VEGETATION, ENVIRONMENT, AND DISTURBANCE IN THE UPLAND FORESTED LANDSCAPE OF ALGONQUIN PARK, ONTARIO

by

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ABSTRACT

The major purpose of this thesis is to examine the two conflicting models that provide an explanation for the influence of environment on upland forest vegetation composition in the Great Lakes-St. Lawrence Forest Region. One model focusses on soil moisture as the primary determinant of vegetation composition whereas the other focusses on fire as the primary determinant. Three studies were conducted. For the first study, an index to fire incidence was developed using modern fire records and forest resource inventory maps. Results of the Chi-squared test and t-test showed that fire incidence for each tree species differed significantly from at least two other species. This index was then used to determine the probability of fire incidence for each stand sampled. The second and third studies examined the relationship between environmental factors, including fire, and upland forest vegetation of the (1) overstory and (2) understory using ordination methods, including detrended correspondence analysis and canonical correlation analysis. Results indicated that the major influence on forest overstory composition is a fire-soil moisture complex gradient in which (1) the two influences are inversely related and (2) fire has greatest impact. The tolerant hardwood stands, dominated by Acer saccharum, Betula lutea, and Tsuga canadensis, occur mainly at the low fire-high moisture end of the gradient, the pines, dominated by Pinus strobus, Pinus resinosa, and Pinus banksiana, occur mainly at the high fire-low moisture end, and the intolerant hardwood stands, dominated by Populus spp., Betula papyrifera, and Quercus rubra, occur at an intermediate position along the gradient. Results also indicated that a light-fire complex gradient exerted the major influence on understory vegetation composition where (1) fire and light are directly related, and (2) light is regarded as the more important influence. Understory species were classified into one of three growth strategy categories. The "stress tolerators/avoiders", dominated by trees, ferns and Lycopods (e.g. Acer saccharum, Dryopteris spinulosa, and Lycopodium obscurum), can tolerate low light stress but not fire. The "ruderals/endurers", dominated by shrubs and summer herbs (e.g. Corylus cornuta and Aralia nudicaulis), can tolerate fire but not low light stress. The "generalists", dominated by all major growth forms including trees, shrubs and summer herbs (e.g. Acer rubrum, Viburnum alnifolium, and Trientalis borealis) are successful across a wide range of fire and light intensities. It is probable that fire suppression in Algonquin Park has changed and will continue to change the composition of the upland vegetation.

CHAPTER 1 - INTRODUCTION

"Natural communities provide the research subjects through which evolution and the function of the living world may be understood, and a standard by which the behavior of ecosystems altered by man can be interpreted" (Whittaker, 1975; pg. 371). We are, however, rapidly losing our opportunity to develop this understanding and to accurately interpret human influence upon the behavior of forested ecosystems throughout the world. This is principally because we have failed to protect many ecosystems from human alteration and because, in those cases where protection is impossible, we have failed to monitor the impacts of our influence.

One such case is Algonquin Park, Ontario. Although it is one of North America's oldest and most well-known parks, it was only recently that small portions of it were designated for protection from human influence (Ontario Ministry of Natural Resources, 1974). The major forms of human influence in the park include timber harvesting, fire suppression, acid deposition, and recreation (Martin, 1959; Pimlott et al., 1969; Ontario Ministry of Natural Resources, 1974; Cwynar, 1977; Cwynar, 1978; Brown, 1980), none of which is currently being monitored for the purpose of conserving the forest resources of the park. The future integrity of Algonquin is dependent upon successful conservation of these forest resources.

To accurately assess alterations due to human activity, one must have a sound concept of the structure and function of the undisturbed or mature ecosystem (Bormann et al., 1974). The first step in developing such a concept for forested ecosystems is to discover the compositional variation in the dominant ecosystem component, the primary producers or the green plants (Carleton, 1984; Weins, 1984). The variation within the dependent variable (vegetation composition) is "ultimately controlled by two sets of independent variables: physical environmental parameters and other species" (Diamond, 1986; pg. 3). Because environmental factors, including resource availability, are more fundamental to the description of species habitat than the effects of other species (Billings, 1952; Daubenmire, 1974; Price et al., 1984), the majority of forest community studies have focussed on the former.

Since Whittaker's (1956) seminal work in the Great Smoky Mountains, many studies have demonstrated the importance of environmental factors in explaining forest composition within various regions of North America. These include studies within the Boreal Region (Damman, 1964; Drew and Sharks, 1965; Jeglum, 1974; Dyrness and Grigal, 1979; Carleton and Maycock, 1980; Carleton, 1982; Corns, 1983; Viereck et al., 1983; Yarie, 1983), the Great Lakes Region (Curtis, 1959; Maycock and Curtis, 1960; Lopoukhine, 1974; Pastor et al., 1982; Pregitzer et al., 1983; Boerner 1984, Whitney 1986), the northern Appalachian Mountains (Holway and Scott, 1969; Bormann et al., 1970; Siccama, 1974; Whitney and Moeller, 1982), the central Appalachian Mountains (McIntosh, 1972; Keever, 1973; Collins and Pickett, 1982), the southern Appalachian Mountains (Mowbry and Oosting, 1968; Golden, 1981; Harmon et al., 1983;

Mansberg and Wentworth, 1984; Rheinhardt and Ware, 1984), the Atlantic Coastal Plains (Pella-Bianca and Olson, 1961; Nesom and Treiber, 1977; Marks and Harcomb, 1981; Jones and Gresham, 1985), the Rocky Mountains (Langenheim, 1962; Patten, 1963; Despain, 1973; Whittaker and Niering, 1975; Peet, 1981). and the Pacific Coast Mountains (Gardner, 1958; Whittaker, 1960; Waring and Major, 1964; Baily and Poulton, 1968; Waring, 1969; Wali and Krajina, 1973; Zobel et al., 1976; Moral, 1978; Vankat, 1982; Parker, 1982; Goldberg, 1982; Borchert and Hibberd, 1984).

Although descriptive, survey oriented scientific studies cannot demonstrate causation (Pianka, 1969), they are extremely useful for identifying and determining the relative importance of ecological relationships, for generating testable hypotheses (Gauch, 1982; Pielou, 1984), and for putting later more detailed studies into context. Quinn and Dunham (1983, pg. 603) state that:

> "In practice, the logic of ecological and evolutionary research differs from the Popperian model in being largely inductive...Generally, no single cause can be shown to account for all of the observed variation in patterns and processes in natural communities. The objective of investigation in cases of this sort is not to determine the single cause of a pattern, as no such cause exists, but rather to assign relative importances to the contributions of, and interactions between, a number of processes, all known or reasonably suspected of operating to some degree...It is certainly true that

> the history and sociology of actual scientific advances often correspond poorly to the process envisioned in the hypothetico-deductive model (Kuhn, 1970; Brush, 1974)."

Relative to the hypothetico-deductive methods of laboratory and field experimentation, the natural experimental or survey approach is most advantageous with regard to temporal scale, spatial scale, realism, and generality (Diamond, 1986). It is, however, the worst procedure with respect to regulation of independent variables and site matching.

For this study, the survey approach was used to examine two conflicting models that provide an explanation for the influence of environment upon forest composition within the Great Lakes-St. Lawrence (GLSL) Forest Region. This involved identification and description of vegetation composition and its variation within typical upland forests of Algonquin Park and examination of relationships between vegetation composition and environmental factors.

Three separate but related studies were conducted for this thesis. The first study involves the development of a method to quantify the incidence of fire in post-fire stands within which the evidence of fire no longer existed or was too scanty to utilize. This method was necessary in order to carry out the second and third studies. For the second study the relationship between environmental factors, including fire, and overstory vegetation was quantified. Because the understory of a temperate forest normally differs substantially from its overstory with regard to plant growth forms (herbs and shrubs versus mature trees) and life cycle stage of the trees (seedlings and saplings versus mature trees), the relationships between understory vegetation and environment were investigated separately from the relationships between overstory vegetation and environment for the third study.

CHAPTER 2 - LITERATURE REVIEW

In 1877 the need for modern science to recognize the concept of biota and environment as an integrated whole was stated by Mobius: "Science possesses, as yet, no word by which such a community of living things (oyster beds) may be designated; no word for a community where the sum of species and individuals, being mutually limited and selected under the average external conditions of life, have, by means of transmission continued in possession of a certain definite territory". To define this phenomenon, he proposed the term "biocoenosis". In western science, however, this concept has come to be known as the "ecosystem", originally coined by Tansley in 1935.

Recognition of the ecosystem concept by the scientific community in the late 19th Century emphasized the need to focus on relationships between and among organisms, their assemblages, and their environment. Early investigations which focussed on the influence of environment upon the composition of biota identified climate, in the form of temperature (Merriam, 1894) and the ratio of precipitation to evaporation (Tanseay, 1905), as the primary determinants of animal and plant community composition. Later, Thornthwaite (1948) analyzed temperature and precipitation records to determine water availability which was then shown to be correlated with the regional distributions of major types of vegetation.

For a number of years, the theory that moisture determined the distribution of vegetation types dominated descriptive forest ecosystem studies within the GLSL Forest Region. The broadest of these studies was carried out by Maycock and Curtis (1960) who sampled stands throughout the Great Lakes region. They explained the occurrence of species and community types using a moisture gradient as the dominant environmental influence. The dry end of their gradient was dominated mainly by white pine and red pine; the wet end was dominated mainly by sugar maple, yellow birch, and hemlock; and the intermediate portion of the gradient was dominated by red maple, white spruce, and white birch. Other studies which focussed on the forests of the GLSL Forest Region were more local in nature.

In a northern Minnesota study, Alway and McMiller (1933) showed that from high levels of site moisture to low levels, the following tree species were observed to dominate, respectively: maple-basswood, white pine, Norway spruce, and jack pine. Flaccus and Ohmann (1964) also presented data which were consistent with the moisture hypothesis. In addition to the types observed by Alway and McMiller (1933), Flaccus and Ohmann (1964) observed forests dominated by red pine, sugar maple-yellow birch, black spruce-tamarack, northern white cedar, and black ash occurring along a moisture gradient from low to high. In adjacent northern Wisconsin, Brown and Curtis (1952) found that, in addition to those observed by Flaccus and Ohmann (1964) and Alway and McMiller (1933), the patterns of forest communities dominated by hemlock, red oak, white birch, trembling aspen, and *Quercus ellipsoidalis* were strongly influenced by soil moisture.

Very little work on the structural relationships between forest composition and environment has been conducted in the eastern portion of the GLSL Forest Region. One study indicated that the occurence of forest communities within Gatineau Park, Quebec is determined primarily by differences in site moisture conditions (Lopoukhine, 1974). Major species included sugar maple, American beech, and yellow birch at the moist end of the gradient, white and red pine at the dry end, and intermediate along the gradient were red oak and poplar. Adjacent to the eastern border of Algonquin Park, closer to the central portion of the GLSL Forest Region, Fraser (1954) also found that moisture was the major determinant of forest composition.

It was not until Hill's (1959) and Anderson's (1969) work within and around Algonquin Park, however, that moisture was perceived as a member of a complex environmental influence rather than the sole forest compositional determinant. In his forest ecosystem classification scheme Hills (1959) considered the influence of soils and disturbance as well as climate. The most important of these were texture, fire, logging, clearing, insects, diseases, browsing, and silvicultural treatments all of which were described as having variable influences upon forest succession based upon qualitative field assessment.

Although it was not noted by Hills (1959), fire is not only important in initiating forest succession, but it is integral to maintaining certain types of mature, or old-growth forest communities such as those dominated by white and red pine (Horton and Brown, 1960; Anderson 1969). Workers such as Stearns (1951), and Flaccus and Ohmann

(1964) mentioned the possible influence of fire, but generally dismissed it as relatively unimportant. Instead, the theory that fire plays an important role in determining forest composition in the GLSL Forest Region was pursued by a different group of researchers than those who focussed on moisture as the major influence upon forest composition.

These fire-based studies began in 1935 when Maissurow showed that natural regeneration of white pine in central Quebec was associated with the effects of fire. Drawing from observations in New England, Michigan, and Wisconsin, Cary (1936) also pointed out the importance of fire in the perpetuation of white pine. Later Maissurow (1941) found that abundant reproduction occurred in yellow birch, basswood, elm, hemlock and white pine stands as a result of surface fire, but that reproduction was very low in similarly affected sugar maple stands. He concluded that fire is a "beneficial and necessary factor in the perpetuation of [many] virgin forests" in the GLSL Forest Region.

Studies of the effects of recent fire stimulated further research into the historical incidence of fire and its relationship to forest composition both in Minnesota (Spurr, 1954; Heinselman, 1973; Swain, 1973) and central Ontario (Cwynar, 1977; 1978). The results of these historical studies confirmed that the presence of pine forests is due mainly to the effects of periodic fire. In addition, the presence of aspen was found to be significantly influenced by fire because of the tendency of aspen to sprout under conditions of increased temperature (Swain, 1973; Heinselman, 1973). Swain (1973) and Cwynar (1977, 1978) have determined that the average fire rotation for portions of the GLSL

Forest Region dominated by pine and poplar ranged from 60 to 80 years.

In addition to being influenced by environmental factors, forest community composition is affected by the process of ecological succession, also known as ecosystem development (Bormann and Likens, 1979b). Succession may be defined as a change in ecological community composition with time. In contrast to the classical succession model of community-by-community replacement, modern concepts suggest that "succession occcurs as the result of differential survival and growth of individual species that are adapted to grow best at different stages in the successional sequence" (Kimmins, 1987; pg. 410). Finegan (1984) states, however, that "Neither reductionist [(modern succession concepts)] nor holistic [(classical succession concepts)] theories of succession have produced models which explain field observations." He argues that a third, synthetic approach representing a combination of the two major successional theories should be sought.

Two primary studies of forest succession have been conducted in the Algonquin Region. Although these studies fit more with the classical theory of succession, they are valuable from a descriptive perspective. For the first study, Martin (1959) identified two major successional pathways in the forests of Algonquin. The hydrosere, a successional sequence that begins with the filling of open water and progresses to dry land, went from bog, to black spruce forest, to black spruce-white cedar forest and finally to a bottomland forest composed of balsam fir and alder.

The other successional pathway identified by Martin (1959) was a xerosere or a successional sequence occuring mainly on well-drained land areas. For the primary xerosere sequence, the progression was from balsam fir-white spruce forest, to white pine forest, to hardwood forest composed of sugar maple, yellow birch and hemlock. Secondary succession in the xerosere progressed from either a white birch-poplar forest or a jack pine forest, to a forest of either balsam fir-white spruce or white pine, to a subclimax of hardwoods and finally to a climax of hemlock. Climax here refers to the endpoint of successional development and subclimax refers to the stage immediately preceeding climax.

In contrast to Martin (1959), Hills (1959) recognized the variable affect of environmental gradients and disturbance on forest successional pathways in the Algonquin Region. He classified the environmental gradients at the first level based on climate using three broad classes: "normal ecoclimate", "hotter ecoclimate" and "colder ecoclimate". Within each broad climate class, six soil moisture classes were identified and various forms of disturbance such as fire, logging, clearing, insects, tree disease, browsing, planting, and silvicultural treatments were also considered. A total of 43 potential successional sequences that varied according to landform, temperature, soil moisture and disturbance were identified by Hills (1959) resulting in as many different climax communities. A total of 20 tree species occurred as dominants or co-dominants in these climax communities, 18 of which are common to Algonquin Park.

Hills' (1959) recognition that different successional sequences occur on different site types under different disturbance regimes was closer to the modern population oriented concept of forest succession than Martin´s (1959) unidirectional, community-by-community replacement sequence.

CHAPTER 3 - STUDY AREA

INTRODUCTION

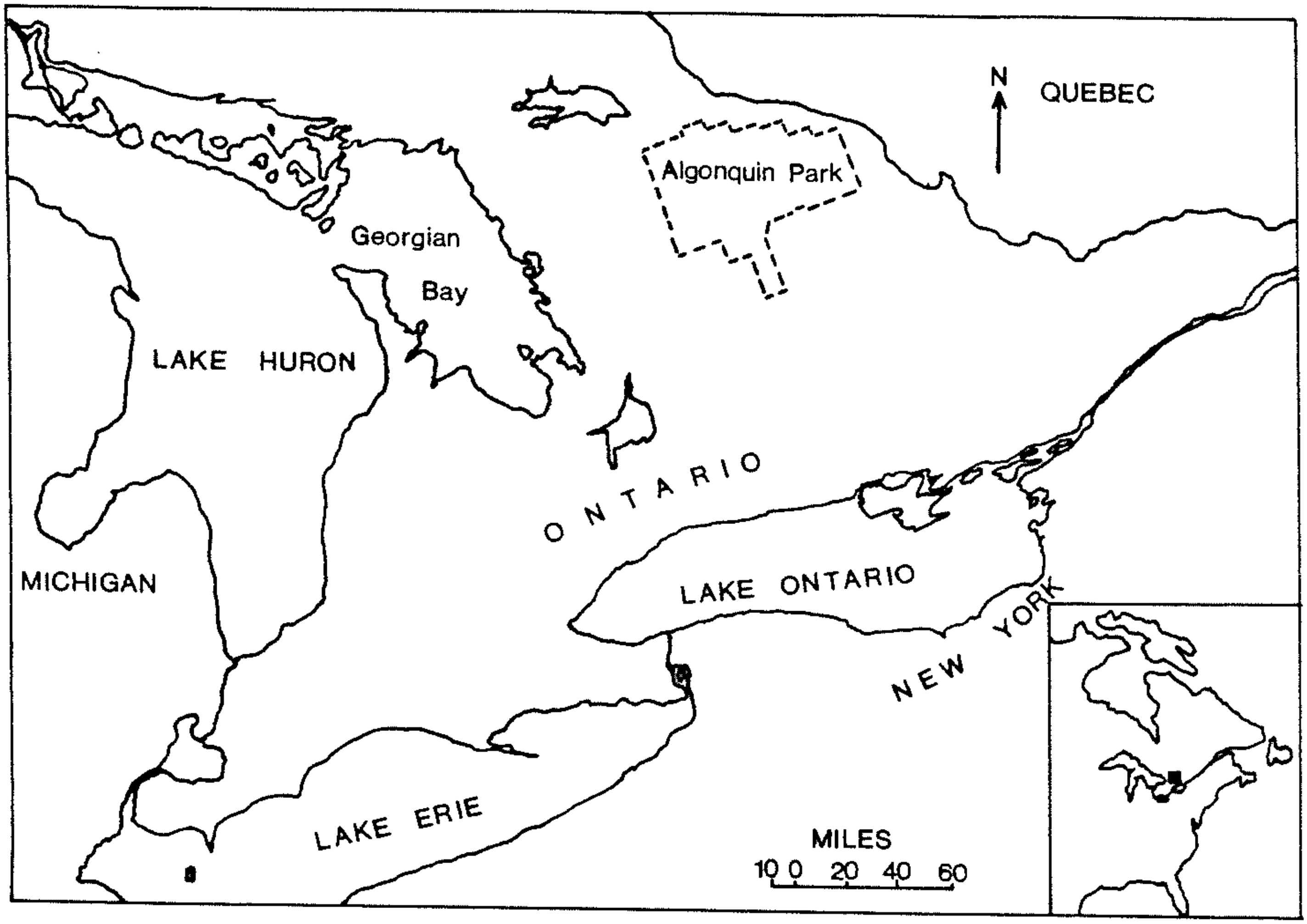
Algonquin Park is located in the northern part of southern Ontario and occupies approximately 770,000 ha (Figure 3-1). Two topographic systems predominate in the park - the Precambrian uplands in the west and the Ottawa lowlands in the east. The highest elevations, up to 580m, occur in the Precambrian uplands. Characteristic of these uplands are small, deep lakes scattered within a rolling, irregular topography. The Ottawa lowlands feature elevations ranging from 180 to 380 m with a more regular relief, a predominance of river systems and fewer lakes.

CLIMATE, GEOLOGY AND SOILS

Compared to adjacent areas, the park has lower temperatures and greater precipitation due to higher than average elevations. The average July air temperature is 19 degrees C and in January the air temperature averages -11.5 degrees C (Brown et al., 1980). Mean annual precipitation varies from 91 cm in the west to 66 cm in the east (Brown et al., 1980).

The bedrock underlying the park is part of the Canadian Shield known as the Grenville Structural Province and is dominated by granitic

FIGURE 3-1 - REGIONAL SETTING OF ALGONQUIN PARK



and biotite gneiss interspersed with intrusive dikes of amphibolites (Adams and Barlow, 1910; Hills, 1959). The soils of Algonquin are predominantly Dystric Brunisols although some Podsols do occur (Canada Soil Survey Committee, 1978). Within the Precambrian uplands, the soils have been derived mainly from glacial deposits of loose and compact till, and they range in depth from 0 to 3m with occasional depths over 10m in some areas. Sandy waterlain deposits do occur in narrow valleys. The Ottawa lowland soils are derived from the same parent material found in the uplands as well as from broad glacial outwash deposits of sand and gravel. These plains vary in texture from course gravel to fine sands with depths occasionally as great as 20m. All upland soils are generally coarse textured and acidic.

FOREST COVER

Pimlott et al. (1969) identified three major forest types in Algonquin Park that include the tolerant hardwoods, intolerant hardwoods, and pines. The tolerant hardwoods and intolerant hardwoods differ with respect to their tolerance to low levels of light. The western uplands of Algonquin Park are dominated by tolerant hardwoods including sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula lutea* Michx. f.), and hemlock (*Tsuga canadensis* (L.) Carr.). The eastern lowlands are dominated by both pines and intolerant hardwoods. The pines include white pine (*Pinus strobus* L.), red pine (*Pinus resinosa* Ait.), and jack pine (*Pinus banksiana* Lamb.). The intolerant hardwoods include trembling aspen (*Populus tremuloides* Michx.), large-toothed aspen (*Populus grandidentata* Michx.), white birch (*Betula papyrifera* Marsh.), and northern red oak (*Quercus rubra* L.).

