		2						6	2	5	10			19									
(4)								5		3	9										1		
(5)			1					2	2	2	3										2		
(6)											1	1											
			Picea glauca								Tsuga canadensis							Picea glauca					
(1-2)	9	6		30	42	2	6	20			11	2				3	1	33	7	2		12	1
(3)	14	2		11	12	3		3			6		4			3	3	6	1	1		2	
(4)	10	3		18	2	2		6			2		6			8	9	3		1	1	1	
(5)		2		3	1		2	1			5		1				3						
(6)								1				2					2						
(7)																	1						
			Pinus-Rhus Association								Pinus-Maianthemum Association							Pinus-Rhamnus Association					

* (Data plotted is the actual number of stems).

Table B.6.3. ...cont'd

Plot #																							
Populus tremuloides									**Acer rubrum**														
(1-2)		8			1	11	53				298		1	3	30	14	250		127	77	36	134	48
(3)				2	4	9	6	2			7				2		8		2	2	6	1	
(4)	2	3		3	2	8					2		1				1			2	6		
(5)				2		2					4												
(6)											1												
Other Species																							
(1-2)	152	407	36	112	125	465	190	7	257	201	69	31	150	64	16	49	12	435	471	414	110	228	259
(3)		2	2		2	12	7	1	11	18	6	15	1	1	2	9			7	30	4	14	7
(4)		2				2	6	2	8	7	3	6	3			16		3	3	9	6	4	5
(5)										5	2	1	2			3							
(6)																							1
(7)			2							1						1			1				
Habitat Data																							
Percent Slope	0	2	0	0	3	0	2	6	0	12	2	4	0	0	0	0	2	0	3	3	6	3	1
Aspect	-	E	-	-	SE	-	W	SE	-	NE	NW	S	-	-	-	-	E	-	SE	W	N	NE	NW
Total Stand Basal Area (m2/ha)	12	27	27	44	27	29	34	46	32	49	68	93	108	13	24	66	94	25	35	37	41	42	50
Soil Type[1]	F	F	Us	F	F	Us	Us	F	F	A	Rs	A	O1	A	Ns	A	E	Gr-s	A	A	A	Ns	Ns

1 (Soil type according to Hills *et al*., 1944).

Table B.7.1. Remainder of the Understory Species (Minor Alliances) *

Forbs	A.sacc-harinum Alliance	Q.rubra Alliance	P.glauca Alliance	P.bank-siana Alliance	T.cana-densis Alliance
Asarum canadense	.	.	4.25	.	+.60
Habenaria spp.	.	.	.	+.50	+.40
Arisaema triphyllum	+.50	.	.	.	+.40
Prenanthes spp.	.	.	.	.	+.40
Clintonia borealis	.	.	.	.	+.40
Polygonatum pubescens	.	+.67	.	.	+.40
Cornus canadensis	.	+.67	+.25	.	.
Ribes spp.	.	+.33	+.25	.	.
Solidago spp.	.	.	+.25	+.50	.
Medeola virginiana	.	.	.	.	+.40
Achillea Millefolium	.	+.33	.	+.50	.
Taraxacum officinale	.	.	+.25	.	+.20
Geum allepicum	+.50	.	.	+.50	.
Rumex Acetosella	+.50	+.33	.	.	.
Cypripedium acaule	.	+.33	.	.	+.20
Linnaea borealis	.	.	3.25	.	.
Arctostaphylos Uva-ursi	.	.	.	+.50	.
Aquilegia canadensis	.	+.33	.	.	.
Pyrola secunda	.	.	+.25	.	.
Echium vulgare	.	.	+.25	.	.
Hepatica americana	.	.	+.25	.	.
Mitella nuda	.	.	+.25	.	.
Gaultheria procumbens	.	.	.	1.50	.
Pyrola rotundifolia	.	.	.	1.50	.
Vaccinium angustifolium	.	.	.	13.50	.
Comptonia peregrina	.	.	.	+.50	.
Vicia Cracca	.	.	.	+.50	.
Aralia racemosa	.	.	.	.	+.20
Tiarella cordifolia	.	.	.	.	+.20
Monotropa uniflora	.	.	.	.	+.20
Amphicarpa bracteata	.	.	.	.	+.20
Dentaria diphylla	.	.	.	.	+.20
Lilium philadelphicum	.	.	.	.	+.20
Goodyera repens	.	.	.	.	+.20
Impatiens biflora	6.50	.	.	.	.
Pilea pumila	6.50	.	.	.	.
Parthenocissus quinquefolia	1.50	.	.	.	.
Circaea quadrisulcata	+.50	.	.	.	.
Chelone glabra	+.50	.	.	.	.
Thalictrum dioicum	+.50	.	.	.	.
Solanum dulcamara	+.50	.	.	.	.
Boehmeria cylindrica	+.50	.	.	.	.
Lysimachia thyrsiflora	+.50	.	.	.	.
Lythrum Salicaria	2.50	.	.	.	.
Lysimachia Nummularia	+.50	.	.	.	.
Iris versicolor	1.50	.	.	.	.
Bidens cernua	+.50	.	.	.	.
Polygonum spp.	+.50	.	.	.	.