There are a variety of similarities and differences between the forest composition in Algonquin and the forest composition in the other portions of the GLSL Forest Region. Lopoukhine's (1974) data from Gatineau Park, Quebec indicate that forest composition there differs from that in Algonquin mainly by the greater representation of black ash and red oak, the lesser dominance of yellow birch and jack pine, the association of red oak with sugar maple, and the association of hemlock with red and white pine. Sugar maple is the dominant forest type in both areas (Lopoukhine, 1974) and throughout southern Quebec (Lemeiux, 1963). Algonquin Park and the Gatineaus are also similar with regard to the common association of sugar maple with yellow birch and beech.

In the upper St. Lawrence River area, common upland tree species not found in Algonquin include white ash, shagbark hickory (*Carya ovata* (Mill.) K. Koch.), gray birch, butternut (*Juglans cinerea* L.), bitternut hickory (*Carya cordiformis* (Wang.) K. Koch.), and pitch pine (*Pinus rigida* Mill.) (Hirvonen and Woods, 1978a). Forest composition similarities include only Hirvonen and Woods' (1978a) poplar-birch association which was most similar to the poplar spp. community type identified within Algonquin.

The upland forests of Algonquin are also very similar to those which are found to the west, along the eastern shore of Lake Huron except that red oak, red maple, and beech are more abundant along the

Huron shore and poplar is much less abundant (Hirvonen and Woods, 1978b). In addition, white oak (Quercus alba L.), white ash (Fraxinus americana L.), and eastern red cedar (Juniperus virginiana L.) occur along Lake Huron's eastern shore but are absent from Algonquin.

Studies of upland forests further west in the Upper Peninsula of Michigan indicate that the majority of upland areas are dominated by sugar maple, yellow birch, and hemlock (Pregitzer and Barnes, 1984; Spies and Barnes, 1985). In addition, white pine, jack pine, red oak, black ash, and red maple occur throughout the upland forest communities. The common Algonquin species red pine, large-toothed aspen, and trembling aspen were not commonly found in northern Michigan.

The GLSL forests of northern Wisconsin differ from those of Algonquin mainly in terms of a greater importance of beech and jack pine, the lesser importance of large-tooth aspen, and the presence of a few common species which do not occur at all in Algonquin (Curtis, 1959). These include Hill's oak (Quercus ellipsoidalis E. J. Hill.) and white oak (Quercus alba L.).

The forests at the western extreme of the GLSL Forest Region in northeastern Minnesota are most dissimilar to those of Algonquin. The major difference is the absence of the tolerant hardwood community dominants including sugar maple, yellow birch, hemlock, and beech in Minnesota (Ohmann and Ream, 1971; Grigal and Ohmann, 1975). Red oak is of low importance in northeast Minnesota but occurs as a community dominant in Algonquin. The western GLSL forests have a greater proportion of boreal species including black spruce as an upland dominant.

FIRE

Palynological data from Barron Township on the east side of Algonquin Park indicate that, for the period 770 to 1270 A.D., the frequency of large fires was approximately once every 80 years (Cwynar, 1978). More recent fire history data for the pre-suppression period 1696 to 1920 indicate that the fire rotation in Barron Township is about 70 years (Cwynar, 1977). In other words, prior to human fire suppression, it took only approximately 70 years for fire to burn over 18,600 ha within Barron Township. Some areas may burn more than once, thus the entire township may not have burned within the 70 year rotation period.

Since 1921, fires have been suppressed in Algonquin Park. Using fire history data from Brown (1980, pg. 37) the fire rotation for Barron Township since suppression was calculated at 936 years, which represents a 13-fold decrease in the amount of forest burned in Barron Township for a 70-year period from 1921 to 1991. Because Barron Township is similar in forest composition to other townships on the east side of Algonquin it is probable that similar increases in fire rotation have taken place in these townships.

In addition to suppressing fires, humans affect the fire regime in Algonquin Park by igniting fires. Table 3-1 lists the causes of fires, their frequency, and area burned. Naturally-caused (lightning) fire for

TABLE 3-1 - THE CAUSES OF ALGONQUIN PARK FIRES AND AREA BURNED FOR 1973-1978 INCLUSIVE (from Brown, 1980, pg. 37)

	FREQUENCY (6 years)		AREA BURNED (acres)	
CAUSE	Absolute	Percent	Absolute	Percent
Lightning	68	22	431	47
Railway	16	5	321	35
Recreation	207	67	144	16
Resident	2	<1	<1	<1
Miscellaneous	6	2	3	<1
Industrial	3	1	1	<1
Incendiary	2	<1	2	<1
Unknown	6	2	5	<1

the period 1973 to 1978 inclusive made up the greatest percentage of the burned area. Railway fire ignition resulted in 35% of the burned area and recreation resulted in 16% of the area burned. Residential, industrial, and incendiary causes made up less than 1% each.

LOGGING

The location and nature of logging effects on forest ecosystems in Algonquin Park are unknown. However, a general review of the logging chronology in Algonquin Park is provided by Brown (1980). Cutting of white and red pine in Algonquin began about 1830 and peaked in 1864. Sawmilling, mainly of white and red pine, replaced the square timber trade in the late 1800's and by the 1930's other tree species were being cut. The harvesting of yellow birch, the first hardwood cut in Algonquin, peaked in the mid-1950's. Sugar maple harvesting began in 1945 and has expanded since then. In addition to coniferous pulpwood, the volume of low quality deciduous pulpwood has increased significantly in the last 15 years. All but the rare tree species in Algonquin are currently harvested.

Many silvicultural systems are used in the 75% of the park that is presently being logged. Variations of the selection method are applied in tolerant hardwood, hemlock, and balsam fir stands. The shelterwood method is used in white pine, black spruce, white cedar, hemlock, and tolerant hardwood stands. For red pine, white spruce, and red spruce stands the seed tree method is used. Lastly, clearcutting is applied in balsam fir, jack pine, poplar, and white birch stands.

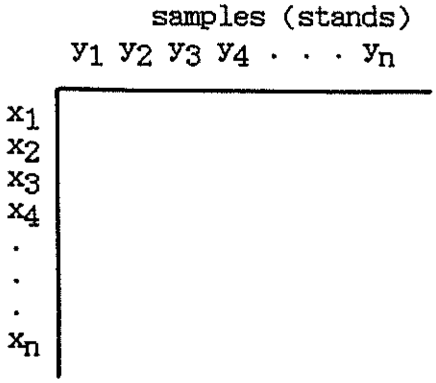
CHAPTER 4 - DESCRIPTION OF MULTIVARIATE METHODS

Data describing the structure of vegetation and environment within forested ecosystems are multivariate in nature. The vegetation structure for the study area was represented within a two-way data matrix which described species abundance for all sampled stands. The structure of the environment within these stands was also represented within a two-way data matrix which described the magnitude of a variety of environmental factors. Figure 1-1 shows the structure of a two-way data matrix which is the first step in data reduction and ordination. By reducing the complexity of these data it is possible to obtain interpretable results. A simple way to do this for vegetation data is to identify the distribution of species along an environmental gradient that is easily recognized and measured. This is called direct gradient analysis (Whittaker, 1948; 1967). Although this approach fulfills the objectives of summarizing and revealing the structure of multivariate data by using simple graphing procedures, it is generally not preferred over other methods because (1) the gradient is based on a single environmental factor when in fact there is usually a complex of environmental factors involved and (2) selection of the controlling environmental factor is subjective.

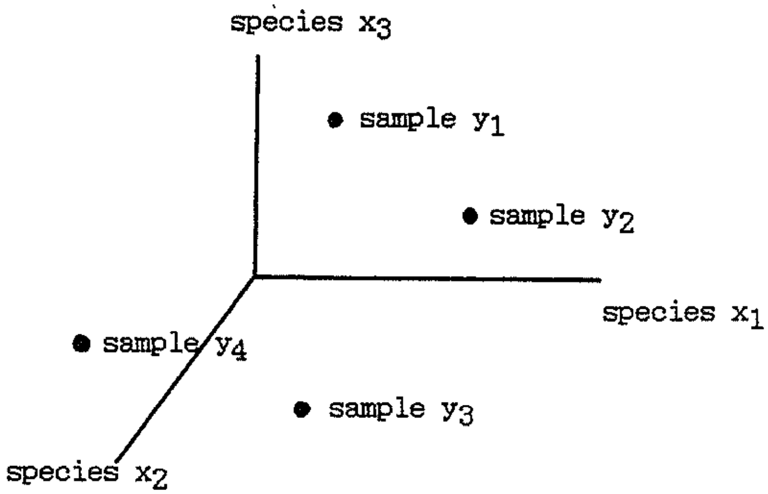
The alternative is indirect gradient analysis or ordination which is defined by Pielou (1984) as "a procedure for adapting a multidimensional swarm of data points in such a way that when it is

FIGURE 4-1 - DATA REDUCTION AND ORDINATION

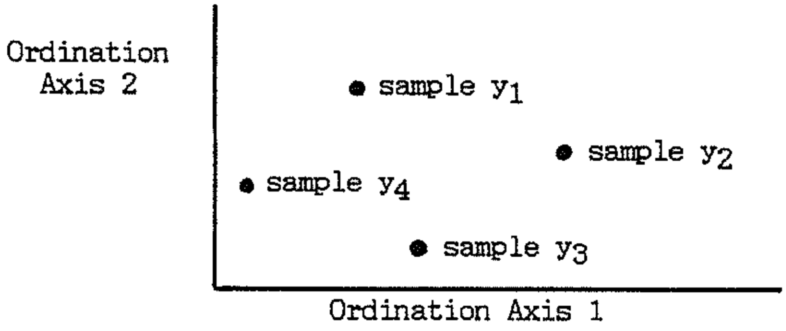
PART A - "Two-Way Data Matrix"



PART B - "Multi-dimensional Swarm of Data Points"



PART C - "Two-dimensional Ordination Plot"



projected onto a two[dimensional]-space any intrinsic pattern the swarm may possess becomes apparent." (see Figure 1-1, Parts B and C). The result is a graph in which similar samples are near each other and dissimilar samples are far apart. It differs from direct gradient analysis mainly in that all environmental influences can be objectively related to the biological data using the ordination results, however, this must be performed in a subsequent step.

Gittins (1979) states that there are three major advantages to ordinating vegetation for eventual analysis with environmental data. These include the following: (1) a sample represented by numerous species abundance values is reduced to a single value associated with each ordination axis which can then be assessed statistically as the dependent variable, (2) it renders the data more continuous, and (3) it transforms the vegetation data into more linear relationships to conform to the nature of the environmental data.

Of all the ordination methods currently available, Hill and Gauch (1980) have shown that detrended correspondence analysis (DCA) is at least as good as, and usually superior to, other ordination techniques. Therefore, DCA was chosen to ordinate the understory and overstory vegetation data collected for this study. DCA is based on the ordination technique reciprocal averaging (RA) (Hill, 1973) with the correction of its two main faults.

There are two ways to produce results using RA. First, RA can be thought of as a version of principal components analysis (PCA) that differs from it "in the way the data matrix is transformed before the eigenanalysis, and in the way in which the eigenvectors are transformed into scores after the eigenanalysis" (Pielou, 1984; pg. 177). The stand and species scores are calculated by RA as to maximize the correlation between them. The proof of this can be found in Anderberg (1973, pg. 215).

RA can also be done by reciprocal averaging. Pielou (1984) provides an outline of this procedure.

> First, arbitrary trial values are chosen for the species scores. Next, a first set of quadrat scores is computed from these species scores. Then a second set of species scores is computed from the first set of quadrat scores, then a second set of quadrat scores from the second set of species scores. And so on, back and forth reciprocally, until the vectors of scores maintain constant relative proportions.

During the process, RA scores are rescaled into a range of 0 to 100 in order to avoid a very small range. Between 20 and 100 iterations are normally required for convergence. However, the closer the first iteration scores are to the final scores, the fewer iterations are required. The amount of variation in the data accounted for by the first ordination axis (the first eigenvalue) is equal to the contraction in the range of species scores in one iteration after convergence. The second and consecutive axes are extracted using the same iterative method except for a correction for independence from the former axis or axes. Each new axis has an eigenvalue less than the one previous.

The two major faults of RA have been alleviated through the development of DCA. These faults include (1) the arch problem - successive axes may be geometric distortions of former axes, and (2) a given distance of separation between points (samples or species) in the ordination does not carry consistent meaning because the points at the first axis ends are compressed relative to those in the axis mid-section.

Both of the above weaknesses were remedied by Hill (1979). To correct the arch distortion problem of RA, detrending of its axes was implemented. This involved dividing axis 1 into a number of segments within which the axis 2 scores were adjusted to have an average of zero. This is done at each iteration until convergence is reached. At this point, final sample scores are determined without using detrending. Each successive axis is calculated by detrending sample scores with respect to all previous axes.

In order to ensure consistent meaning for distances between points in the ordination space, rescaling is undertaken. The objective of this is to (1) ensure that species turnover occurs at a random uniform rate along the species ordination axis and (2) that equal distances in the ordination correspond to equal distances in species composition. Rescaling was accomplished by assuring a constant within-sample standard deviation by contracting or expanding small segments of the sample ordination. This constant was set to 1 to achieve a standard scaling. Thus, instead of being scaled into a range of 0 to 100 as is done with RA, DCA is scaled in natural units. Detrending is applied to the second and higher axes and rescaling is applied to all axes.

The advantages of DCA over other ordination techniques include (1) species as well as sample ordinations (RA also provides this), (2) elimination of the arch problem, and (3) uniform axis scaling. The disadvantages of DCA include (1) coping with outliers and discontinuities - outliers must be removed, (2) interpretation of axes, (3) species ordinations are usually less satisfactory than stand ordinations, and (4) rather than a geometric process, detrending is empirical in nature.

The ordinated vegetation data in this study were correlated with environmental data using the multivariate technique called canonical correlation analysis (CCA) (Hotelling, 1936) which has been effectively applied and demonstrated by Gittins (1979, 1985). CCA is an eigenanalysis method designed to measure correlations between data sets (Pimentel, 1979). It is readily applicable to a samples scores-by-vegetation axes matrix of vegetational data and a samples-by-environmental measurements matrix of environmental data (Gauch, 1982). The correlations between the two sets of variables are examined by constructing two groups of linear compounds which are called canonical variates. Carleton (1984) states that "The variates may be conceived as a group of ordination axes derived from one set of variables (e.g. species in vegetation data) rotated, under certain constraints, to correlate maximally with a group of ordination axes derived from the other set of variables (e.g. environmental measurements at vegetation sample locations)." Intraset and interset correlations may be derived and their squared values indicate the proportion of variance explained by the corresponding canonical variate.

The value obtained by averaging the interset correlations for each canonical variate is termed the redundancy measure. This measure is equivalent to the R^2 criterion which is maximized in the techniques of multiple regression and multiple correlation problems (Cooley and Lohnes, 1971) and is synonymous with explained variance. The largest possible redundancy value is 1 which can only occur when canonical correlation is 1 and all the variance of a set is extracted. The larger the redundancy of sets, the greater is the relationship between the two.

The advantages of the use of CCA for elucidating vegetation-environment relationships include objectivity (Gauch, 1982) and consideration of environmental factors as interdependent and interrelated influences on vegetation as opposed to the straight regression approach which considers environmental factors as isolated, independent influences.

There are, however, three major problems associated with this technique which should be avoided (Carleton, 1984). First, linearity of data is assumed when, in fact, vegetation data are non-linear. To mitigate the effects of this problem, the vegetation variables were reduced and transformed from discontinuous, nonlinear data to continuous, linear form using the ordination technique of DCA. Second, spuriously high canonical correlations may arise from chance correlations between a single minor variable in each data set even though redundancy levels may be low. Therefore, emphasis should be placed on redundancy levels rather than canonical correlations. Third, small sample sizes can lead to a low sample:variance ratio which in turn can cause unreasonably high canonical correlations and/or insignificant redundancy levels.

CHAPTER 5 - AN INDEX TO FIRE INCIDENCE

INTRODUCTION

When assessing environmental influences on community structure and dynamics, it is necessary to consider the role of natural disturbance (Harmon et al., 1983; Sousa, 1984; Canham and Marks, 1985; Pickett and White, 1985). Naturally caused fire is often a very important influence on forest composition within the mixed forest region of eastern North America. The most suitable methods presently available for assessing the role of naturally caused fire in this region include (1) paleoecological analysis of lake sediments for influx of charcoal, aluminum, vanadium, varve thickness, and the charcoal/pollen ratio (Swain, 1973; Cwynar, 1978), (2) fire scar dating and mapping (Heinselman, 1973; Cwynar, 1977), (3) use of stand origin and age information from even-aged stands (Heinselman, 1873; Cwynar, 1977; Van Wagner, 1978), and (4) the use of historical documents and modern fire records (Spurr, 1954; Wein and Moore, 1977; Wein and Moore, 1979; Fahey and Reiners, 1981).

Paleoecological methods result in broad temporal and spatial generalizations which are usually based on evidence from one or a few sites and, therefore, are not capable of providing site specific fire measures for a series of individual stands distributed across a broad landscape. Fire scar evidence is most abundant and reliable on coniferous trees. Accurate aging of a stand which has resulted from a destructive crown fire requires the presence of even-aged stands. Because the mixed forest region of North America is populated by substantial amounts of uneven-aged deciduous forest, the use of fire scars and stand aging to study fire are not entirely suitable. Historical documents provide only very rough fire size and location estimates, while for modern fire records, the fire size data do not reflect the role of naturally caused fire because of the modifying influence of suppression.

The purpose of this study, therefore, was to develop a method of quantifying the occurrence of naturally caused (lightning caused) fires which (1) could be applied to both deciduous and coniferous dominated stands, (2) would not be subject to the confounding effect of fire suppression, and (3) could be calculated for any stand or community type sampled within the study area. Development of this method was based on testing the null hypothesis that fire incidence within pine, intolerant hardwood, and tolerant hardwood forest types does not differ significantly. Each forest type included a unique set of three species dominance types and fire incidence was defined as "one fire event taking place within a designated area during a designated time" (Romme, 1980; pg. 135).

METHODS

Fire records (Archives of Ontario, 1930-1979) for a 50 year period were analyzed to determine the location of 252 lightning caused fires within a two township wide and eight township long transect which traversed the 72 kilometer east-west width of Algonquin Park, Ontario (see Appendix I for fire information). To determine the species composition of the overstory vegetation at the fire sites, the method of Fahey and Reiners (1981) was used. This involved sampling the vegetation on Forest Resource Inventory (FRI) Maps (Ontario Ministry of Natural Resources; 1959, 1978) at the 252 fire locations using the latitude, longitude coordinates of each fire. Those fires which occurred during or before 1967 were located on the 1959 FRI maps and those occurring after 1967 were located on the 1978 FRI maps. The fire boundary locations obtained from these records, however, did not reflect the results of natural fire because of the modifying influence of fire suppression.

To minimize the influence of fire suppression, a standard FRI map area was sampled with a plot the shape and size of one lot by one concession (approximately 400m X 1000m) at each fire location. This plot configuration was used because it was the limiting resolution of fire location information provided in the fire records.

It was necessary to assume either that lightning strikes occurred randomly throughout the transect in Algonquin Park or that a greater number of lightning strikes occurred on the park's west side which is dominated by the tolerant hardwood forest where there is greater thunderstorm activity (Hills, 1959; Brown et al., 1980). In order to test the null hypothesis that forest types in

Algonquin Park do not differ in terms of fire incidence, the frequency distribution of the species dominance-types (Whittaker, 1973) within the 252 fire stricken plots was compared with the frequency distribution of the species dominance-types within 252 randomly chosen plots which were sampled from the same set of FRI maps. Species dominance-types were designated with the name of the most abundant overstory species within each plot. The chi-squared test of goodness of fit was used to compare these two distributions.

Following the comparison of observed versus expected results, fire incidence for the ten species dominance-types was examined for significant differences. To do this, a greater degree of accuracy for species abundances was required than that obtained from the chi-squared test. For each burn plot, therefore, a list of its tree species and their abundance (percent cover) was compiled. These data were summarized by species for all 252 burn plots in order to estimate each species' abundance within the total area burned over the 50 year period. The relative abundance of each species within the total area burned, expressed in decimal form, represented the probability that the species would be associated with fire in the transect area during a 50 year period.

The influence of unequal aerial coverages of the ten tree species resulted in higher burning probabilities for those species with relatively greater aerial coverage. In order to eliminate the influence of unequal species coverages so that probabilities would reflect only the association of the species with fire, the probabilities were expressed for a standard area. This was done by dividing the raw probability for each species by the number of ha within which that species was dominant throughout the entire transect to obtain the probability per unit area. The number of ha dominated by each species within the transect area was determined from a separate 15% systematic point sample of all forest stands designated on FRI maps for each of the 16 townships. This new value was called the fire incidence probability and was expressed as a function of the plot size (40 ha) and the time period represented by the data (50 years).

In order to test for differences between fire incidence probabilities of tree species and forest types, Sokal and Rohlfs' (1969) test for the equality of two percentages was used. A t-test was applied to the arcsine-transformed data which in turn were obtained by expressing probabilities as percentages.

RESULTS

Results of the chi-squared test of goodness of fit (x^2=28.22; p<.005) indicated that the frequency distribution of the species dominance-types within the burned area and the distribution of the species dominance-types within the randomly chosen plots were significantly different (see Table 5-1). The null hypothesis that forest types within the study area do not differ in terms of fire incidence was, therefore, rejected.

Table 5-2 provides a summary of species and forest type abundance

TABLE 5-1 - CHI-SQUARED CONTINGENCY TABLE COMPARING SPECIES DOMINANCE-TYPES IN FIRE-STRICKEN AREAS AND RANDOMLY CHOSEN AREAS (shows number of plots dominated by each species; $X^2=28.22$, $p<.005$)

	White Birch	Jack Pine	Red Pine	Yellow Birch	White Pine	Red Oak	Poplar	Hemlock	Sugar Maple	Others	Total
Randomly Chosen Areas	28	3	3	11	46	4	56	7	77	17	252
Fire Striken Areas	23	6	4	11	68	6	38	4	84	8	252

TABLE 5-2 - ABUNDANCE OF TREE SPECIES AND FOREST TYPES AND THEIR ASSOCIATED FIRE PROBABILITIES

		Abundance in Entire Transect Area		Abundance in Burned Areas Relative (%)	Raw Probability	Fire Incidence Probability (FIP) (x 10^{-3}) (40 ha/50 years)	Species with Significantly Different FIP ($p<.05$)
		Absolute (ha)	Relative (%)				
TREE SPECIES	white birch (1)	13,525	4.1	9.7	.097	.287	4,5,6,7,8,9,10
	red pine (2)	8,247	2.5	4.8	.048	.233	6,7,8,9,10
	jack pine (3)	3,629	1.1	1.9	.019	.209	7,8,9,10
	yellow birch (4)	19,463	5.9	8.4	.084	.172	1,10
	white pine (5)	58,058	17.6	22.7	.227	.156	1,10
	red oak (6)	8,577	2.6	3.0	.030	.140	1,2,10
	poplar (7)	51,790	15.7	15.3	.153	.118	1,2,3
	hemlock (8)	15,504	4.7	4.1	.041	.106	1,2,3
	others (9)	46,512	14.1	12.3	.123	.106	1,2,3
	sugar maple (10)	104,570	31.7	17.8	.178	.068	1,2,3,4,5,6
FOREST TYPES	pines (11)	69,934	21.2	29.4	.294	.598	13
	intolerant hardwoods (12)	73,892	22.4	28.0	.280	.545	13
	tolerant hardwoods (13)	139,537	42.3	30.3	.303	.346	11,12

values and their associated fire probabilities. Sugar maple has the second highest raw probability (.178) of the ten species, however, in terms of fire incidence probability it is ranked lowest (.068 x 10^{-3}). This is due to its low dominance within the total area burned (17.8%) relative to its very high dominance within the entire transect area (31.7%), which results in a low probability on a per hectare basis. This contrasts with jack pine which has a much higher fire incidence probability (.209x10^{-3}) than sugar maple in spite of its lower dominance than sugar maple in the total area burned (1.9%). Because of the lower dominance of jack pine within the entire transect area (1.1%) relative to its higher dominance in the total area burned its probability on a per hectare basis is higher than that of sugar maple. Results of the t-test indicate that although no one species fire incidence probability is significantly different from the rest, each species differs significantly from at least two others.

Using the addition rule of probability, the fire incidence probability for each forest type was calculated by summing the fire incidence probabilities for each of the three species which occurred within a forest type. The pines included red, jack, and white pine; the intolerant hardwoods included white birch, red oak and poplar; and the tolerant hardwoods included yellow birch, hemlock and sugar maple. Results of the t-test indicate that fire incidence probability for the pines (.598x10^{-3}) and the intolerant hardwoods (.545x10^{-3}) do not differ significantly, but that their fire incidence probabilities both differ significantly from the fire incidence probability for the tolerant hardwoods ($.346 \times 10^{-3}$).

DISCUSSION AND CONCLUSION

The results of this study indicate that fire incidence is significantly higher within both the pine forest and the intolerant hardwood forest compared to the tolerant hardwood forest. Results of this study also indicate that fire incidence for the ten overstory species in Algonquin Park differ significantly from one another, although no one overstory species differs significantly in terms of fire incidence from all others.

The major problem of using these historical data, however, was that both pre-fire and post-fire vegetation was sampled. Thus, it was impossible to separate species flammability which would be indicated by sampling pre-fire overstory vegetation from species regeneration strategy which could be, but is not necessarily, indicated by sampling post-fire overstory vegetation. For example, it is quite possible that the high fire incidence probabilities obtained for white and yellow birch resulted from sampling their early colonization of severely burned sites where the original overstory had been eliminated. Because the 1959 FRI maps were used to sample 29 years of previously burned vegetation, there was sufficient time for an early successional community of birch to develop following a fire which may have occurred early in this 29 year period. In this instance, the early successional birch community would be sampled rather than the community which was originally ignited.

Examining fire records and forest cover type maps in New Hampshire, Fahey and Reiners (1981) recognized this phenomenon with white birch. Maissurow (1941) found that yellow birch also exhibited early colonization characteristics on burned sites in the hardwood forests of northern Wisconsin. In cases where destructive crown fire did occur within the transect, it is likely that the birch and poplar species colonized the burned sites due to their r-selected regeneration strategy.

However, fires that destroy the forest overstory are rare within the North American temperate forest (Chandler et al., 1983). Therefore, it is probable that on most sites in Algonquin the dominant pre-fire forest overstory species survived fire and remained as the dominant overstory species on the site. Thus, it is likely that the majority of post-fire vegetation sampled represented the vegetation type ignited which in turn would indicate vegetation flammability.

The relationship between fire incidence and the flammability of vegetation has been discussed extensively in the literature (Mutch, 1970; Rundel, 1981; Snyder, 1984). The greater flammability of pine species than intolerant and tolerant hardwood species is due to a higher concentration of oils, waxes, and resins in the needles (Van Wagner, 1977; Rundel, 1981), a lower fuel moisture loading (Kourtz, 1967; Rowe and Scotter, 1973), a difference in stand structure featuring more fuel at intermediate heights and a more aerated litter layer (Van Wagner, 1971; Barden and Woods, 1974), and fewer natural firebreaks in areas of dominance. Intolerant hardwoods are more flammable than the tolerant hardwoods because of their lower leaf moisture content (Van Wagner, 1967) and a greater proportion of volatile chemical compounds in their leaves (Philpot, 1969).

Examination of pre-suppression fire rotations for forest types similar to those sampled in this study (Table 5-3) show that fire rotations for pines (22-80 years) and intolerant hardwoods (70-240 years) are much lower than fire rotations for tolerant hardwood forests (1200 years). It is not clear from the data in Table 5-3, however, whether fire rotation differs for pine and intolerant hardwood forests. Because fire suppression increases the fire rotation, forest type comparison for pre-suppression and suppression periods must be made independently. The suppression period data in Table 5-3 show similar relationships between fire rotations for the pine, intolerant hardwood, and tolerant hardwood forest types compared to the pre-suppression period. The obvious difference between the pre-suppression and suppression data is the much greater rotation period for forest types affected by fire suppression.

These fire rotation data support the findings that fire incidence is higher for the pine and intolerant hardwood forests compared to the tolerant hardwoods. A forest type with a high fire incidence is likely to burn more often than a forest type with a low fire incidence. The forest type that burns more frequently than another is likely to require less time to be completely burned over. Thus a forest type with a high fire incidence will most probably also have a low fire rotation.

The index to fire incidence can be determined for any stand within

TABLE 5-3 - FIRE ROTATIONS FOR SOME GREAT LAKES-ST. LAWRENCE FOREST TYPES

PRE-SUPPRESSION

Forest Type	Fire Rotation (yrs)	Location	Reference
Jack, Red, White Pine	22	Minnesota	Frissell (1973)
Jack Pine	60-70	Minnesota	Swain (1973)
Jack Pine	80	Michigan	Whitney (1986)
White Pine-Poplar	70	Ontario	Cwynar (1977)
White Pine-Poplar	80	Ontario	Cwynar (1978)
Pine, Spruce, Poplar, Birch	100	Minnesota	Heinselman (1973)
Pine-Hardwoods	120-240	Michigan	Whitney (1986)
Northern Hardwoods	1200	Michigan	Whitney (1986)

SUPPRESSION

Forest Type	Fire Rotation (yrs)	Location	Reference
Pine	530	Maine	Fahey and Reiners (1981)
Pine	660	New Hampshire	Fahey and Reiners (1981)
Red Spruce-Hemlock-Pine	476	New Brunswick	Wein and Moore (1977)
Red Spruce-Hemlock-Pine	2000	Nova Scotia	Wein and Moore (1978)
Birch-Aspen	100	Maine	Fahey and Reiners (1981)
Birch-Aspen	510	New Hampshire	Fahey and Reiners (1981)
Sugar Maple-Yellow Birch-Fir	625	New Brunswick	Wein and Moore (1977)
Sugar Maple-Yellow Birch-Fir	3000	Nova Scotia	Wein and Moore (1978)
Northern Hardwoods	770	New Hampshire	Fahey and Reiners (1981)
Northern Hardwoods	910	Maine	Fahey and Reiners (1981)
Sugar Maple-Ash	>10,000	New Brunswick	Wein and Moore (1977)

the study area once the fire incidence probabilities and relative abundances are known for the overstory species within the stands of interest. This is done by simply calculating a weighted average of fire incidence probability for the stand using the fire incidence probability of each constituent species, basing the weight of the species probability on its relative abundance. For example, the index to fire incidence for a stand in Algonquin which is composed of 60% sugar maple, 30% yellow birch, and 10% hemlock would be $[(.60)(.068\text{x}10^{-3})+(.30)(.172\text{x}10^{-3})+(.10)(.106\text{x}10^{-3})]$ which is equal to $.103\text{x}10^{-3}$. This value can then be used in ecological analyses to represent naturally caused fire within that particular stand relative to other stands sampled in the study area for which the index is calculated.

CHAPTER 6 - OVERSTORY, ENVIRONMENT AND DISTURBANCE

INTRODUCTION

Modern forest ecological studies within the Great Lakes-St. Lawrence (GLSL) Forest Region have identified soil moisture as the primary determinant of forest composition over the landscape (Brown and Curtis, 1952; Fraser, 1954; Maycock and Curtis, 1960; Flaccus and Ohmann; 1964; Lopoukhine, 1974). These studies do not, however, incorporate natural disturbance as an important influence despite the obvious environmental changes and biological destruction which can result from it (Canham and Marks, 1985). Overlooking the role of disturbance in explaining community patterns often results in the misinterpretation of ecological data (Sousa, 1984; Pickett and White, 1985). For example, by incorporating the influence of fire and exotic species, Harmon et al. (1983) have revised Whittaker's (1956) original forest vegetation model of the Great Smoky Mountains.

Studies focussing on fire within the GLSL Forest Region have presented substantial evidence to show that fire plays an important role in developing and maintaining pine forests (Maissurow, 1935; Cary, 1936; Maissurow, 1941; Spurr, 1954; Heinselman, 1973; Swain, 1973; Cwynar, 1977; Cwynar, 1978) and aspen forests (Heinselman, 1973; Swain, 1973).

The prominent role of both soil moisture and fire as influences upon the composition of GLSL forests was addressed by Hills (1959) and

Anderson (1969) through their work in the Algonquin Park region of Ontario. Later a fire incidence gradient across the width of the park was identified by Terasmae and Weeks (1979).

Algonquin Park is located within Nichol's (1935) and Braun's (1950) Hemlock-White Pine Northern Hardwood Region of eastern North America. It can be further classified into the Great Lakes-St. Lawrence Division (Braun, 1950) or Forest Region (Rowe, 1972). The region is characterized by eastern white pine and red pine, hemlock and yellow birch. Associated with these species are more typically northern species such as jack pine, white spruce, aspen and white birch as well as some which are more characteristic of southern forests such as sugar maple, red oak, beech, and basswood. All of these are common species throughout the Algonquin landscape.

An hypothesis to explore the influences of soil moisture and fire along with other selected environmental variables upon forest composition within the GLSL Forest Region has not yet been examined. The purpose of this study is to examine this hypothesis using multivariate techniques that allow for the ranking of independent (environmental) variables with regard to the amount of variance they explain within a set of dependent variables (vegetation axes). These techniques are applied to the geographical distribution of plants rather than to the dynamics of plants over time. Although there are many factors that may affect vegetation composition some play a greater mediating role than others (Greig-Smith, 1979; Noy-Meir and van der Maarel, 1987). It was with this in mind that environmental variables were selected.

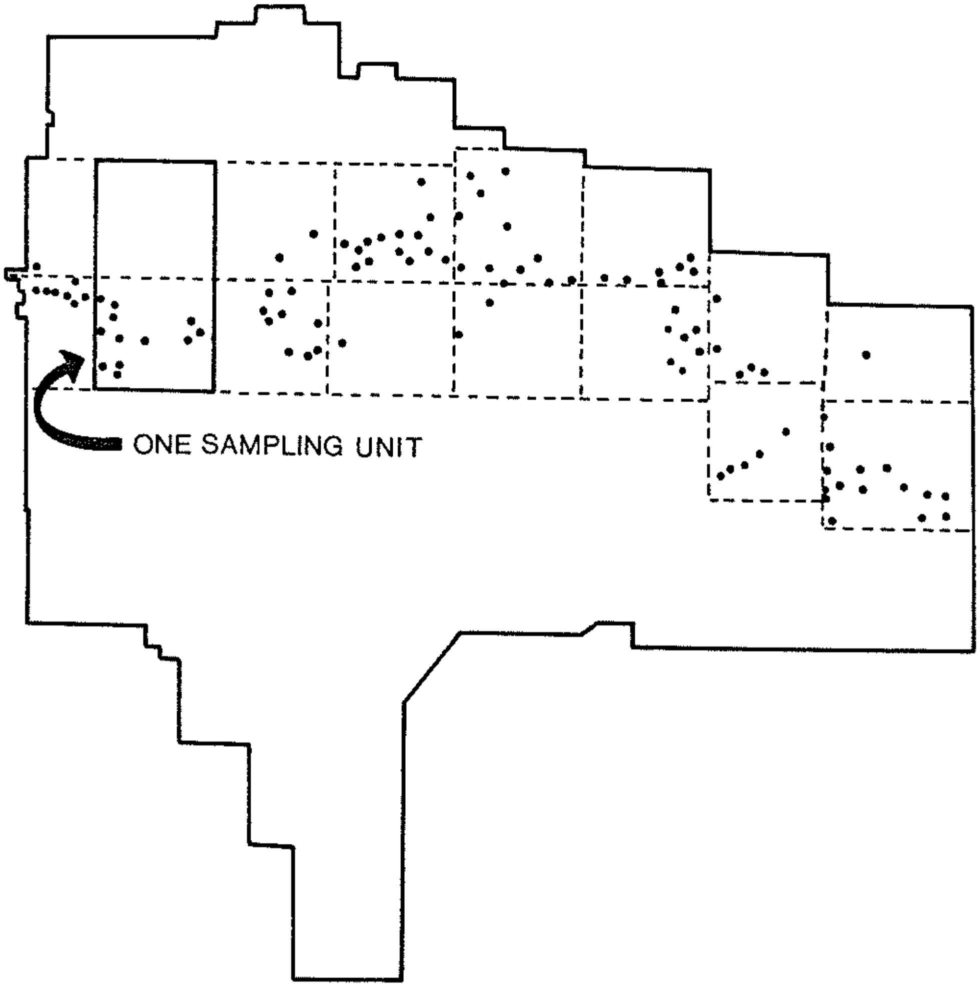
METHODS

FIELD

The typical upland vegetation of the park was sampled for overstory vegetation and environmental variables in 100 forest stands within a transect which was two townships wide extending across the approximate 72 km width of the park (Figure 6-2). Nine tree species were identified as typical upland forest dominants from a survey of Forest Resource Inventory (FRI) Maps (Ontario Ministry of Natural Resources, 1978). This survey consisted of a 15% systematic sample of the forest stands designated on the FRI map for each of the 16 townships included in the transect. The relative abundance of each upland forest dominant within a township was determined by summing the number of stands dominated by the species and converting that into a relative value (see Appendix II for results of the survey). This value was then used as a guide for stand selection within each sampling unit. For example, approximately 45% of the Fitzgerald-White sampling unit is dominated by poplar. Therefore, 45% of the stands sampled in these two townships were poplar or six out of 13 stands.

Selection of stands in the field was based on the following criteria: stands were (1) dominated by one of nine typical upland tree species, (2) restricted to upland sites on which surface runoff waters

FIGURE 6-1 - SAMPLING UNITS AND STAND LOCATIONS WITHIN ALGONQUIN PARK



never accumulate, (3) at least 6 ha in size, and (4) not recently disturbed by natural or human agency. Mature stands were selected in order to avoid as much as possible the sampling of early successional stands. To the extent possible, stands representing the variety of surficial geological deposits associated with each stand type were included in the sample set through the use of surficial geological maps (Ontario Ministry of Natural Resources, 1983). The location, cover type, substrate type, and size of each stand is provided in Appendix III.

The overstory was defined as all trees 2cm dbh and greater. During the 1983 and 1984 field seasons, the overstory was sampled by recording tree diameter at breast height (dbh) within three randomly placed 10m X 30m quadrats per stand. Once a stand was selected based on the four criteria, the quadrats were selected by subjectively identifying a representative portion of the stand, locating the center of that portion, and randomly selecting a compass bearing that served as the first side of a quadrat. Dbh measurements were converted to basal area values per ha for each species within each stand for analysis. Appendix IV provides the summarized basal area for overstory species within each stand. Nomenclature follows Fernald (1950).

Soil profile descriptions and homogenized soil samples from the 0 to 10cm portion of the mineral soil for lab analysis were obtained from each of the three excavated soil pits (1m depth) within each stand (see Appendix V). For the soil profiles, the following was measured: thickness of the LFH, Ae, Ah, A, and B horizons and the depth to the C horizon and depth to mottling. Latitude, longitude, and elevation for each stand were determined from topographic maps (see Appendix VI). Evidence of disturbance was noted at each site.

LABORATORY

Fire

The index to fire incidence was used to quantify fire. The index was obtained by calculating a weighted average of fire incidence probability for the stand using the fire incidence probability of each constituent species (see Table 5-1). The weighting of the species probability was based on its relative abundance. For example, the index to fire incidence for a stand in Algonquin which is composed of 60% sugar maple, 30% yellow birch, and 10% hemlock would be $[(.60)(.068\text{x}10^{-3})+(.30)(.172\text{x}10^{-3})+(.10)(.106\text{x}10^{-3})]$ which is equal to $.103\text{x}10^{-3}$/40ha/50yrs. The index to fire incidence was then used as one of the 24 independent variables in the canonical correlation analysis (see Appendix VI for the index to fire incidence values for each stand). The derivation of the index is described in greater detail in Chapter 5.

Since the derivation of the fire index showed that fires historically have occurred in all upland dominance-types in Algonquin Park, it was assumed that all upland stands in Algonquin have been affected to some extent by fire. This assumption is supported by

Cwynar's (1977) findings that the fire rotation in Barron Township, Algonquin Park (pine-poplar forest) was approximately 70 years between the years 1696 and 1920 and by Whitney's (1986) findings that northern hardwoods had a fire rotation of 1200 years in Michigan.

Climate

Mean annual precipitation and mean daily temperature for July were estimated for each stand using interpolation applied to the precipitation and temperature isolines for southern Ontario provided by Brown et al. (1980) (see Appendix VI for stand values). To determine the accuracy of iso-line values, correlations between iso-line based estimations of precipitation and temperature values for Algonquin region weather station locations and the actual station measurements (Atmospheric Environment Service, 1982) for both of these parameters were determined (see Appendices VII and VIII for real and predicted values). For 39 stations, the correlation between predicted and actual values for precipitation was .8753 ($p<.001$). For 34 stations, the correlation between predicted and actual values for temperature was .7662 ($p<.001$). However, because isolines are generally drawn more accurately close to known data points, it is likely that real values and estimates of precipitation and temperature for the sampled stands would have lower correlations than those obtained for the stations.

Soils

Three soil samples from each plot within a stand were combined into a composite stand soil sample. From these samples, the following Zparameters were analyzed for: % sand, % silt, % clay, % organic matter, total nitrogen, calcium, magnesium, potassium, phosphorus, and pH (see Appendices IX and X). Analysis of the latter five parameters was provided by Agri-Food Laboratories, Guelph, Ontario. Soil particle size distribution was determined using the hydrometer method (Day, 1965), percent organic matter was determined using the loss on ignition method (Ball, 1964), and the Kjeldahl method (Bremner, 1965) was used to analyze for total nitrogen. The soil moisture stress index was calculated by rescaling precipitation and the sum of %silt and %clay (inverse of %sand) from 0 to 100. The rescaled values for precipitation and soil texture were then summed, divided by two and subtracted from 100.

NUMERICAL

Detrended correspondence analysis (DCA) (Hill and Gauch, 1980) was used to ordinate overstory vegetation samples based on the basal area of each species within each stand using the computer program DECORANA (Hill, 1979) (see Appendix XI for stand scores on axes 1 and 2). In order to examine relationships between overstory vegetation composition and environmental variables, canonical correlation analysis (CCA)

(Hotelling, 1936) was used through the SAS computer program (Sarle, 1982). Carleton (1984) provides a detailed explanation of the strengths and weaknesses of using these two methods (refer also to Chapter 4). Miller's (1975) F-ratio approximation was used to test for significant interset correlations.

RESULTS

DESCRIPTION OF OVERSTORY COMPOSITION

In total, 23 tree species were found within 100 upland forest stands in Algonquin Park (Table 6-1). Of these 23 species, sugar maple, white pine, and large-toothed and trembling aspen dominate approximately 60% of the study area. Table 6-2 shows the relative abundance of the 23 tree species in the study area. A total of nine species were present in quantities of less than 1%. These species include white cedar, basswood, hop hornbeam, striped maple, black cherry, black spruce, black ash, mountain maple, and speckled alder.