(Table B.7.1. lists those species showing less than 15% constancy).
(number to left of dot is percent coverage, that to right is percent constancy).

Table B.7.1. ...cont'd

Forbs	A. sacc-harinum Alliance	Q. rubra Alliance	P. glauca Alliance	P. bank-siana Alliance	T. cana-densis Alliance
Xanthium strumarium	+.50	.	.	.	.
Sagittaria latifolia	+.50	.	.	.	.
Lobelia cardinalis	+.50	.	.	.	.
Mentha canadensis	+.50	.	.	.	.
Grasses					
Carex retrorsa	+.50	.	.	.	.
Elymus virginicus	+.50	.	.	.	.
Cinna latifolia	+.50	.	.	.	.
Carex crinita var. crinita	+.50	.	.	.	.
Ferns and Allies					
Dryopteris marginalis	.	+.33	.	.	+.40
Lycopodium complanatum	.	.	.	+.50	+.40
Botrychium multifidum	.	.	+.25	.	+.20
Botrychium virginianum	.	.	+.25	.	+.20
Athyrium Filix-femina	1.50	.	.	.	+.20
Adiantum pedatum	.	.	.	+.50	+.20
Thelypteris palustris	12.50	+.33	.	.	.
Osmunda cinnamomea	.	.	.	.	+.20
Osmunda regalis	.	.	.	.	+.20
Equisetum sylvaticum	.	.	.	.	+.20
Equisetum pratense	.	.	.	.	+.20
Thelypteris Phegopteris	.	.	.	.	+.20
Matteuccia Struthiopteris	2.50	.	.	.	.
Dryopteris Clintoniana	+.50	.	.	.	.
Polypodium vulgare	.	+.33	.	.	.

Table B.7.2. Minor Alliances Population Structure* and Habitat Data

Plot #	153	149	70	64	62	148	77	52	55	157	47	82	5	6	10	151
	A.saccharinum		Q.rubra			Picea glauca				P.banksiana		Tsuga canadensis				
(1-2)	328		13	39	105	2	1	11	6	1	3	5		4		11
(3)	3	3	1		1	1	8	17	14		11	1	4	13	6	23
(4)	3	14	3		7	4	25	5	3	21	15	4	5	13	15	24
(5)	1	10	9		4	7	10	2	2	10	2	1		1	4	2
(6)	3	7	1	1	3	2	1		3		2		1		2	2
(7)	1	3		2		1	1									1
(8)	1	1							2							1
(9)	1															1
(10)		1														
	Fraxinus nigra					Pinus strobus						B.alleghaniensis				
(1-2)	22	43	10		37						36		1			1
(3)		3											4	2		
(4)	1	1				1					2		2	10	1	1
(5)	1										2			7		2
(6)	1		1										2	1		1
(7)	1		1										1			
(8)	1			1												
	Other Species		F.americana					Abies balsamea					Acer rubrum			
(1-2)	4	123	160	148	83	430		236	81		51		9			
(3)		8			3	39		45					4			
(4)		2	1		4	2		5	3		2		2			
(5)		1			1				3		3		3			
			A.saccharum			Other Species				A.rubrum			A.saccharum			
(1-2)			19	88	13	113	152	201	324	3	950	118	26	3		21
(3)			3	1	3	9	23	8	3				2	4	9	1
(4)			2	2			14	8	7			3	3	2	18	2
(5)				1		2	1	4	5						4	2
(6)			1						3			1			1	3
(7)							2					1				
	A.saccharinum Alliance		Q.rubra Alliance			Picea glauca Alliance				P.banksiana Alliance		Tsuga canadensis Alliance				