The average per stand basal area for all overstory species was calculated by species dominance-type (Whittaker, 1973) and is shown in Table 6-3. This table shows that each dominance-type is composed of a variety of species with varying levels of abundance. For purposes of discussion, three terms will be used and should be defined. The dominant is defined as the species with the greatest basal area within a particular dominance type and its name is used to identify that

TABLE 6-1 - OVERSTORY SPECIES LIST

Abies balsamea (L.) Mill. (balsam fir)
Acer pennsylvanicum L. (striped maple)
Acer rubrum L. (red maple)
Acer saccharum Marsh. (sugar maple)
Acer spicatum Lam. (mountain maple)
Alnus rugosa (Du Roi) Spreng. (speckled alder)
Betula lutea Michx. f. (yellow birch)
Betula papyrifera Marsh. (white birch)
Fagus grandifolia Ehrh. (American beech)
Fraxinus nigra Marsh. (black ash)
Ostrya virginiana (Mill.) K. Koch (hop hornbeam)
Picea glauca (Moench) Voss (white spruce)
Picea mariana (Mill.) B.S.P. (black spruce)
Pinus banksiana Lamb. (jack pine)
Pinus resinosa Ait. (red pine)
Pinus strobus L. (white pine)
Populus grandidentata Michx. (large-toothed aspen)
Populus tremuloides Michx. (trembling aspen)
Prunus serotina Ehrh. (black cherry)
Quercus rubra L. (red oak)
Thuja occidentalis L. (white cedar)
Tilia americana L. (basswood)
Tsuga canadensis (L.) Carr. (eastern hemlock)

TABLE 6-2 - RELATIVE ABUNDANCE OF THE OVERSTORY SPECIES FOUND WITHIN THE STUDY AREA

SPECIES	RELATIVE ABUNDANCE (% basal area)
Acer saccharum	28.51
Pinus strobus	16.94
Populus grandidentata	14.83
Betula lutea	8.67
Tsuga canadensis	6.46
Pinus resinosa	5.74
Betula payrifera	3.21
Populus tremuloides	2.93
Quercus rubra	2.38
Acer rubrum	2.20
Abies balsamea	2.15
Picea glauca	1.73
Fagus grandifolia	1.55
Pinus banksiana	1.35
Thuja occidentalis	.40
Tilia americana	.38
Ostrya virginiana	.25
Acer pennsylvanicum	.13
Prunus serotina	.13
Picea mariana	.03
Fraxinus nigra	.03
Acer spicatum	.01
Alnus rugosa	.01

TABLE 6-3 - AVERAGE PER STAND BASAL AREA FOR OVERSTORY SPECIES BY DOMINANCE TYPE (m^2/ha)

MAJOR SPECIES	DOMINANCE TYPE								
	hemlock	yellow birch	sugar maple	white birch	red oak	poplar	white pine	red pine	jack pine
Tsuga canadensis	44.36	3.98	1.51			.02			
Betula lutea	1.35	34.52	4.13	.03		.07	.05		
Acer saccharum	2.41	8.68	25.85	3.69	.16	1.66	.40		
Fagus grandifolia	.01	.16	1.35	.48	.61	.08	.05		
Abies balsamea	.56	.38	.33	13.15		.56	.79	.63	
Acer rubrum	.96	.64	.61	1.33	1.04	1.66	.89	.17	
Betula papyrifera	.54	.31	.52	17.69	.12	1.39	1.22	.10	
Picea glauca	.01	.22	.32	.55	.09	1.18	1.54	.21	.21
Quercus rubra			.25	.57	18.33	.25	1.22		
Populus grandidentata			.07	.38	1.39	26.55	3.27	3.43	
Pinus strobus			.34	.75	5.52	4.43	27.48	7.10	1.13
Populus tremuloides			.13		.63	2.81	2.00	2.37	3.57
Pinus resinosa			.01	.04	.01	2.27	2.29	27.48	2.21
Pinus banksiana				1.90		.09	.22	1.50	17.32
MINOR SPECIES (< 1% relative basal area)									
Prunus serotina			.12			.01			
Tilia americana			.37				.03		
Fraxinus nigra		.03	.01				.01		
Ostrya virginiana			.17	.20	.26	.05	.07		
Thuja occidentalis	.39	1.01	.03		.42	.08	.28	.01	
Acer pennsylvanicum	.15		.04	.04	.02	.10	.06		
Alnus rugosa						.01			
Acer spicatum						.01	.01		
Picea mariana					.04	.01	.01	.06	.13
No. of stands	4	5	40	3	3	19	19	5	2
Mean basal area (m^2/ha)	50.74	49.93	36.16	40.80	28.64	43.29	44.65	43.06	24.57

dominance type. Common associates are defined as species which are found within a particular dominance type in amounts that average greater than 1 m^2/ha/stand but less than the basal area of the dominant. Rare associates are defined as those which have a basal area less than 1 m^2/ha/stand. Based on their dominants, the nine upland forest dominance-types in Algonquin can be grouped into forest type categories which consist of the tolerant hardwoods, intolerant hardwoods, and pines.

Tolerant Hardwood Forest

Hemlock type

Within this dominance-type hemlock constituted 87.4% of the overstory basal area, the two common associates were sugar maple (4.7%) and yellow birch (2.7%), and the seven rare associates constituted 5.2% of the overstory basal area.

Yellow birch type

For this dominance-type yellow birch constituted 69.1% of the overstory basal area, sugar maple (17.4%), hemlock (8.0%), and white cedar (2.0%) were the common associates, and the six rare associates composed 3.5% of the overstory basal area.

Sugar maple type

In this dominance-type sugar maple constituted 71.5% of the overstory basal area, common associates included yellow birch (11.4%), hemlock (4.2%), and American beech (3.7%). Fifteen rare associates were found within this community and contributed 9.2% of the overstory basal area.

Intolerant Hardwood Forest

White birch type

For this dominance-type white birch constituted 43.4% of the overstory basal area, common associates included balsam fir (32.2%), sugar maple (9.0%), jack pine (4.7%), and red maple (3.3%), and nine rare associates occupied 7.5% of the overstory basal area.

Red oak type

Within this dominance-type red oak constituted 64% of the overstory basal area. The common associates included white pine (19.3%), large-toothed aspen (4.9%), and red maple (3.6%). Ten rare associates constituted 8.2% of the overstory basal area.

Poplar type

For this dominance-type poplar constituted 61.3% of the overstory basal area. This dominance-type also had the greatest number of common associates which was seven. They included white pine (10.2%), trembling aspen (6.5%), red pine (5.2%), sugar maple (3.8%), red maple (3.8%), white birch (3.2%), and white spruce (2.7%). The 13 rare associates occupied 3.1% of the overstory basal area.

Pine Forest

White pine type

In this dominance-type white pine constituted 61.5% of the overstory basal area. Six common associates included large-toothed aspen (7.3%), red pine (5.1%), trembling aspen (4.5%), white spruce (3.4%), red oak (2.7%), and white birch (2.7%). The 13 rare associates constituted only 6.4% of the overstory basal area.

Red pine type

For this dominance-type red pine constituted 63.8% of the overstory basal area. Common associates included white pine (16.5%), large-toothed aspen (8.0%), trembling aspen (4.6%), and jack pine (3.5%). The six rare associates made up only 2.7% of the overstory basal area.

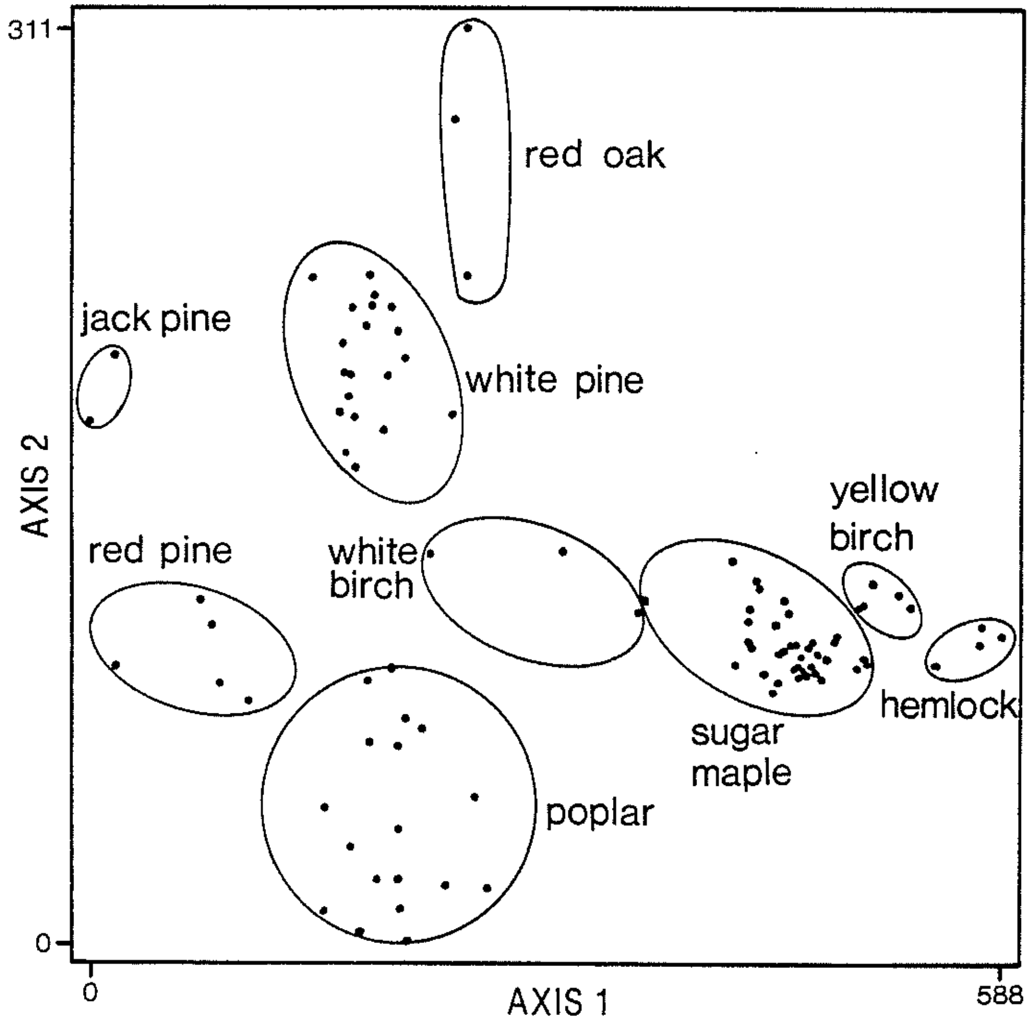
Jack pine type

For this dominance-type jack pine contributed 70.5% of the overstory basal area. The three common associates included trembling aspen (14.5%), red pine (9.0%), and white pine (4.6%). The two rare associates constituted only 1.4% of the overstory basal area.

STAND ORDINATION

Eigenvalues resulting from DCA for axes 1 through 4 were .870, .459, .211, and .173. Figure 6-2 shows each stand plotted with respect to their scores on DCA axis 1 and 2 and the dominance-type designations. Since the first DCA axis explains the greatest amount of variation in the species composition data, approximately 87%, the spatial arrangement of stands along the first axis is of greatest importance. It can be seen that along this axis, the pine dominance-types occupy the low end of the gradient, the tolerant hardwood dominance-types occupy the high end of the gradient and the intolerant hardwood dominance-types occupy an intermediate position. The greater the distance between two stands the more dissimilar is their species composition.

FIGURE 6-2 - SCATTERGRAM OF STANDS PLOTTED WITH RESPECT TO OVERSTORY DCA AXES 1 AND 2



INDIRECT GRADIENT ANALYSIS

Stand means and ranges for the selected environmental variables were summarized by dominance-type and are presented in Table 6-4. Dominance-types are arranged according to average stand position on the first DCA axis. Stand values used to obtain this summary of environmental variables were utilized in CCA along with stand scores from DCA which were used to represent overstory composition. The results of CCA facilitated the identification of important composition-environment relationships. Table 6-5 provides interset correlations between the first four DCA axes and the first four canonical variates.

Using Miller's (1975) F-ratio approximation it was possible to identify significant interset correlations. Results of this test indicated that the only significant interset correlation existed between DCA axis 1 and canonical variate 1 (.9069; p<.001). It is the relationship between these two linear models, therefore, that provides the greatest explanation for the joint variance within the biological and environmental data sets.

Each individual environmental variable was then assessed with regard to its contribution to the structure of the first canonical variate. This was done by examining factor loadings which are simply correlations of the individual factor values with the values obtained from projecting the real factor values onto the canonical variate. The greater the absolute value of the loading, the greater its contribution

TABLE 6-4 - STAND MEANS AND RANGES FOR ENVIRONMENTAL DATA BY DOMINANCE-TYPE

ENVIRONMENT	DOMINANCE TYPE								
	yellow birch	sugar maple	hemlock	white birch	poplar	white pine	red oak	red pine	jack pine
Soils									
sand (%)	55.0 43.5-64.1	53.1 39.3-77.7	51.0 31.7-63.4	59.4 50.0-71.7	61.3 38.0-78.4	61.8 47.0-85.8	50.6 40.8-56.5	77.7 70.8-84.0	85.5 84.5-86.5
silt (%)	38.5 29.3-49.9	41.4 18.6-55.6	40.1 28.6-53.9	35.5 23.6-45.0	32.0 17.8-50.9	31.9 10.3-45.8	41.7 36.7-49.0	16.9 11.0-24.2	9.9 9.4-10.4
clay (%)	6.5 4.4-8.0	5.5 3.6-6.6	8.9 5.8-14.4	5.1 4.7-5.7	6.7 2.8-12.1	6.3 2.6-8.6	7.7 6.0-10.2	5.4 5.0-5.7	4.6 4.1-5.1
organic (%)	7.9 6.5-11.7	6.5 2.0-22.0	7.1 1.9-12.8	6.0 3.2-9.2	4.7 3.2-7.3	5.1 2.5-10.4	7.2 5.2-9.5	3.3 3.0-4.0	2.8 2.3-3.3
total N (%)	.24 .15-.40	.27 .11-.67	.16 .13-.20	.15 .06-.24	.11 .06-.27	.11 .03-.23	.12 .09-.17	.07 .06-.08	.06 .05-.06
P (ppm)	10 4-22	14 5-53	8 6-12	25 17-40	28 7-61	23 7-62	11 4-16	13 8-22	16 8-24
K (ppm)	35 25-44	45 32-72	33 24-45	55 44-61	49 27-80	47 22-75	40 35-48	31 26-40	18 16-20
Ca (ppm)	256 61-680	272 62-1200	173 57-347	545 226-1135	259 64-650	247 83-550	132 122-150	175 86-300	175 150-200
Mg (ppm)	47 25-82	40 20-72	29 24-38	47 33-62	38 16-72	43 20-105	26 17-39	28 20-37	17 17
pH	4.8 4.4-5.0	4.6 4.0-5.4	4.6 4.2-4.9	5.2 4.9-5.7	5.0 4.1-5.4	4.8 4.4-5.2	4.7 4.4-5.1	4.8 4.5-5.4	4.8 4.6-4.9
C/N ratio	34.7 29.3-43.3	33.6 10.0-56.4	41.9 14.6-60.0	42.2 35.0-53.0	46.7 14.4-63.3	47.0 34.4-83.3	59.1 55.9-63.6	46.3 37.5-57.1	50.5 46.0-55.0
LFH (cm)	5.17 3.81-6.35	4.84 1.96-7.20	6.83 5.70-9.95	4.51 2.96-5.60	4.24 2.94-5.72	4.69 2.22-6.35	4.62 3.49-5.72	4.74 3.81-5.72	5.29 5.29
Ah (cm)	2.04 .85-3.81	2.49 .85-5.50	1.65 1.48-2.54	2.75 1.91-3.60	1.71 .64-3.81	1.88 .64-2.96	1.43 .85-2.17	1.99 1.06-3.18	1.59 1.06-2.12
Ae (cm)	5.44 4.45-7.20	5.18 1.91-9.74	7.78 5.51-9.94	3.84 3.17-4.23	4.53 1.27-7.94	4.44 1.91-7.62	3.95 2.81-5.32	3.84 2.86-6.19	2.23 1.91-2.55
A (cm)	7.48 5.93-9.42	7.61 3.81-13.34	9.63 6.98-11.85	6.60 6.04-6.98	6.17 3.71-9.94	6.30 3.91-9.95	5.46 3.65-7.48	5.63 4.45-7.25	3.81 3.60-4.02
B (cm)	43.75 37.90-49.95	44.59 33.34-64.35	38.74 34.93-43.82	32.99 23.64-37.88	43.55 32.71-58.45	42.66 30.51-63.71	40.23 33.13-50.49	46.86 34.29-68.26	51.55 36.63-66.47
Depth to C (cm)	51.90 46.14-58.42	53.12 44.87-72.39	46.90 44.03-53.34	43.74 40.64-45.72	50.65 41.49-59.27	51.19 42.33-73.66	44.81 39.37-50.00	52.07 40.64-73.24	57.06 43.87-70.28
Depth to M (cm)	51.90 46.14-58.42	53.46 43.18-73.29	48.90 45.72-50.80	45.30 40.64-49.53	52.59 43.18-63.50	52.67 45.09-76.20	52.21 48.66-57.15	54.77 40.64-74.02	58.77 43.87-73.66
Climate									
temperature (degrees C)	18.64 18.5-18.8	18.66 18.5-19.1	18.68 18.6-18.8	18.77 18.6-18.9	18.82 18.7-19.0	18.95 18.6-19.3	19.00 18.9-19.1	19.04 18.8-19.3	19.10 18.9-19.3
precipitation (mm)	870 843-907	861 725-907	849 841-858	835 827-848	813 736-863	798 735-859	765 738-813	784 734-828	782 742-821
light (%)	14.7 10.0-20.0	13.8 5.0-21.7	10.0 5.0-13.3	17.2 13.3-18.3	20.8 6.7-31.7	26.2 16.7-38.3	19.4 13.3-23.3	28.2 24.3-38.3	42.2 41.0-43.3
Disturbance									
fire index ($x10^{-3}$)	.147 .142-.149	.090 .072-.115	.107 .102-.111	.209 .180-.228	.131 .116-.159	.153 .128-.170	.140 .135-.143	.201 .178-.225	.213 .207-.219
Physiography									
elevation (m)	408 320-457	425 259-493	393 320-427	366 320-396	312 213-427	289 198-213	302 264-336	233 183-290	214 168-259
latitude	45 50 45,41-46,00	45 51 45,43-46,04	45 54 45,49-46,01	45 57 45,50-46,03	45 57 45,50-46,01	45 57 45,52-46,03	45 54 45,52-45,57	45 57 45,54-46,00	45 56 45,55-46,00
longitude	78 44 78,30-78,59	78 40 77,40-79,03	78 35 78,28-78,40	78 24 78,09-78,36	78 12 77,47-78,43	78 01 77,47-78,41	77 50 77,46-77,57	77 56 77,45-78,16	77 50 77,45-78,06

TABLE 6-5 - INTERSET CORRELATIONS BETWEEN OVERSTORY DCA AXES AND CANONICAL VARIATES

	V1	V2	V3	V4
AX1	.9069*	.0136	.0314	.0017
AX2	-.2601	.1029	.5232	.2390
AX3	.2188	.0284	-.4713	.3116
AX4	.3497	-.5868	.1109	.1111

* P<.001 using Miller´s (1975) F-ratio approximation; the remainder are not statistically significant

is to determining the structure of the variate.

Miller's F-ratio approximation was used again to identify a predictor set - or a set of environmental variables that contribute significantly to the interset correlation. This was done by successively eliminating the highest ranked factors until the remaining factors were no longer significantly correlated with the first DCA axis scores. Table 6-6 shows the predictor set for DCA axis 1 with 13 ranked environmental factors and their loadings.

Elevation had the greatest loading (.8397) on the first canonical variate. Fire also loaded highly on the first variate (-.8351) - its absolute value was only slightly less than that for elevation. Excluding longitude and the indirect influence of elevation, the loading of temperature ranks second and precipitation fourth on the first canonical variate. Of the five soil nutrients measured, only total nitrogen showed a significant contribution. Only two (A and Ae horizons) of the seven soil profile descriptors showed significant correlations with DCA stand scores. The loading for soil pH was the lowest of the predictor set factors.

EFFECTIVE FACTORS

Rather than having a direct effect on plant growth and distribution, some environmental variables, such as elevation, act indirectly. It has been shown that elevation is a temporally static component of a complex environmental gradient that influences forest

TABLE 6-6 - ENVIRONMENTAL FACTOR LOADINGS ON THE FIRST CANONICAL VARIATE FOR THE OVERSTORY PREDICTOR SET

Environmental Factor	Loading
elevation	.8397
fire	-.8351
longitude	.7470
temperature	-.7373
total nitrogen	.6948
precipitation	.6880
organic matter	.5904
sand	-.5803
latitude	-.5338
A horizon	.5330
carbon-nitrogen ratio	-.5102
Ae horizon	.4116
pH	-.4080

composition indirectly through affecting other more dynamic and physiologically influential environmental variables (Bormann et al., 1970; Siccama, 1974; Rheinhardt and Ware, 1984). Normally it is temperature which is most affected by elevation (Zobel, et al., 1976; Yarie, 1983). Other variables such as longitude and latitude also lack direct ecological meaning in that they are a means of measuring for geographic location. Due to the difficulty of dealing with a complex multitude of both direct and indirect environmental variables, it has been pointed out that it is most useful to focus on the primary ecological features of moisture supply, nutrient supply, and local climate (Hills, 1952; Loucks, 1962). Those factors most closely related to these primary ecological features were called "effective factors" by Waring and Major (1964). The significant effective factors identified in the current study included fire, climate measured by temperature and precipitation, and soil factors including total nitrogen, organic matter, % sand, and pH. Table 6-7 shows mean values of the significant effective factors for each of the three forest types.

Fire

Fire, measured by the index to fire incidence, attained its maximum mean value in the jack pine dominance-type (.213 X 10^{-3}) and its minimum mean value in the sugar maple dominance-type (.090 X 10^{-3}). Figure 6-3 shows the relative values of fire overlayed on a scatterplot of the first two axes of the DCA stand scores. Considering mean values

TABLE 6-7 - MEAN STAND VALUES FOR OVERSTORY EFFECTIVE FACTORS BY FOREST TYPE

EFFECTIVE FACTOR	FOREST TYPES		
	Tolerant Hardwoods	Intolerant Hardwoods	Pines
Fire	$.097 \times 10^{-3}$	$.141 \times 10^{-3}$	$.167 \times 10^{-3}$
Temperature (C)	18.66	18.84	18.98
Total Nitrogen (%)	.26	.12	.10
Precipitation (mm)	861	798	787
Organic Matter (%)	8.3	5.2	4.6
Sand (%)	53.1	59.8	66.7
pH	4.6	5.0	4.8
No. of Stands	49	25	26

FIGURE 6-3 - SCATTERGRAMS OF THE RELATIVE MAGNITUDES OF IMPORTANT ENVIRONMENTAL FACTORS ON THE OVERSTORY STAND ORDINATION BY DCA (circle size is proportional to the magnitude of the variable)

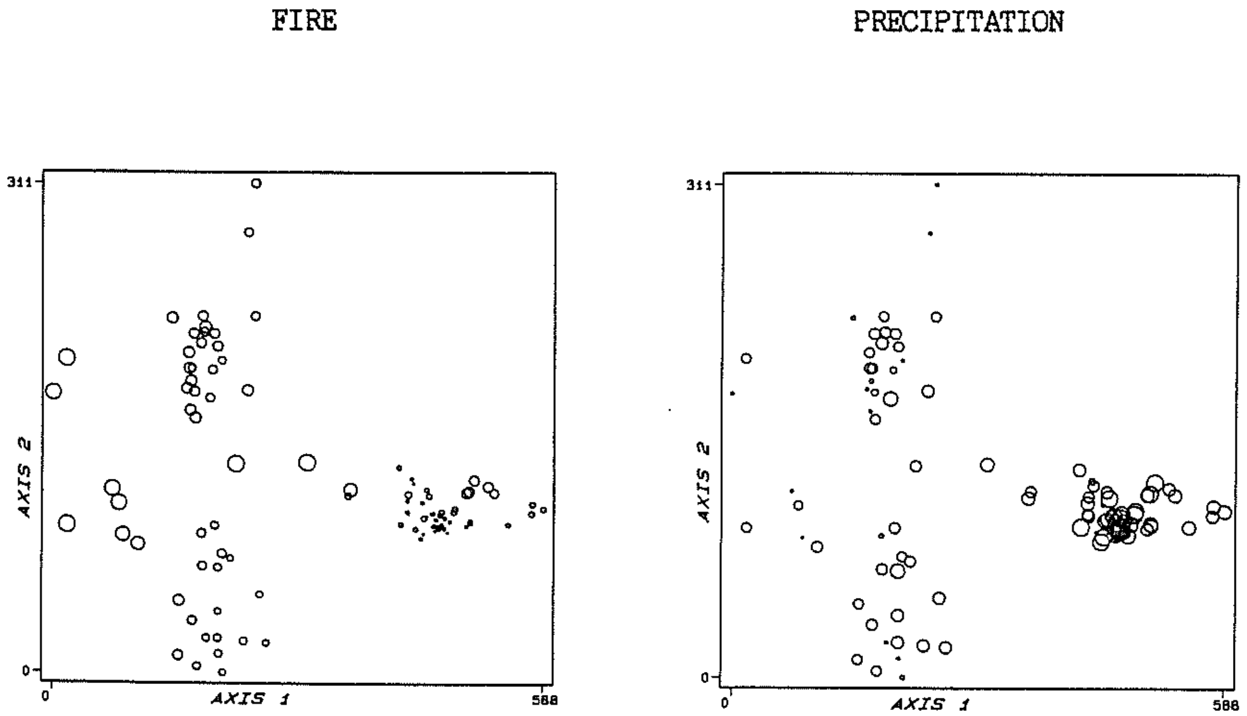
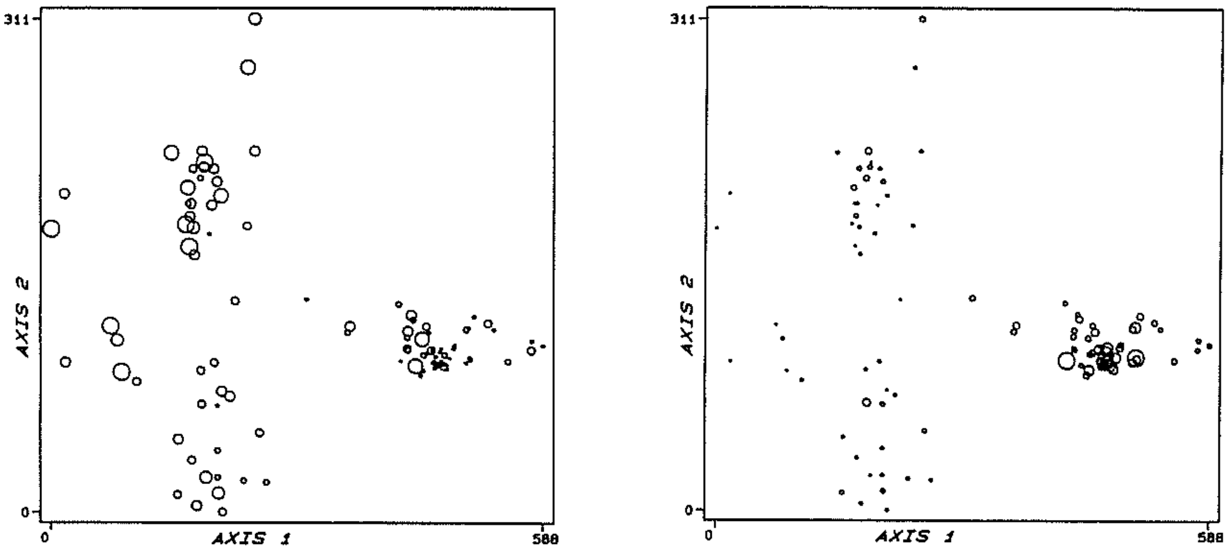
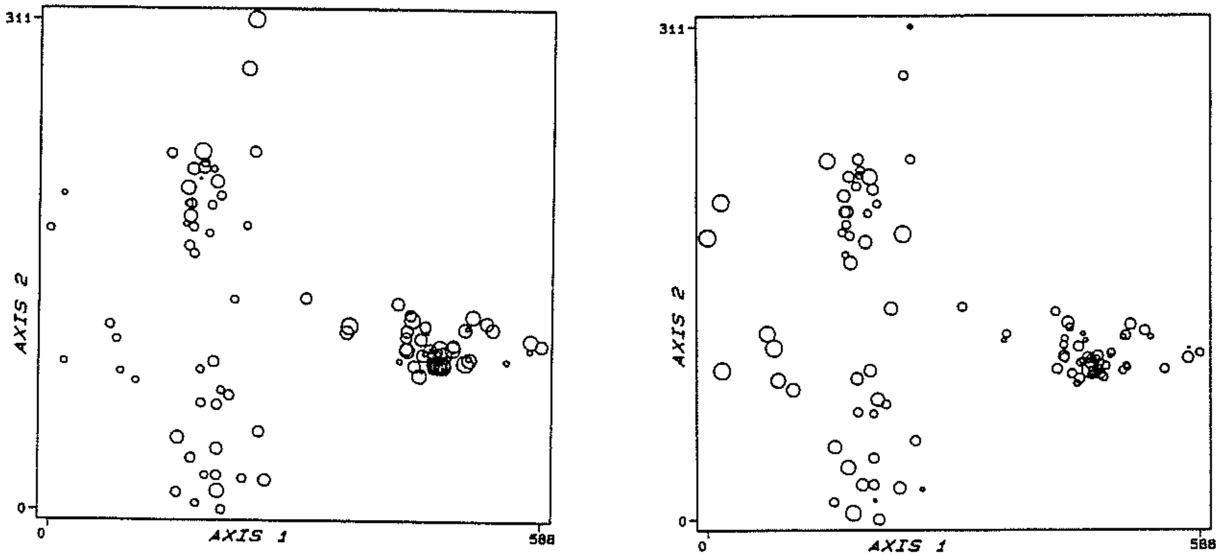


FIGURE 6-3 (CON'T)



TEMPERATURE

TOTAL NITROGEN



ORGANIC MATTER

SAND

for the three general forest types, the pines have the highest mean index to fire incidence (.167 X 10^{-3}), the tolerant hardwoods have the lowest (.097 X 10^{-3}), and intolerant hardwoods are intermediate (.141 X 10^{-3}). Almost one-half of the white and jack pine plots had charcoal in the upper part of the soil profile. Charcoal was found in approximately one-third of the poplar, white birch and red oak plots and in only a very few plots within the tolerant hardwood forest.

Climate

Among the nine dominance types, mean stand temperature (mean daily for July) ranged from 18.64 degrees C for the yellow birch dominance-type to 19.10 degrees C for the jack pine dominance-type. On average, mean stand temperature for the tolerant hardwoods (18.66 degrees C) was lower than that for the intolerant hardwoods (18.84 degrees C) which was lower than that for the pine forest type (18.98 degrees C). Figure 6-3 shows temperature for all stands plotted against DCA axes 1 and 2.

Mean stand precipitation ranged from a low of 765mm for the red oak dominance-type to a high of 870mm for the yellow birch dominance-type. The pine forest type averaged 787mm, the intolerant hardwood forest type averaged 798mm, and the tolerant hardwood forest type averaged 861mm (see Table 6-7).

Soils

The effective soil factors of the predictor set, from highest to lowest ranking on the first canonical variate, included total nitrogen, organic matter, sand, (see Figure 6-3) and pH. Of these four factors, total nitrogen is most highly correlated with upland forest overstory composition in Algonquin Park. Stand means varied from a low of .06% for the jack pine dominance-type to a high of .27% for the sugar maple dominance-type. The stand mean for the tolerant hardwood forest type (.26%) was over twice that for the intolerant hardwood forest type (.12%) and pine forest type (.10%).

Organic matter content of the mineral soil varied from 2.8% in the jack pine dominance-type to 8.5% in the sugar maple dominance-type. The amount of organic matter in the tolerant hardwood forest type (8.3%) was close to double the amount in the pine forest type (4.6%). The intolerant hardwoods had slightly more organic matter (5.2%) than the pines.

The percentage of sand in the top 10cm of the mineral soil varied substantially from 50.5% in the red oak dominance-type to 85.5% in the jack pine dominance-type. On average, the pine forest type had a greater percentage of sand (66.7) than the intolerant hardwoods (59.8) and the tolerant hardwoods (53.1).

The pH of the mineral soil was highest in the white birch dominance-type (5.2) and lowest in the tolerant hardwood dominance-types (all at 4.6). It showed little variation between forest types and extensive range overlap between and among dominance-types.

Factor Interactions

Because the factors of an environmental complex do not vary alone (McIntosh, 1970), it is necessary to consider factor interactions when describing a model of environmental influence upon overstory composition. The relationships between environmental variables in the predictor set are presented in Table 6-8 in the form of Pearson product-moment correlations. Fire is the only environmental factor that is significantly correlated with every other environmental factor within the predictor set. The factor that has the least number of significant correlations with other environmental factors is the Ae horizon depth which is correlated with only two other environmental factors within the predictor set (A horizon and fire). Correlations between longitude and both precipitation (-.9335) and temperature (.8954) are the highest of all univariate correlations.

DIRECT GRADIENT ANALYSIS

Grime's (1974, 1977, 1979) plant strategy and vegetation process model states that stress, or resource shortage, and disturbance are the two major influences "which limit the amount (and type) of living and dead plant material present in any habitat". He proposes that the variety of two-dimensional combinations of points along these two

TABLE 6-8 - OVERSTORY PREDICTOR SET CORRELATION MATRIX

	EV	FR	LG	TP	TN	PP	OM	SD	LT	A	CN	A2	PH
EV	1.0000												
FR	-.6538	1.0000											
LG	-.8651	.5414	1.0000										
TP	-.8730	.5583	.8954	1.0000									
TN	.6288	-.5515	-.6082	-.6065	1.0000								
PP	.8144	-.4805	-.9335	-.8905	.6065	1.0000							
OM	.5913	-.4847	-.5335	-.5264	.8278	.5091	1.0000						
SD	-.4917	.5092	.3467	.3289	-.3460	-.2543*	-.4096	1.0000					
LT	-.5571	.3985	.4986	.5059	-.5326	-.3973	-.5255	.3052	1.0000				
A	.2807	-.3299	-.3190	-.2826	.2810	.2661	NS	-.2163*	-.2431*	1.0000			
CN	-.3962	.3538	.4420	.4316	-.5273	-.4736	NS	NS	NS	-.2518*	1.0000		
AE	NS	-.2739	NS	NS	NS	NS	NS	NS	NS	.8595	NS	1.0000	
PH	-.3954	.3438	.4611	.3604	-.4309	-.4695	-.3909	NS	.4110	-.2851	NS	NS	1.0000

EV-elevation, FR-fire, LG-longitude, TP-temperature, TN-total nitrogen, PP-precipitation, OM-organic matter, SD-sand, LT-latitude, A-A horizon thickness, CN-carbon-nitrogen ratio, AE-Ae horizon thickness, PH-pH

* p<.05; NS-not significant; all others p<.01

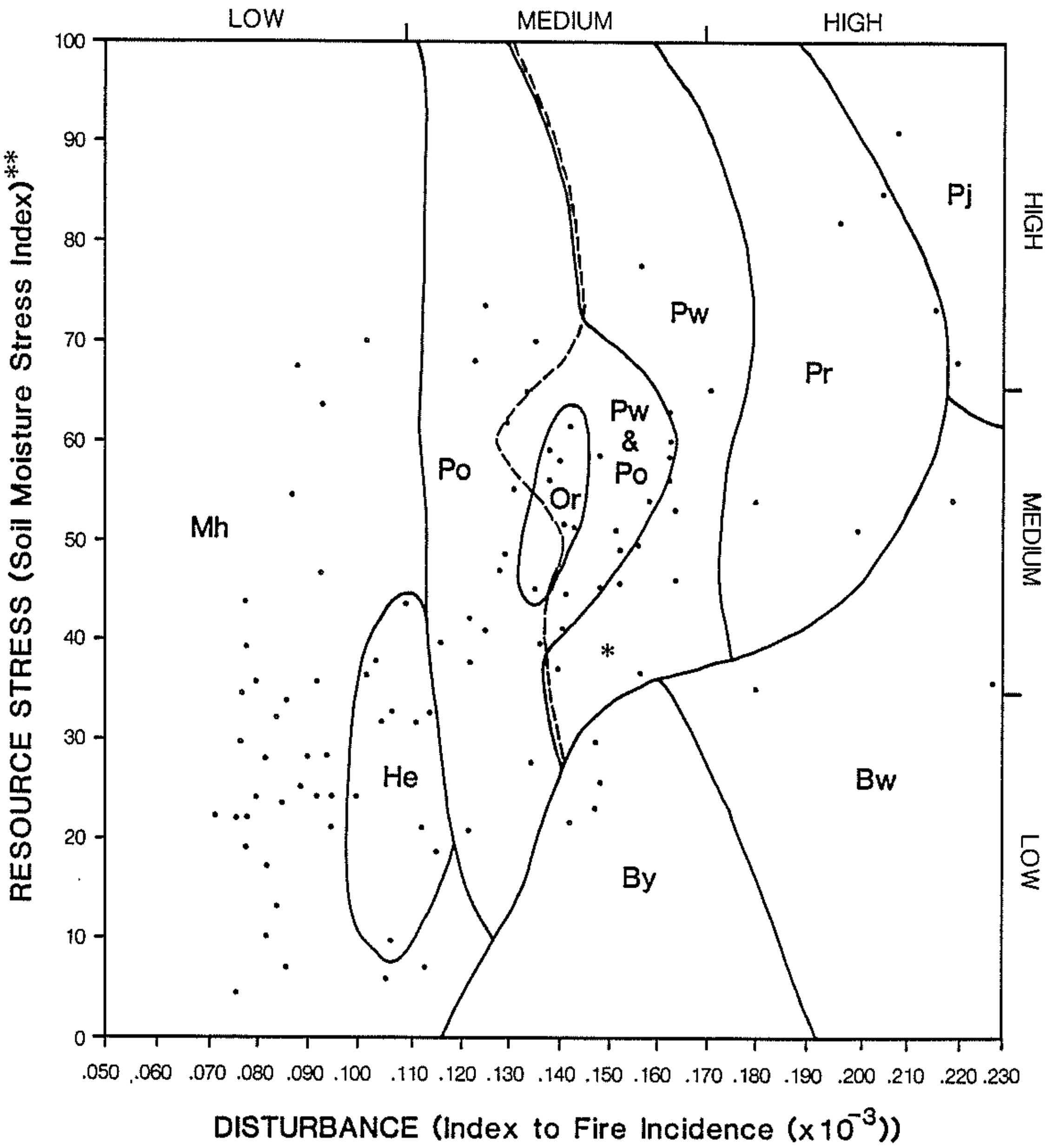
continuous gradients should produce unique vegetation types within any given landscape. Figure 6-4 provides a fit of this model to the fire and soil moisture stress data for the nine upland forest dominance-types in Algonquin Park.

The figure shows that jack pine and red pine occupy the "high to medium stress-high disturbance" portion of the matrix. At the opposite extreme, sugar maple and hemlock occupy the "low to medium stress-low disturbance" portion of the matrix. The other dominance-types occupy intermediate portions of the matrix. The greatest amount of dominance-type overlap occurs at the combination of medium disturbance and medium soil moisture stress. Red oak, white pine, and poplar all overlap in this area.

The forest types occupy the following portions of the matrix: tolerant hardwoods in the "low to medium stress-low to medium disturbance" area; intolerant hardwoods in the "low to medium stress-medium to high disturbance" area; and the pines in the "medium to high stress-medium to high disturbance" area.

The higher correlation between fire and forest composition versus soil moisture and forest composition can be observed in the figure. This is shown by the greatest amount of variation among samples in all dominance-types being along the direction of the resource stress axis.

FIGURE 6-4 - FOREST OVERSTORY COMPOSITION MATRIX
WITH RESPECT TO RESOURCE STRESS AND DISTURBANCE



KEY: Bw-white birch, By-yellow birch, He-hemlock, Mh-sugar maple, Or-red oak, Pj-jack pine, Po-poplar, Pr-red pine, Pw-white pine

* yellow birch stand outside of the yellow birch matrix space

DISCUSSION

INFLUENCE OF FIRE

Results of the canonical correlation indicate that elevation is most highly correlated with variation in overstory composition. This relationship, however, has been manifested indirectly as variations in available moisture through the combination of precipitation and soil texture. Because fire ranked higher on the first environmental variate than these latter two variables, however, it is possible that naturally-caused fire may play a greater ecological role than soil moisture in affecting overstory forest composition within a large portion of Algonquin Park. As well as being highly correlated with overstory composition, fire is the only factor that is correlated with all other significant environmental variables. For the GLSL forests of Michigan, Whitney (1986) also found that "most of the forests can be placed along a fire frequency continuum". It should be noted, however, that all variables other than fire are derived independently of vegetation, whereas the fire incidence index is derived from mapped vegetation data.

Fire is particularly important in perpetuating the pine communities within Algonquin Park (Cwynar, 1977; 1978). Its ecological importance in eastern North America has been well documented for jack pine (Heinselman, 1973; Ahlgren, 1974; Cayford and McRae, 1983), red pine (Van Wagner, 1971; Burgess and Methven, 1977), and white pine communities (Maissurow, 1935; Maissurow, 1941; Frissell, 1973; Fahey and Reiners, 1981).

The intolerant hardwoods such as trembling and large-tooth aspen are less fire prone than conifers such as jack pine (Carleton and Maycock, 1978). However, Heeney et al. (1975) state that most of the present poplar stands in Ontario originated as a result of fire. This is probably because of the pioneer nature of poplar rather than its flammability.

Although fire also occurs in the tolerant hardwood forest, it is generally agreed that fire in this forest type has had a relatively minor ecological influence upon overall forest vegetation composition (Bormann and Likens, 1979a; Fahey and Reiners, 1981). Rather than fire, the creation of canopy gaps by windthrow and tree senescence are the major forms of disturbance within eastern North American tolerant hardwood forest types (Bormann and Likens, 1979b; Hibbs, 1982; Runkle, 1982).

The relationship between fire and overstory composition in Algonquin can be explained in terms of foliage flammability, tree and stand structure, reproductive strategies, anatomical features (Mutch, 1970; Kimmins, 1987), and natural firebreaks (Heinselman, 1973).

The greater flammability of pine needles than deciduous leaves results from a higher concentration of oils, waxes, and resins in the needles (Van Wagner, 1977) and from the lower needle moisture content (Van Wagner, 1967). The dead pine biomass on the forest floor is also very flammable (Van Wagner, 1972; Williamson and Black, 1981) because of the more open canopy structure of pine stands which allows for greater desiccation of the litter (Barden and Woods, 1974) and because of the dryer soil conditions (Kourtz, 1967; Vogl, 1970; Rowe and Scotter, 1973) associated with these stands. The low frequency of fire within Algonquin's tolerant hardwood forest is due mainly to the high moisture content of sugar maple foliage (Van Wagner, 1967). Because their moisture content is lower than that of sugar maple, poplar leaves tend to be more flammable than sugar maple but less than the drier foliage of the pines (Van Wagner, 1967). Poplar foliage flammability is also related to its high chemical extract content (Philpot, 1969).

Due to a well aerated needle litter which keeps it dry and a crown structure reaching close to the ground which acts as a fuel ladder, pine stands are more susceptible to crown fire than the tolerant and intolerant hardwoods (Van Wagner, 1971; Barden and Woods, 1974). Despite their high aromatic content, poplar stands do not normally support crown fires because of relatively low amounts of combustible fuel in and the high moisture content of the duff layer (Horton and Hopkins, 1965). These stands do, however, become extremely flammable when the stand turns decadent (Vogl, 1969). This is often due to the increased presence of balsam fir and other conifers as poplar stands age. It is the bark rather than the foliage of the white birch that is most flammable (Fowells, 1965).

Life history strategies affect the response of plant species to fire. The serotinous character of jack pine cones is the result of a reproductive strategy that renders jack pine dependent upon crown fires for seed release (Cameron, 1953; Beaufait, 1960). The reproductive strategies of red and white pine relate more to establishment and early growth than the release of their seeds which normally die in crown fire (Van Wagner, 1971; Rowe and Scotter, 1973; Burgess and Methven, 1977). They reproduce best when surface fires leave a mineral seedbed or thin litter layer, eliminate understory competition (Methven, 1973), and do not scorch the crowns (Van Wagner, 1971; Ahlgren, 1976). Jack pine is not impeded as much by understory competition (Methven, 1973). In the absence of fire, white pine regeneration has been found to be more successful than that for red and jack pine (Van Wagner, 1963).

One reproductive strategy of the intolerant hardwoods is that of sprouting and root suckering. Many workers have observed the sprouting and rapid growth of oaks (Brown, 1960; Heinselman, 1973; Forman and Boerner, 1981) and white birch (Heinselman, 1973) following fire. Root suckering of trembling and largetooth aspen, which is their primary mode of regeneration (Farmer, 1962), has been linked to an increase in soil temperature which can be caused by fire (Maini and Horton, 1966; Bartos and Mueggler, 1981). The ability to sprout, however, does not enable red oak to outcompete the pines (Cline and Spurr, 1942; Williamson and Black, 1981) mainly because of its thinner bark which makes it less resistant to fire than the pines. Following fire the oaks become highly susceptible to decay (Fowells, 1965). White birch is quite susceptible to intense fire due to its thin bark (Fowells, 1965). Severe fire can also eliminate aspen (Horton and Hopkins, 1965) which is better adapted to fires of low intensity (Lutz, 1956). In addition, white birch and the poplars are light seeded fast growing species which gives them a reproductive advantage on local open sites.