* (Data plotted in the table is the actual number of stems).

Table B.7.2. ...cont'd

Plot #	153	149	70	64	62	148	77	52	55	157	47	82	5	6	10	151
			Acer rubrum							Picea glauca		Other Species				
(1-2)			5	147	226						34	226	24			5
(3)				10	15							12	6		1	
(4)			1	3	6						1	9	5		2	1
(5)					1						2	6	4	3		1
(6)				2								1	1	3		
			Other Species							Other Species						
(1-2)			72	134	82					321	360					
(3)			15	26	5					11	2					
(4)			3	6	2					5	5					
(5)											3					
Habitat Data																
Percent Slope	0	0	2	1	6	3	2	0	0	10	0	2	34	55	3	8
Aspect	-	-	SE	SW	S	SE	S	-	-	SW	-	W	W	N	SW	W
Total Stand Basal Area (m2/ha)	50	75	36	44	38	38	53	30	50	31	59	33	35	39	47	61
Soil Type[1]	M	Kg	A	A	A	F	A	F	F	E/Us	F	Ns	Er	Er	F	Er

1 (Soil type according to Hills *et al*., 1944).

Table C. Tree and Shrub Species Abbreviations

Trees

Abb	Abies balsamea
Acne	Acer negundo
Acni	A.nigrum
Acr	A.rubrum
Acs	A.saccharum
Acsi	A.saccharinum
Bea	Betula alleghaniensis
Bep	B.papyrifera
Caca	Carpinus caroliniana
Caco	Carya cordiformis
Fag	Fagus grandifolia
Fra	Fraxinus americana
Frn	F.nigra
Juc	Juglans cinerea
Lal	Larix laricina
Osv	Ostrya virginiana
Pib	Pinus banksiana
Pig	Picea glauca
Pir	Pinus resinosa
Pis	P.strobus
Pob	Populus balsamifera
Pog	P.grandidentata
Pot	P.tremuloides
Prs	Prunus serotina
Qum	Quercus macrocarpa
Qur	Q.rubra
Tho	Thuja occidentalis
Tia	Tilia americana
Tsc	Tsuga canadensis
Ula	Ulmus americana

Shrubs

Acp	Acer pensylvanicum
Acsp	A.spicatum
Alr	Alnus rugosa
Amel	Amelanchier spp.
Apa	Apocynum androsaemifolium
Ces	Celastrus scandens
Clv	Clematis virginiana
Coco	Corylus cornutus
Cor	Cornus rugosa
Cos	Cornus stolonifera
Crat	Crataegus spp.
Dil	Diervilla lonicera
Dip	Dirca palustris
Ilv	Ilex verticillata
Juc	Juniperus communis
Loc	Lonicera canadensis
Prp	Prunus pensylvanica
Prv	P.virginiana
Rha	Rhamnus alnifolius
Rhar	Rhus aromatica
RhF	Rhamnus Frangula
Rht	Rhus typhina
Sac	Sambucus canadensis
Sal	Salix spp.
Sap	Sambucus pubens
Shc	Shepherdia canadensis
Soa	Sorbus americana
Spl	Spiraea latifolia
Tac	Taxus canadensis
Via	Viburnum alnifolium
Vib	Viburnum spp.
Vic	V.cassinoides
Vir	Vitis riparia
ViL	Viburnum Lentago
Zam	Zanthoxylum americana