The thick bark of the pines enables them to resist fires that do not affect the living crown (Hare, 1965; Van Wagner, 1971). The bark of red pine is thought to be thicker and more resistant to fire than that of white pine (Van Wagner, 1971). White pine is also more susceptible than red pine to root injury by fire (McConkey and Gedney, 1951) which can facilitate root rot (Frissell, 1973). When roots are not injured by fire, large white pine can tolerate light to moderate surface fires about every 20 to 30 years (Wright and Bailey, 1982). When fire occurs in the tolerant hardwoods, the shallow roots of the hemlock can be damaged leading to mortality (Hough and Forbes, 1943; Cline and Spurr, 1942). This may account for its predominance on fire protected sites (Milne, 1985). The thin bark of young sugar maple and mature yellow birch renders them highly susceptible to fire (Fowells, 1965).

It is likely that fire on the pine-dominated east side has also been facilitated by fewer natural firebreaks because of the subdued relief, fewer lakes and streams, and fewer moist slopes. Conversely, the rugged topography, many lakes and streams, and moist slopes which are characteristic of Algonquin's west side have probably reduced the spread and influence of fire.

From the results of this study it is not possible to determine whether the variation in vegetation composition is controlled by fire or whether the variation in fire is controlled by vegetation. It is likely that each affects the other depending on species and environmental conditions.

INFLUENCE OF CLIMATE AND SOIL

In addition to fire, the results indicate that soil moisture is highly correlated with overstory composition of upland forests in Algonquin. For this study, soil moisture was assessed through the synthetic combination of both precipitation and and soil texture.

The majority of precipitation received in Algonquin Park comes from air masses that follow the Alberta cyclone track (Hills, 1959). As these dry western air masses move easterly over Lake Superior, northern Lake Michigan, and Georgian Bay, they absorb large quantities of moisture (Brown et al., 1980). They rise gradually as they move from the eastern shore of Georgian Bay (177 m elevation) towards Algonquin Park (580m elevation). Approximately 30km from the western park boundary elevation begins to increase rapidly causing orographically induced precipitation in the western highlands. As the air mass descends towards the eastern lowlands, it warms and becomes more stable resulting in the formation of a rain shadow. Even highlands such as Algonquin´s, which rise to only 580m may thus become distinctly wetter than surrounding lowlands due to orographic precipitation (Trewartha, 1968).

To assess the moisture actually available to the growing plant, atmospheric moisture must be considered in combination with the ability of the soil to retain moisture. Moisture retention is directly related to soil texture (Brady, 1974) which, in Algonquin, is related to elevation through the effects of the most recent glacial activity approximately 10,000 years ago. During the Wisconsin glacial retreat, glacial meltwaters drained from ancient Lake Algonquin in a southeasterly direction through an expansive portion of the eastern lowlands area of the park called the Fossmill Outlet (Chapman, 1954). As a result, these meltwaters deposited large amounts of sorted and unsorted sands in the eastern lowland area. Due to their higher elevation, the western uplands were not subject to this major meltwater activity. Here instead, the advancing ice left compacted basal till, and retreating ice left loosely dumped ground moraine, both of which were lower in sand content and higher in silt than the majority of east side deposits.

Greater moisture availability in the uplands due to higher rainfall combined with greater soil moisture retention has facilitated the dominance of sugar maple, yellow birch, and hemlock which are more competitive on moist sites than white, red, and jack pine which in turn are more competitive on the drier sites (Alway and McMiller, 1933; Fraser, 1954; Hills, 1959; Horton and Brown, 1960; Maycock and Curtis, 1960; Lopoukhine, 1974). Among other things, superior root penetrating ability (Brown and Lacate, 1959), deep tap roots (Spurr and Barnes, 1980), and sinker roots (Fowells, 1968) contribute to the ability of the pine species to outcompete the other overstory dominants under low moisture conditions. Dominance of the tolerant hardwood species on sites with greater moisture is apparently enhanced by their greater photosynthetic efficiency (Logan and Krotkov, 1969; Logan, 1970) and their ability to maintain lower rates of respiration per unit leaf area (Grime, 1965; Loach, 1967) under shaded conditions.

The intolerant hardwood species are most competitive on those sites which are intermediate in moisture content (Scholz, 1937; Stoeckeler, 1948; Spurr, 1956; Stoeckeler, 1959, Carleton and Maycock, 1978). This is most likely because of their lower shade tolerance than the tolerant hardwoods and their greater need for moisture than the pine species.

As well as influencing vegetation, the factors of total nitrogen, organic matter, and pH of the mineral soil have all been to some degree affected by the growth and development of vegetation and by fire. Greater amounts of total nitrogen and organic matter in the upper mineral soil of the tolerant hardwood communities compared to intolerant and pine communities have commonly been found (Alway and McMiller, 1933; Pastor et al., 1982; Pregitzer and Barnes, 1984; Spies and Barnes, 1985). This may be due to the higher production of litter in deciduous forests compared to coniferous forests (Bray and Gorham, 1964), the faster rate of deciduous litter decomposition (Millar, 1974), and to the higher nitrogen content in deciduous leaves (Williams and Gray, 1974). The latter observation was confirmed in the present study by obtaining generally lower carbon-nitrogen ratios for the tolerant hardwood communities compared to the pine communities.

The pines seem to compensate for low nitrogen availability by retranslocating nitrogen within the tree (Miller et al., 1979; Spurr and Barnes, 1980). In addition, nitrogen mineralization has been associated with the white pine rhizosphere (Fisher and Stone, 1969). Fire can also reduce the amount of total nitrogen in the mineral soil and increase soil pH (Ahlgren and Ahlgren, 1960; Boerner, 1982; MacLean et al., 1983).

Although pH was included as one of the effective factors within the predictor set, it was not considered a major determinant of composition because of the minor differences observed among forest types and because of the extensive range overlap between community types.

There are also other factors which may affect the composition of overstory vegetation in Algonquin Park. Those of greatest significance include disturbances such as grazing by insects and mammals, disease, wind storms, logging and possibly acid precipitation. Assessment of these disturbances, however, was beyond the scope of this study.

COMMUNITY DYNAMICS

As in all forests, the composition of forests in Algonquin Park has changed with successional development. Thus the species composition of the stands sampled may, in part, reflect a range in successional stages as well as a range in environmental conditions. Evidence of historical forest composition in Algonquin Park obtained by Terasmae and Weeks (1979) provide for a general comparison of present to past forest composition in the Park. Their palynological data from a site on the west side of Algonquin (Terasmae and Weeks, 1979), which is dominated by the tolerant hardwood forest, indicate that 8,000 to 10,000 years ago there was more pine forest and less tolerant hardwood forest in this area. Similar data obtained by Cwynar (1978) for Algonquin's east side indicate that the percentage of pine increased steadily there between 770 and 1200 A.D.

Work on the present forests in Algonquin by Hills (1959) and Martin (1959) indicate that white and red pine stands establish as early to mid-successional community dominants within the tolerant hardwood forest of Algonquin mainly on dry, shallow exposed ridges and upland flats. These dry soil conditions are similar to those in eastern Algonquin where pines are more common. Hills (1959) and Martin (1959) also observed that poplar and white birch usually dominate the first successional communities on all site types within the upland tolerant hardwood forest of Algonquin.

This regional climax view of forest communities, however, must be tempered by the now accepted fact that "xeric, mesic, and hydric environments will support different equally valid climax communities" (Marks and Harcomb, 1981; pg. 299; see also Finegan, 1984; Tilman, 1985). From the data obtained in this study it was not possible to determine the successional nature of sampled stands. It is likely, however, that some of the birch, poplar and white pine stands sampled, particularly those within the tolerant hardwood forest, were early as opposed to later successional stands.

CONCLUSION

Approximately 60% of the upland forest landscape in Algonquin Park is dominated by sugar maple, white pine, and large-toothed aspen, in order of decreasing dominance. The remainder is dominated by yellow birch, hemlock, red pine, white birch, trembling aspen, red oak, and jack pine. Variation within the overstory composition of these upland forest dominance-types is best related to a fire incidence-soil moisture complex gradient.

The high fire-high moisture stress end of the complex gradient supports mainly pine forest communities dominated by jack, red, and white pine. Whitney (1986) suggests that for a similar substrate in Upper Michigan "the coarse textured outwash soils favored the pines, which in turn initiated a fire regime that perpetuated the more flammable pine species". The tolerant hardwood forest species dominate the low fire-low moisture stress end of the complex gradient due to their superior adaptation to moist sites and their low flammability. Occurring at an intermediate position along the gradient are the intolerant hardwood forest communities which are dominated by poplar, white birch and red oak.

Because of its higher ranking on the first canonical variate, its greater dynamic association with other environmental factors, and because of the human tendency to modify it, naturally-caused fire is considered of greater ecological concern than soil moisture for long-term forest management in Algonquin Park. In Algonquin, humans have interfered with naturally-caused fire mainly in two ways. Slash left by timber harvesting which began in the 1830's, probably increased the destructiveness of natural fires (Smith, 1968; Cwynar, 1977) and since 1921, fire suppression has dramatically decreased the role of naturally-caused fire in forest development (Brown, 1980).

In addition to affecting forest development, suppression of forest fire also results in the accumulation of live and dead forest fuels which in turn increases the hazard of fire (Dodge, 1972; Parsons and DeBenedetti, 1979). Both increased fire intensity due to slash and a decreased fire rotation due to fire suppression can result in a modification of forest composition (Chandler et al., 1983; Kimmins, 1987). In eastern North America, fire suppression has modified pine community composition in the Pine Barrens of New Jersey (Boerner, 1981; Forman and Boerner, 1981), in central New York (Milne, 1985), in northern New England (Fahey and Reiners, 1981), and in Minnesota (Spurr, 1954). Fire suppression may ultimately lead to a reduction in biological diversity (Heinselman, 1973; Taylor, 1973; Kessell, 1979), pest outbreaks (Heinselman, 1971), and even species extinctions under specialized circumstances (Oberle, 1969; Forman and Boerner, 1981). Due to the suppression of naturally-caused fire in Algonquin Park since 1921, it is likely that human-caused changes in vegetation composition within Algonquin's pine and intolerant hardwood communities has and will continue to occur.

CHAPTER 7 - UNDERSTORY AND ENVIRONMENT

INTRODUCTION

The forest understory is important for a number of reasons. It plays a significant role in animal food chains, it is subject to major modification by grazing herbivores, it contributes significantly to the circulation of nutrients within the forest, and through arboreal reproduction it influences overstory composition (Siccama et al., 1970; Spurr and Barnes, 1980; Maguire and Forman, 1983). In addition, understory species can be used as indicators of site quality for forest management purposes (Rowe, 1956; Coffman and Willis, 1977; Carleton et al., 1985).

A variety of environmental factors have been identified as key influences upon understory composition within the mixed temperate forest of North America. These include light (Bratton, 1976; Davison and Forman, 1982; Menges, 1986), soil moisture (Maycock and Curtis, 1960; Siccama, 1974; Hicks, 1980; Pregitzer and Barnes, 1984), and nutrients (Graves and Monk, 1982; Rheinhardt and Ware, 1984; Graves and Monk, 1985). These studies have not, however, included the potential influence of disturbance upon understory vegetation composition. Disturbance may result in subtle to severe changes in environmental conditions as well as biological destruction (Canham and Marks, 1985). Misinterpretation of ecological data may result when the role of disturbance is overlooked in explaining community patterns (Sousa, 1984; Pickett and White, 1985).

To date, the analysis of plant population responses to the complete environmental complex has been lacking due to the difficulty of relating populations to one another along two- or three-dimensional continua in a rigorous manner (Rowe, 1983). The purpose of this study was to determine the effect of an entire range of environmental variables, including fire, on the composition of understory forest vegetation through rigorous quantitative description. Field data were collected in Algonquin Park which is centrally located within the Great Lakes-St. Lawrence (GLSL) Forest Region.

METHODS

FIELD

Understory vegetation and environmental factors were sampled in 100 upland forest stands within a transect which was two townships wide extending across the approximate 72 km width of Algonquin Park (Figure 6-2). The understory included saplings (sa), seedlings (se), shrubs, and vascular herbaceous plants. Cryptogams were not included in the survey. Saplings were sampled by recording the percent cover and species for all tree species less than 2cm dbh and greater than .5m in height within 15 systematically placed 2.5m x 2.5m quadrats per stand. Five sapling quadrats were placed along the length of the three 10x30m tree quadrats per stand - three within the tree quadrat and one placed on the outside of each end of the quadrat. Within the entire transect 1500 sapling quadrats were sampled. The remainder of the understory was sampled by recording percent cover and species type within 21 systematically placed 1m x 1m quadrats per stand. Seven of these quadrats were placed along the length of the three 10x30m tree quadrats per stand - three within the tree plot, and one placed at each end and at each side of the tree quadrat. In total, 2100 of these quadrats were sampled. Sampling occurred during summer months, thus certain spring ephemerals such as Claytonia caroliniana and Erythronium americanum were not encountered. Appendix XII provides summarized cover values for understory species within each stand. Nomenclature follows Fernald (1950).

The environmental variables included in this study can be grouped as follows: microclimate, macroclimate, soils, physiography, and disturbance. The influence of microclimate was assessed through the use of indices that were composed of stand basal area values for each of the nine dominant overstory species. These species included yellow birch, sugar maple, hemlock, white birch, poplar, red oak, white pine, red pine, and jack pine. The use of overstory species basal area was based on the assumption that the overstory canopy will have major effects on microclimatic conditions at the forest floor. The amount of light reaching the forest floor was also evaluated by visually estimating the amount of unoccupied space in the forest canopy. Macroclimate, soils, physiography and fire variables were sampled and measured as described in Chapter 6. In total, 34 environmental factors were related to understory composition.

NUMERICAL

Detrended correspondence analysis (DCA) (Hill and Gauch, 1980) was used to ordinate understory vegetation samples based on percent cover of each species within each stand using the computer program DECORANA (Hill, 1979) (see Appendix XIII for stand scores on axes 1 and 2). For each stand, the understory was represented by combining observations for both the sapling and herbaceous layers. Species occurring in only one stand were removed to run DCA. In order to examine relationships between understory vegetation trends and environmental factors, canonical correlation analysis (CCA) (Hotelling, 1936) was used through the SAS computer program (Sarle, 1982). Carleton (1984) provides a detailed explanation of the strengths and weaknesses of using these two methods (see also Chapter 4). Miller's (1975) F-ratio approximation was used to test for significant intra- and interset correlations.

The relative abundance of understory species was plotted with respect to light stress and fire incidence probability. Light stress values for each stand were calculated by rescaling the sugar maple canopy variable and the %canopy cover variable from 0 to 100, summing these rescaled values and dividing by two.

RESULTS

DESCRIPTION OF UNDERSTORY COMPOSITION

In total, 130 vascular plant species were found growing in the understory of upland forests in Algonquin Park (see Table 7-1). These included 25 tree species, 22 shrub species, and 84 herbaceous species. The five most abundant understory species were *Acer saccharum* (se) (15.2%), *Aralia nudicaulis* (7.7%), *Acer saccharum* (sa) (7.0%), *Corylus cornuta* (6.7%), and *Pteridium aquilinum* (6.2%). There were 32 species that had 0.5% or greater relative abundance in the entire study area (see Table 7-2). The abundances for the more important understory species by overstory dominance-type are shown in Table 7-3. This included species with an average of at least 5.0% cover per stand or 80% relative stand frequency. Those species that met both criteria were considered the understory dominants and were classified into overstory dominance-types and forest types which included tolerant hardwoods, intolerant hardwoods, and pines (see Chapter 6 for explanation of these dominance- and forest types.

Tolerant Hardwood Forest

Yellow birch type

The three dominant understory species within this overstory

TABLE 7-1 - UNDERSTORY SPECIES LIST

Abies balsamea
Acer pennsylvanicum
Acer rubrum
Acer saccharum
Acer spicatum
Actaea pachypoda
Actaea rubra
Alnus rugosa
Amelanchier sanguinea
Apocynum androsaemifolium
Aralia nudicaulis
Arctostaphylos uva-ursi
Arisaema triphyllum
Aster macrophyllus
Aster umbellatus
Athyrium Felix-femina
Betula lutea
Betula papyrifera
Botrychium virginianum
Brachyelytrum erectum
Carex arctata
Carex communis
Carex deweyana
Carex intumescens
Carex leptonervia
Carex spp.
Chimaphila umbellata
Cinna latifolia
Circaea alpina
Clintonia borealis
Comptonia peregrina
Coptis groenlandica
Cornus canadensis
Cornus rugosa
Corylus cornuta
Cypripedium candidum
Diervilla lonicera
Dirca palustris
Dryopteris spinulosa
Epigaea repens
Equisetum scirpoides
Fagus grandifolia
Fragaria vesca
Fragaria virginiana
Fraxinus americana
Fraxinus nigra
Galium trifolium
Gaultheria hispidula
Gaultheria procumbens
Goodyera repens
Gramineae spp.
Gymnocarpium dryopteris
Habenaria orbiculata
Hepatica americana
Impatiens capensis
Kalmia angustifolia
Linnaea borealis
Lonicera canadensis
Lycopodium annotinum
Lycopodium clavatum
Lycopodium complanatum
Lycopodium lucidulum
Lycopodium obscurum
Medeola virginiana
Melampyrum lineare
Maianthemum canadense
Milium effusum
Mitchella repens
Monotropa uniflora
Onoclea sensibilis
Ostrya virginiana
Oxalis montana
Pedicularis canadensis
Picea glauca
Picea mariana
Pinus banksiana
Pinus resinosa
Pinus strobus
Polygala pauciflora
Polygonatum biflorum
Polygonum cilinode
Polypodium virginianum
Populus grandidentata
Populus tremuloides
Prunus pumila
Prunus serotina
Pteridium aquilinum
Pyrola elliptica
Pyrola rotundifolia
Pyrola secunda
Pyrola virens
Quercus rubra
Ribes glandulosum
Ribes lacustre
Rubus canadensis
Rubus pubescens
Rubus strigosus
Rubus spp.
Sambucus canadensis

TABLE 7-1 (CON´T)

Sanicula marilandica
Solidago canadensis
Solidago squarrosa
Smilacina racemosa
Streptopus amplexifolius
Taxus canadensis
Thelypteris noveboracensis
Thelypteris phegopteris
Thuja occidentalis
Tiarella cordifolia
Tilia americana
Trientalis borealis
Trillium cernuum
Trillium erectum
Trillium grandiflorum
Trillium undulatum
Tsuga canadensis
Vaccinium angustifolium
Vaccinium myrtilloides
Viburnum acerifolium
Viburnum alnifolium
Viburnum cassinoides
Viola adunca
Viola cucullata
Viola incognita
Viola pubescens
Viola renifolia
Viola selkerkii
Viola septentrionalis
Viola spp.
Waldsteinia fragariodes

TABLE 7-2 - TOTAL COVER (%) OF THE UNDERSTORY SPECIES FOUND WITHIN THE STUDY AREA (>0.5% relative abundance)

SPECIES	TOTAL COVER (%)
Acer saccharum (se)	15.2
Aralia nudicaulis	7.7
Acer saccharum (sa)	7.0
Corylus cornuta	6.7
Pteridium aquilinum	6.2
Maianthemum canadense	3.9
Acer rubrum (sa)	3.8
Dryopteris spinulosa	3.3
Acer rubrum (se)	3.3
Aster macrophyllus	2.6
Abies balsamea (sa)	2.5
Acer pennsylvanicum (sa)	2.0
Lycopodium obscurum	1.9
Viburnum alnifolium	1.8
Acer pennsylvanicum (se)	1.7
Abies balsamea (se)	1.7
Vaccinium angustifolium	1.6
Trientalis borealis	1.5
Gramineae spp.	1.2
Gaultheria procumbens	1.2
Fagus grandifolia (sa)	1.1
Cornus canadensis	1.1
Lonicera canadensis	1.0
Clintonia borealis	.9
Ostrya virginiana (sa)	.7
Pinus strobus (sa)	.7
Carex spp.	.7
Lycopodium lucidulum	.7
Acer spicatum (se)	.6
Amelanchier sanguinea	.6
Streptopus amplexifolius	.6
Tiarella cordifolia	.5

TABLE 7-3 - DOMINANT UNDERSTORY SPECIES BY OVERSTORY DOMINANCE-TYPE
(includes species with at least 80% relative stand frequency
(first value) or at least 5% cover (second value) - asterisks
indicate those species that satisfy both conditions)

	Dominance-Type								
Understory Species	Yellow Birch	Sugar Maple	Hemlock	White Birch	Poplar	White Pine	Red Oak	Red Pine	Jack Pine
Oxalis montana	100 4.8								
Betula lutea (sa)	80 0.4		100 1.1						
Lycopodium lucidulum	100 1.5								
Dryopteris spinulosa	*100 7.6	*95 7.3	100 4.5						
Acer saccharum (sa)	100 4.0	100 3.4		100 0.9					
Thelypteris phegopteris	80 4.3								
Acer saccharum (se)	*100 19.1	*100 37.1	100 2.1						
Tsuga canadensis (sa)			100 3.6						
Acer pennsylvanicum (se)	80 2.4	85 2.7	*100 5.7						
Viola spp.	80 1.7			100 1.4					
Streptopus amplexifolius	100 2.0		100 1.0						
Acer pennsylvanicum (sa)	80 1.0	80 0.7	100 0.3	100 0.5					
Lycopodium obscurum	100 4.1	88 3.0							
Acer spicatum (se)	*100 5.2								
Trientalis borealis	100 1.4	93 2.2	100 2.1	*100 5.7	95 3.0	95 1.5		80 0.8	
Lonicera canadensis	80 0.5			100 1.6					
Aralia nudicaulis	100 4.1		*100 5.1	*100 11.3	*95 15.3	*100 13.9	*100 8.8	*80 12.2	
Corylus cornuta					*100 11.7	*100 16.5		*80 10.9	
Maianthemum canadense	100 1.9		100 4.7	100 3.5	*100 7.0	100 3.2	100 4.1	*100 13.4	*100 8.1
Acer rubrum (se)				*100 5.9	*100 7.2	95 4.6	*100 6.9	100 1.6	
Abies balsamea (sa)			100 0.6	100 0.7				80 0.9	
Abies balsamea (se)				*100 6.3		90 2.9			
Acer rubrum (sa)	80 0.2			100 0.4	100 2.2	95 1.5	100 1.4		
Clintonia borealis	80 0.4								
Carex spp.	80 0.6						100 3.0	100 2.8	
Gramineae spp.	80 0.3			100 1.2	100 1.5	100 1.9	*100 6.3	100 3.0	100 4.9
Cornus canadensis				100 2.3					
Aster macrophyllus					*100 6.2	*95 5.7	100 4.9	100 3.5	
Quercus rubra (se)							100 4.3		
Gaultheria procumbens					95 2.1	95 2.5	100 3.0	100 2.0	*100 7.1
Quercus rubra (sa)							100 2.4		
Pteridium aquilinum					*95 13.0	*95 11.3	*100 6.6	*100 17.0	*100 35.2
Linnaea borealis						84 1.3		100 2.7	
Populus tremuloides (sa)								80 1.0	
Pinus strobus (sa)								80 0.6	
Vaccinium angustifolium					84 2.3	90 2.5	100 4.4	80 3.6	*100 23.4
Pinus strobus (se)								80 1.7	
Amelanchier sanguinea							100 3.2	100 1.6	100 1.8
Melampyrum lineare								100 0.8	
Kalmia angustifolia									100 3.6
Comptonia perigrina									100 3.2
Pinus resinosa (sa)									100 1.0

dominance-type included *Acer saccharum* (se), *Dryopteris spinulosa*, and *Acer spicatum* (se). Other less abundant dominant understory species that characterized this overstory dominance-type in order of decreasing abundance included *Oxalis montana*, *Thelypteris phegopteris*, *Lycopodium obscurum*, *Aralia nudicaulis*, *Acer saccharum* (sa), *Acer pennsylvanicum* (se), *Streptopus amplexifolius*, *Maianthemum canadense*, *Viola* spp., *Trientalis borealis*, *Lycopodium lucidulum*, *Acer pennsylvanicum* (sa), *Carex* spp., *Lonicera canadensis*, *Clintonia borealis*, *Betula lutea* (sa), *Gramineae* spp., and *Acer rubrum* (sa). Approximately 80.5% of the forest floor was covered by vascular understory growth.

Sugar maple type

The two dominant understory species within this overstory dominance-type included *Acer saccharum* (se) and *Dryopteris spinulosa*. Other less abundant dominant understory species that characterized this overstory dominance-type in order of decreasing abundance included *Acer saccharum* (sa), *Lycopodium obscurum*, *Acer pennsylvanicum* (se), *Trientalis borealis*, and *Acer pennsylvanicum* (sa). Approximately 76.1% of the forest floor was covered by vascular understory growth.

Hemlock type

The two dominant understory species for this overstory dominance-type included *Acer pennsylvanicum* (se) and *Aralia nudicaulis*.

Other less abundant dominant understory species that characterized this overstory dominance-type in order of decreasing abundance included Maianthemum canadense, Dryopteris spinulosa, Tsuga canadensis (sa), Acer saccharum (se), Trientalis borealis, Betula lutea (sa), Streptopus amplexifolius, Abies balsamea (sa), and Acer pennsylvanicum (sa). Approximately 46.0% of the forest floor was covered by vascular understory growth.

Intolerant Hardwood Forest

White birch type

The four dominant understory species in this overstory dominance-type included Aralia nudicaulis, Abies balsamea (se), Acer rubrum (se), and Trientalis borealis. Other less abundant dominant understory species that characterized this overstory dominance-type in order of decreasing abundance included Maianthemum canadense, Cornus canadensis, Lonicera canadensis, Viola spp., Gramineae spp., Acer saccharum (sa), Abies balsamea (sa), Acer pennsylvanicum (sa) and Acer rubrum (sa). Approximately 90.5% of the forest floor was covered by vascular understory growth.

Poplar type

The six understory dominants for this dominance-type included

Aralia nudicaulis, *Pteridium aquilinum*, *Corylus cornuta*, *Acer rubrum* (se), *Mianthemum canadense*, and *Aster macrophyllus*. Other less abundant dominant understory species that characterized this overstory dominance-type in order of decreasing abundance include *Trientalis borealis*, *Vaccinium angustifolium*, *Acer rubrum* (sa), *Gaultheria procumbens*, and *Gramineae* spp. Approximately 90.5% of the forest floor was covered by vascular understory growth.

Red oak type

The four dominant understory species in this dominance-type included *Aralia nudicaulis*, *Acer rubrum* (se), *Pteridium aquilinum*, and *Gramineae* spp. Other less abundant dominant understory species that characterized this overstory dominance-type in order of decreasing abundance include *Aster macrophyllus*, *Vaccinium angustifolium*, *Quercus rubra* (se), *Maianthemum canadense*, *Amelanchier sanguinea*, *Carex* spp., *Gaultheria procumbens*, *Quercus rubra* (sa), and *Acer rubrum* (sa). A total of 62.9% of the forest floor was covered by vascular understory growth.

Pine Forest

White pine type

The four understory dominants within this dominance-type included

Corylus cornuta, *Aralia nudicaulis*, *Pteridium aquilinum*, and *Aster macrophyllus*. Other less abundant dominant understory species that characterized this overstory dominance-type in order of decreasing abundance include *Acer rubrum* (se), *Maianthemum canadense*, *Abies balsamea* (se), *Gaultheria procumbens*, *Vaccinium angustifolium*, *Gramineae* spp., *Trientalis borealis*, *Acer rubrum* (sa), and *Linnaea borealis*. Approximately 83.8% of the understory was covered by vascular plants.

Red pine type

The three understory dominants for this dominance-type included *Pteridium aquilinum*, *Maianthemum canadense*, and *Aralia nudicaulis*. Other less abundant dominant understory species that characterized this overstory dominance-type in order of decreasing abundance include *Vaccinium angustifolium*, *Aster macrophyllus*, *Gramineae* spp., *Linnaea borealis*, *Carex* spp., *Gaultheria procumbens*, *Pinus strobus*, *Acer rubrum* (se), *Amelanchier sanguinea*, *Populus tremuloides* (sa), Abies balsamea (sa), *Melampyrum lineare*, *Trientalis borealis*, and *Pinus strobus* (sa). A total of 77.7% of the understory was covered by vascular plants.

Jack pine type

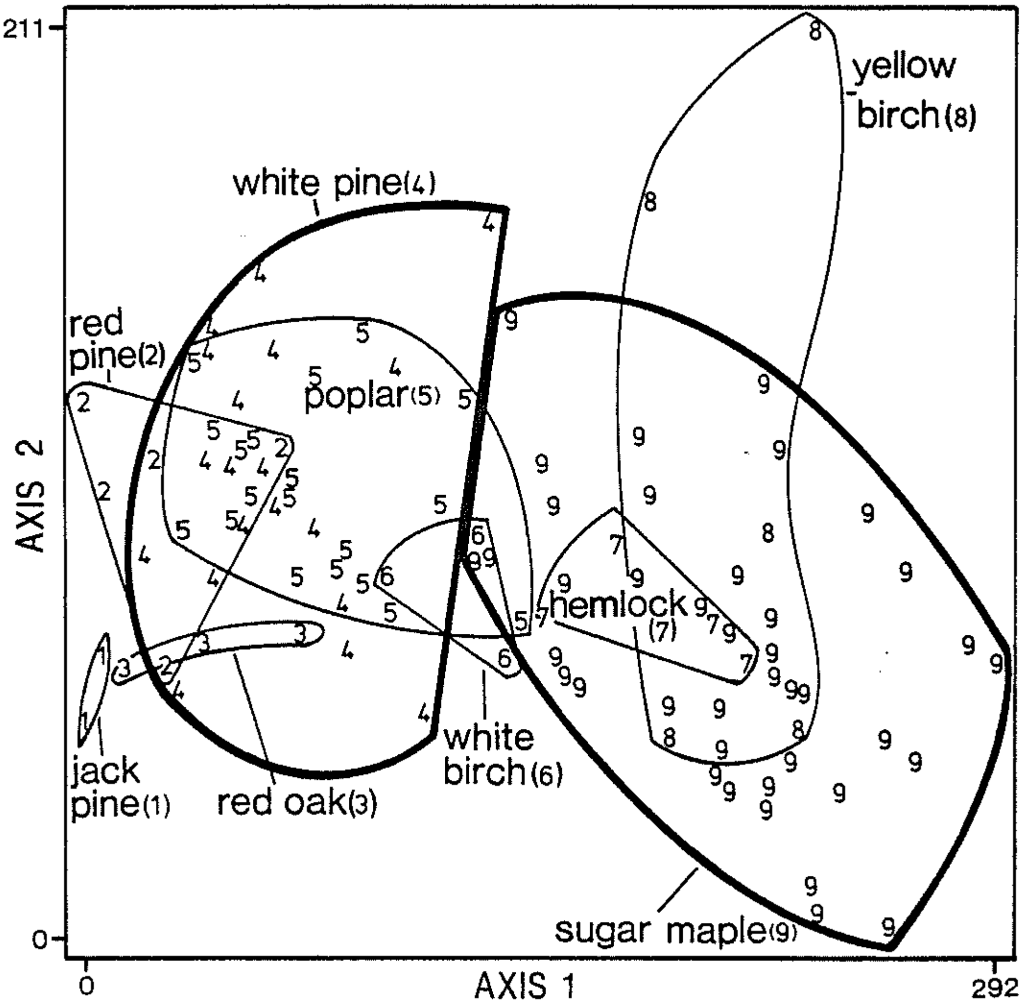
The four understory dominants for this dominance-type included *Pteridium aquilinum*, *Vaccinium angustifolium*, *Maianthemum canadense* and *Gaultheria procumbens*. Other less abundant dominant understory species that characterized this overstory dominance-type in order of decreasing abundance include Gramineae spp., Kalmia angustifolia, Comptonia perigrina, Amelanchier sanguinea, and Pinus resinosa (sa). A total of 94.0% of the understory was covered by vascular plants.

STAND ORDINATION

Eigenvalues resulting from DCA for axes 1 through 4 were .378, .154, .110, and .087. The relatively large difference between the first and second axis of the DCA compared to the much smaller difference between the remaining successive axes indicates that the first DCA axis contains a large portion of the variation in the vegetation composition data. Figure 7-1 shows each stand plotted with respect to both its DCA axes (1 and 2) scores and the dominance-type designations. The most obvious pattern in this figure is the separation of the tolerant hardwood understory at the high end of axis one from the intolerant hardwood and pine understories at the lower extreme of this same axis. This is with the exception of one poplar and one white birch stand, both of which fall within the understory ordination space of the tolerant hardwood forest.

From Figure 7-1 it can also be seen that 92 of the 100 stands fall within one of two dominance-type ordination spaces. Except for two yellow birch stands, the understory composition of the hemlock and yellow birch dominance-types forms a subset of the sugar maple understory ordination space. To a lesser extent, the same situation

FIGURE 7-1 - SCATTERGRAM OF STANDS PLOTTED WITH RESPECT TO DCA AXES 1 AND 2 FOR THE UNDERSTORY



occurs with the other two forest types. The understory composition of the poplar, red pine, red oak, and white birch dominance-types generally falls within the understory ordination space of the white pine dominance-type.

A notable exception is the understory composition of the jack pine dominance-type which occupies the only non-overlapping region of the ordination space compared with other dominance-types. The understory dominants which are unique to this dominance-type include Vaccinium angustifolium and Gaultheria procumbens. It should be noted, however, that the degree of understory composition similarity between dominance-types is affected by the number of stands sampled. In this case only two jack pine stands were sampled.

SPECIES ORDINATION

In addition to providing a stand ordination, DCA provides a species ordination. Table 7-4 provides three sets of 20 species: one at either end of the first ordination axis and one representing the mid-portion of the axis. Those species at the high end are characteristic of the tolerant hardwood forest, those at the low end are characteristic of the pine forest and those in the intermediate portion are characteristic of the intolerant hardwoods. Some of these species such as Trientalis borealis, Aralia nudicaulis, Mianthemum canadense, and Acer rubrum (se) are among the most common understory species in the study area. Not only do they occur within the intolerant hardwood forest but also within

TABLE 7-4 - UNDERSTORY SPECIES CHARACTERISTIC OF THE EXTREME ENDS AND INTERMEDIATE PORTION OF THE FIRST DCA AXIS OF THE STAND ORDINATION

(species also listed in Table 7-3 appear in dark print - numbers represent position along first axis of the DCA species ordination)

HIGH END (dominated by tolerant hardwoods)

1 ***Milium effusum***
2 *Thelypteris noveaboracensis*
3 *Viola cucullata*
4 *Viola septentrionalis*
5 ***Impatiens capensis***
6 ***Brachyelytrum erectum***
7 *Viola selkerkii*
8 *Carex arctata*
9 ***Trillium erectum***
10 ***Trillium grandifolium***
11 *Ribes glandulosum*
12 *Monotropa uniflora*
13 *Viola incognita*
14 *Prunus serotina* (sa)
15 *Betula lutea* (se)
16 ***Oxalis montana***
17 *Cinna latifolia*
18 *Viburnum alnifolium*
19 ***Betual lutea*** (sa)
20 *Gymnocarpium dryopteris*

LOW END (dominated by pines)

111 ***Pinus strobus*** (sa)
112 ***Vaccinium angustifolium***
113 *Viburnum cassinoides*
114 *Apocynum androsaemifolium*
115 ***Pinus strobus*** (se)
116 *Diervilla lonicera*
117 *Polypodium virginianum*
118 ***Amelanchier sanguinea***
119 ***Waldsteinia fragariodes***
120 ***Melampyrum lineare***
121 ***Chimaphila umbellata***
122 ***Epigaea repens***
123 ***Lycopodium complanatum***
124 *Kalmia angustifolia*
125 ***Solidago squarrosa***
126 ***Taxus canadensis***
127 *Comptonia peregina*
128 ***Pinus banksiana*** (sa)
129 *Pinus resinosa* (sa)
130 *Cypripedium candidum*

INTERMEDIATE (dominated by intolerant hardwoods)

55 ***Fagus grandifolia*** (sa)
56 *Medeola virginiana*
57 ***Fagus grandifolia*** (se)
58 *Carex deweyana* (se)
59 *Rubus pubescens*
60 *Botrychium virginianum*
61 ***Trientalis borealis***
62 *Polygonatum biflorum*
63 *Viola pubescens*
64 *Coptis groenlandica*
65 *Habenaria orbiculata*
66 ***Lonicera canadensis***
67 ***Aralia nudicaulis***
68 *Mitchella repens*
69 *Corylus cornuta*
70 ***Maianthemum canadense***
71 *Sanicula marilandica*
72 ***Acer rubrum*** (se)
73 ***Abies balsamea*** (sa)
74 *Aster umbellatus*

the tolerant hardwood and pine forests. Whereas Table 7-3 includes only common or dominant species, Table 7-4 includes those that are less common or rare as well as some that are more common.

INDIRECT GRADIENT ANALYSIS

Mean stand basal area for the nine overstory species that were used as indices to microclimate are presented for each of the nine dominance-types in Table 6-3. The rest of the environmental variables are summarized by dominance-type in Table 6-4. Stand values for the environmental variables were used in CCA along with stand scores from DCA which were used to represent understory composition.

Because of suspected collinearity between the nine microclimate indices (overstory species basal areas) and the 25 directly measured environmental factors, the final predictor set was identified in three steps. First, the interset correlations between the four environmental variates and the four DCA axes obtained from CCA were tested for significance using Miller´s (1975) F-ratio approximation (see Table 7-5). Using Miller´s (1975) F-ratio approximation, five significant interset correlations were identified. However, because the eigenvalues for axis 2 (.154), axis 3 (.110) and axis 4 (.087) were so low relative to the axis 1 eigenvalue (.378), only the relationship between DCA axis 1 and environmental variate 1 was considered important.

Second, the significance of the cumulative intraset correlation for each of the 34 environmental factors was tested to identify a

TABLE 7-5 - INTERSET CORRELATIONS BETWEEN ORDINATION AXES AND CANONICAL VARIATES FOR THE UNDERSTORY

	V1	V2	V3	V4
AX1	-.973**	.080	.022	-.013
AX2	.463	.507*	.516*	-.176
AX3	-.136	-.747*	.444	.061
AX4	-.020	-.211	.350	-.565*

** p<.001; Miller's (1975) F-ratio approximation
* p<.01

TABLE 7-6 - ENVIRONMENTAL FACTOR LOADINGS ON THE FIRST CANONICAL VARIATE FOR THE UNDERSTORY PREDICTOR SET

Environmental Factor	Loading
elevation	.872
sugar maple	.871
longitude	-.815
precipitation	.793
temperature	-.784
fire	-.782
total nitrogen	.742
light	-.707
c/n ratio	-.650

preliminary predictor set, again using Miller's (1975) F-ratio approximation. This resulted in the selection of eleven variables.

Third, a CCA was performed using only the first DCA axis, which was identified from step one, and the preliminary predictor set of 11 variables which was identified from step two. Of these 11 environmental variables, calcium and magnesium were dropped because they did not contribute significantly to the interset correlation due to their low intraset correlations (.022 and .124).

Table 7-6 shows the environmental factors and their loadings for the final predictor set. Elevation had the highest loading on the first canonical variate and sugar maple canopy effect had the next highest loading. Excluding longitude, precipitation and temperature ranked next. Fire, total nitrogen, light and the carbon:nitrogen ratio followed.

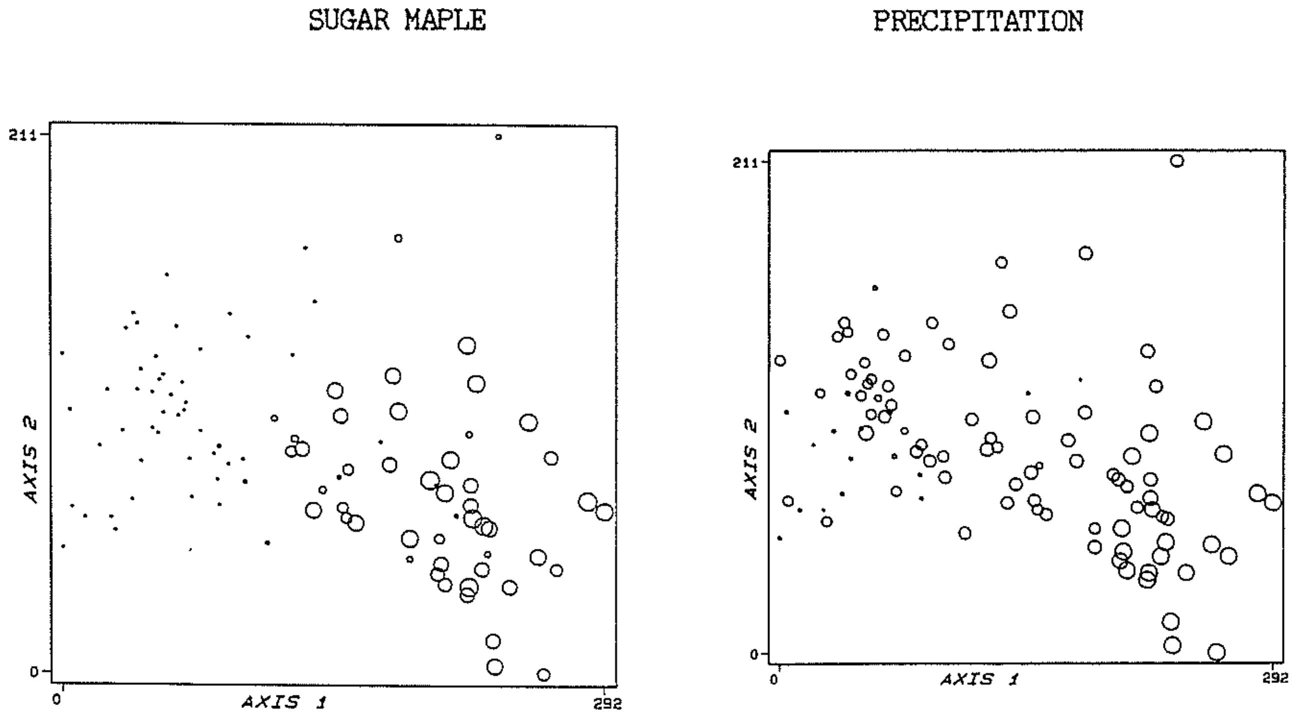
EFFECTIVE FACTORS

A discussion and description of effective factors can be found in Chapter 6. Table 7-7 shows the effective factors identified for this study. Those that are not included in the overstory predictor set are sugar maple canopy effects, % canopy opening (light) and carbon:nitrogen ratio. The sugar maple canopy effect varied from a mean high of 25.85 m^2/ha in the sugar maple dominance-type to a mean low of 0 m^2/ha in the red oak, red pine, and jack pine dominance-types. The mean sugar maple canopy effect was greatest for the tolerant hardwood

TABLE 7-7 - MEAN STAND VALUES FOR EFFECTIVE FACTORS BY FOREST TYPE FOR THE UNDERSTORY

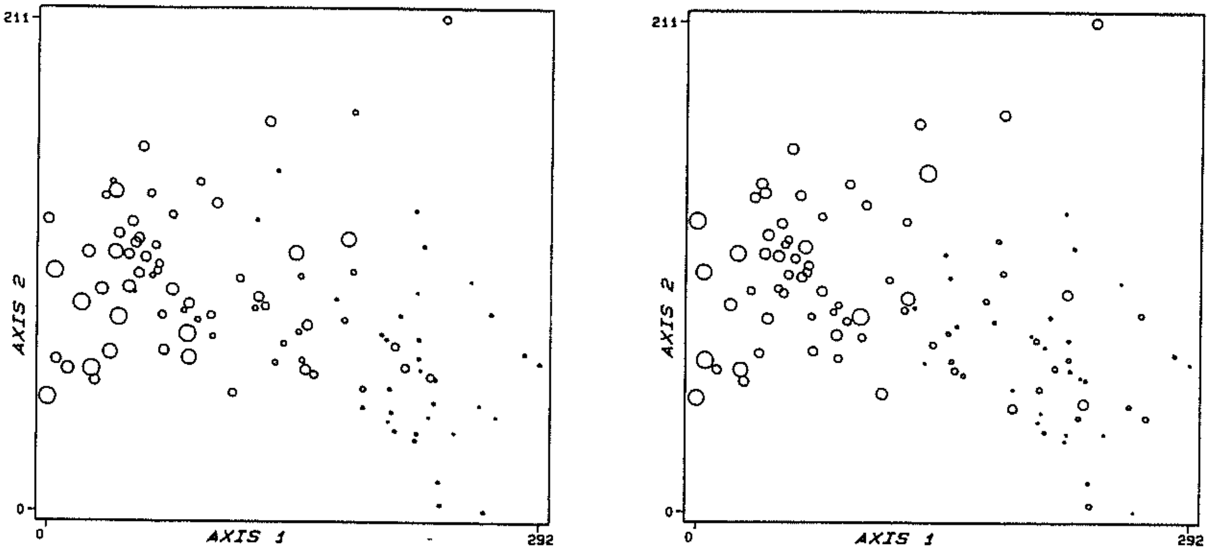
EFFECTIVE FACTOR	FOREST TYPES Tolerant Hardwoods	 Intolerant Hardwoods	 Pines
Sugar Maple (m^2/ha)	22.2	1.7	0.3
Precipitation (mm)	861	798	787
Temperature (degrees C)	18.66	18.84	18.98
Fire	$.097 \times 10^{-3}$	$.141 \times 10^{-3}$	$.167 \times 10^{-3}$
Total Nitrogen (%)	.26	.12	.10
Light (% canopy open)	13.6	20.2	28.0
C/N Ratio	34.4	47.7	47.3
No. of Stands	49	25	26

FIGURE 7-2 - SCATTERGRAMS OF THE RELATIVE MAGNITUDE OF IMPORTANT ENVIRONMENTAL FACTORS ON THE STAND ORDINATION BY DCA (circle size is proportional to the magnitude of the variable)


SUGAR MAPLE

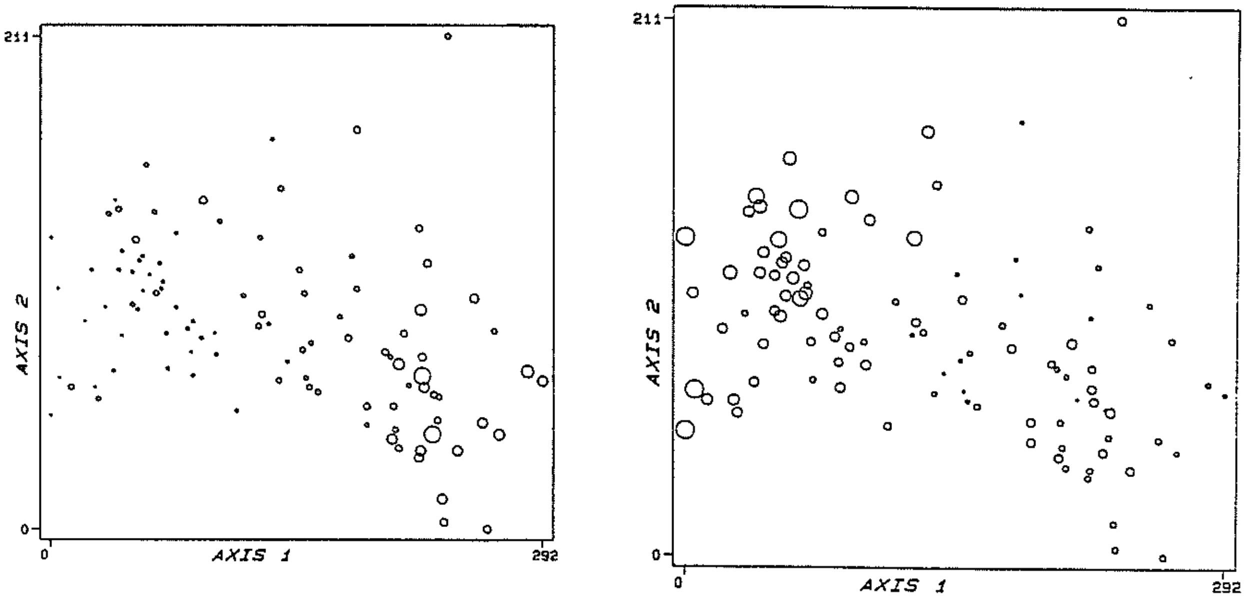
PRECIPITATION

FIGURE 7-2 (CON'T.)



TEMPERATURE

FIRE

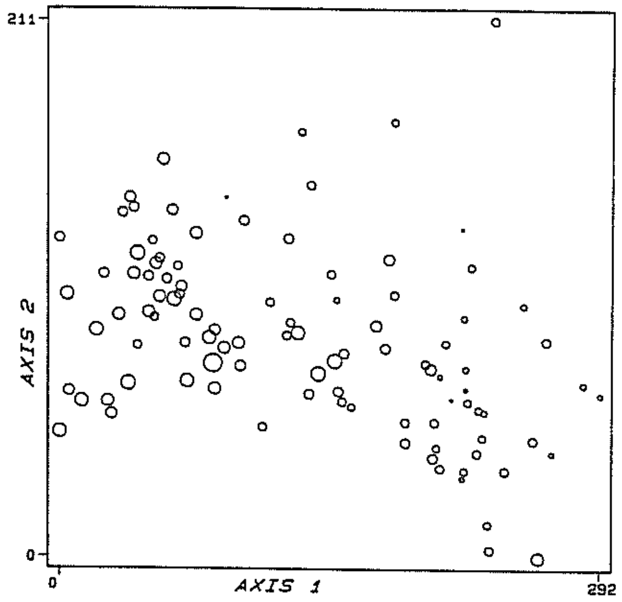


TOTAL NITROGEN

LIGHT

FIGURE 7-2 (CON'T.)

C/N RATIO



forest type (22.2m^2/ha), least for the pine forest type (0.3m^2/ha) and intermediate for the intolerant hardwood forest type (1.7m^2/ha).

Light (% canopy opening) varied from a mean of 42.2% for the jack pine dominance type to a mean of 10.0% for the hemlock dominance-type. Mean values for light also varied from a high of 28.0% for the pine forest type to a low of 13.6% for the tolerant hardwood forest type with an intermediate value of 20.2% for the intolerant forest type.

The carbon:nitrogen ratio varied from a mean of 59.1 for the red oak dominance-type to a mean of 33.6 for the sugar maple dominance-type. The intolerant hardwood forest had the highest carbon:nitrogen ratio (47.7), the tolerant hardwood forest had the lowest value (34.4) and the pine forest had an intermediate value (47.3). Figure 7-5 shows the magnitude of these effective factors plotted with respect to the first and second DCA axes.

FACTOR INTERACTIONS

Because the factors of an environmental complex do not vary alone (McIntosh 1970), it is necessary to consider factor interactions when describing a model of environmental influence upon understory composition. The relationships between environmental factors in the predictor set are presented in Table 7-8 in the form of Pearson product-moment correlations. The highest correlation between effective factors is between temperature and precipitation (-.888). High correlations also exist between fire and sugar maple canopy (-.790),

TABLE 7-8 - PREDICTOR SET CORRELATION MATRIX
(all correlations are significant at the p<.01 level)

	EV	MH	LG	PP	TP	FR	TN	LT	CN
EV	1.000								
MH	.667	1.000							
LG	-.875	-.566	1.000						
PP	.814	.533	-.934	1.000					
TP	-.870	-.539	.893	-.888	1.000				
FR	-.654	-.790	.541	-.481	.557	1.000			
TN	.619	.650	-.600	.592	-.580	-.507	1.000		
LT	-.515	-.565	.435	-.351	.358	.621	-.322	1.000	
CN	-.423	-.563	.476	-.524	.513	.426	-.540	.292	1.000

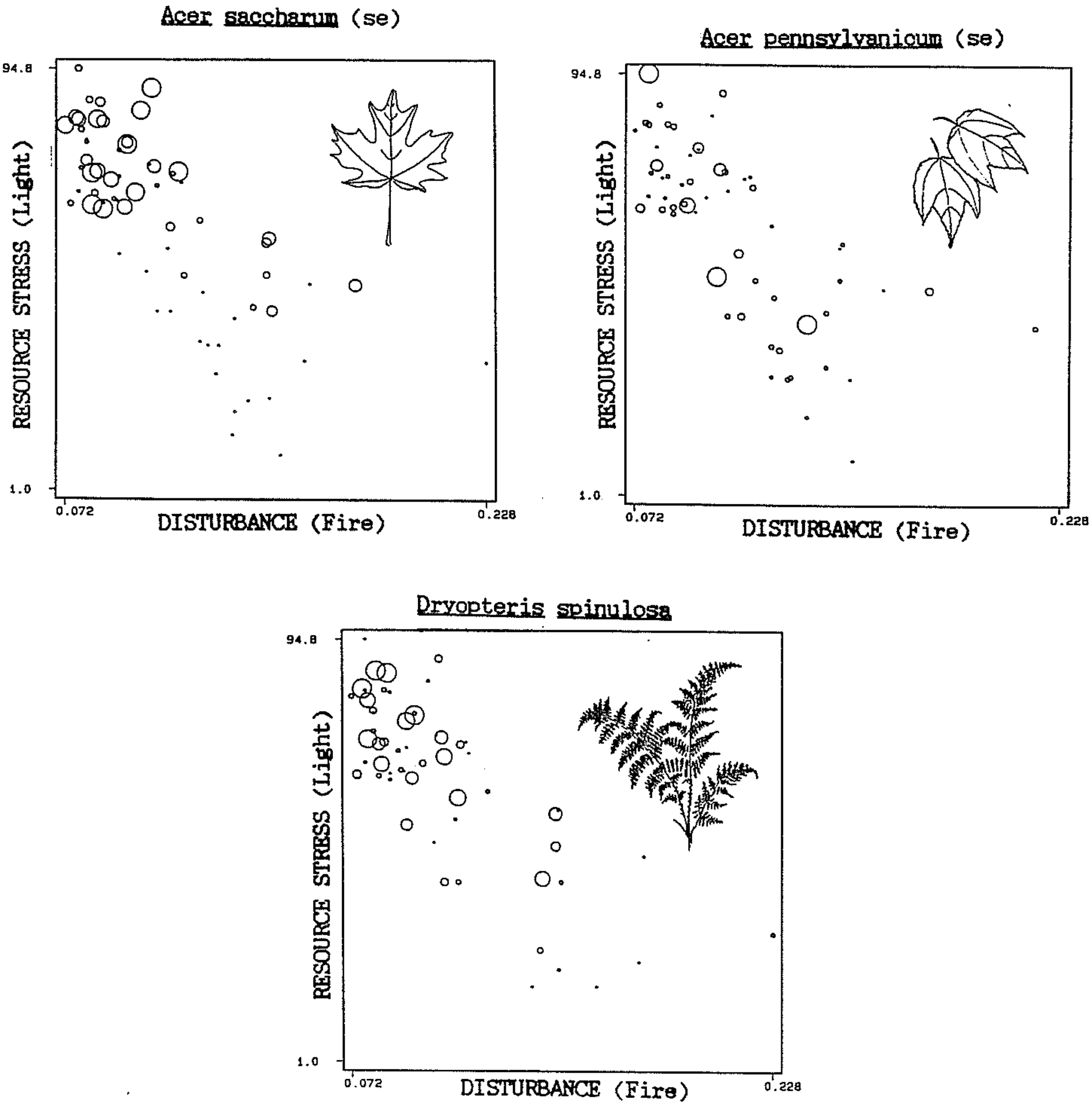
EV-elevation, MH-sugar maple, LG-longitude, PP-precipitation, TP-temperature, FR-fire, TN-total nitrogen, LT-latitude, CN-carbon-nitrogen ratio total nitrogen and sugar maple canopy (.650), and fire and % canopy opening (.621).

DIRECT GRADIENT ANALYSIS

To examine plant growth strategies, species abundance can be viewed in relation to resource stress and disturbance (Grime, 1979). Results of the indirect gradient analysis show that light, represented by both the sugar maple canopy effect and percent canopy opening, is the most highly correlated plant growth resource with the first environmental variate. Disturbance in the form of fire is also highly correlated with the first environmental variate. Therefore, the abundance of the 15 most common understory species (those with both >80% stand frequency and >5% cover per stand) was plotted against fire (disturbance gradient) and light (resource stress gradient).

The dominant understory species from Table 7-3 that are associated mainly with the low fire-low light condition include Acer pennsylvanicum (se), Acer saccharum (se), and Dryopteris spinulosa (see Figure 7-2). Those dominants having a greater association with the high fire-low light stress include Aralia nudicaulis, Corlylus cornuta, Gaultheria procumbens, Gramineae spp., Maianthemum canadense, Pteridium aquilinum, and Vaccinium angustifolium (see Figure 7-3). And those dominant species having no particular association with a disturbance or resource stress condition include Abies balsamea (se), Acer rubrum (se), Acer spicatum (se), Aster macrophyllus, and Trientalis borealis (see Figure 7-4).

FIGURE 7-3 - RELATIVE ABUNDANCE OF SPECIES OCCUPYING THE
LOW DISTURBANCE-HIGH RESOURCE STRESS CONDITION



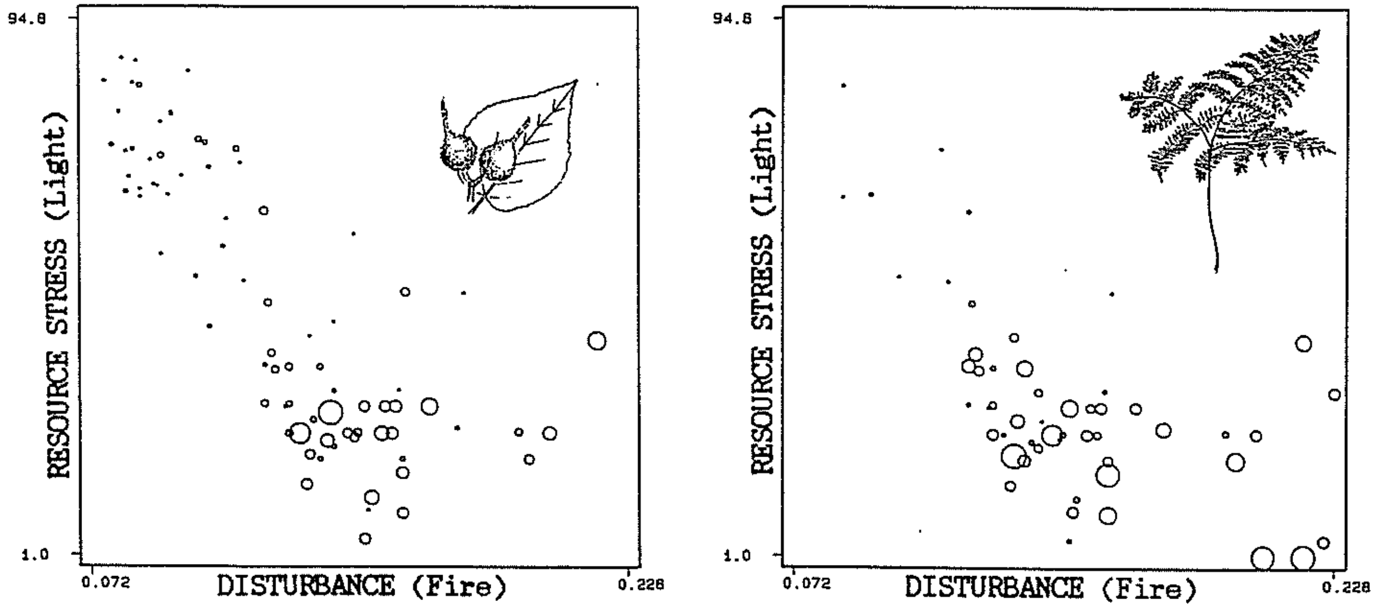
Acer saccharum (se)

Acer pennsylvanicum (se)

Dryopteris spinulosa

FIGURE 7-4 - RELATIVE ABUNDANCE OF SPECIES FAVORING THE
HIGH DISTURBANCE-LOW RESOURCE STRESS CONDITION

Corylus cornuta *Pteridium aquilinum*



Aralia nudicaulis *Maianthemum canadense*

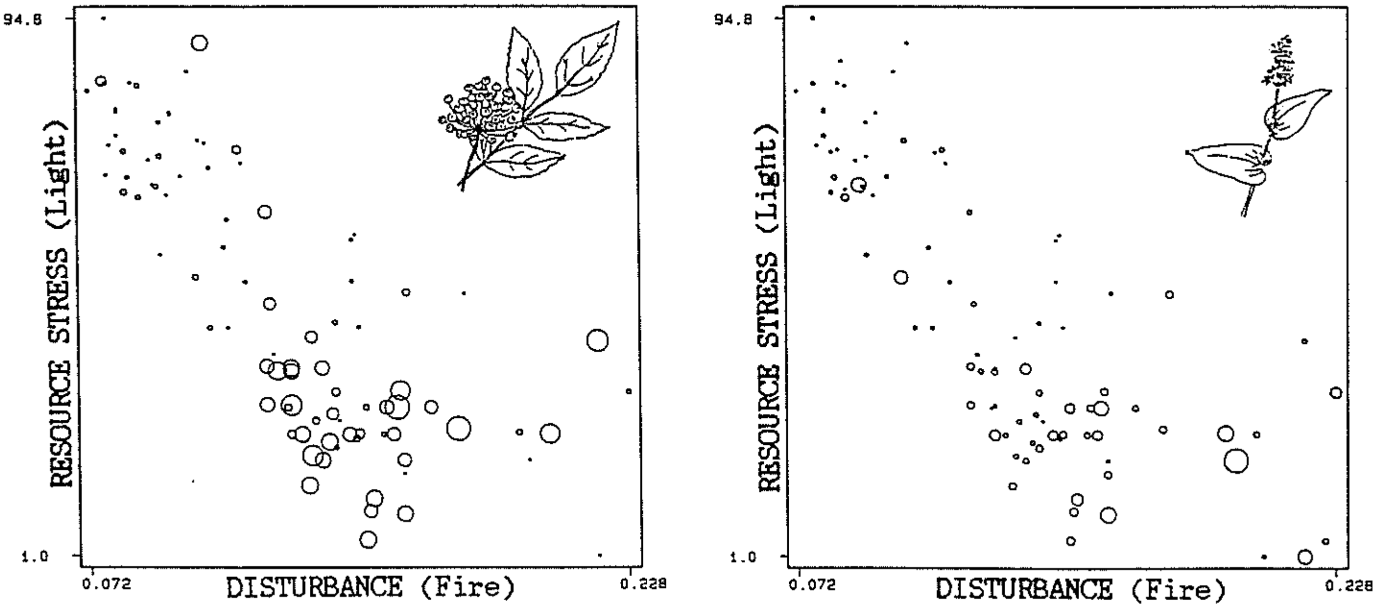
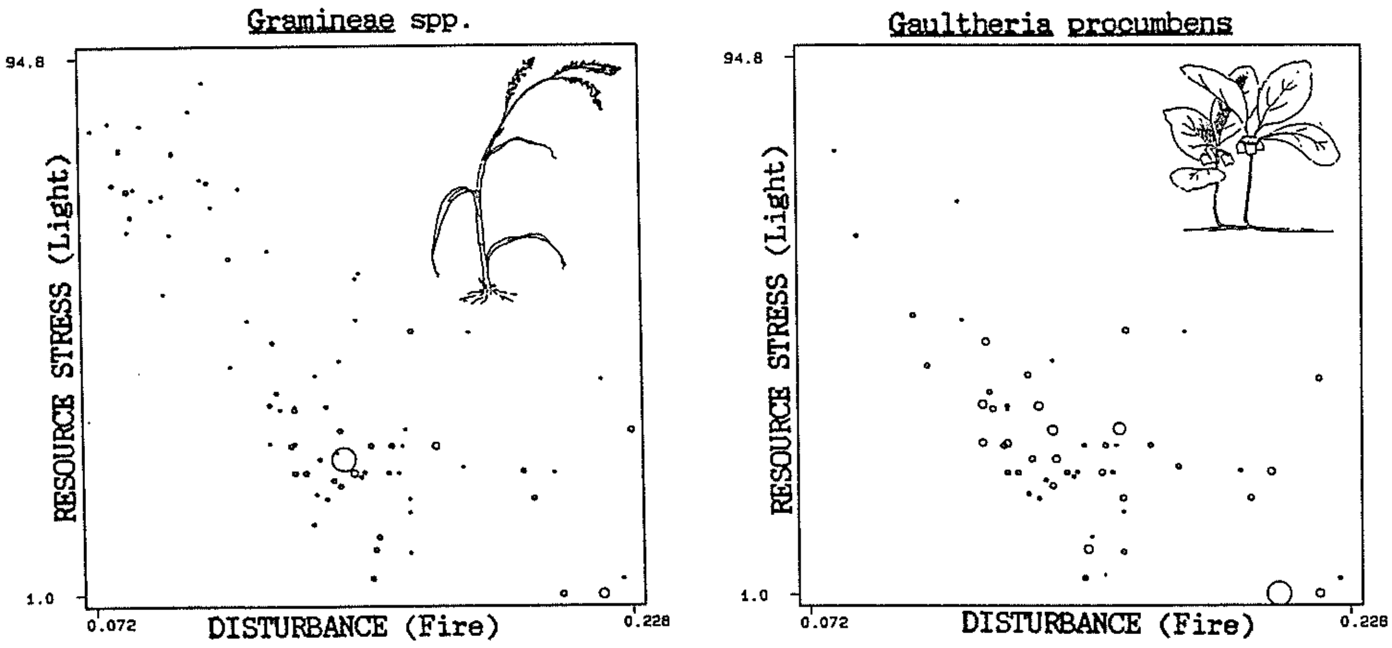


FIGURE 7-4 (CON'T)



Vaccinium angustifolium

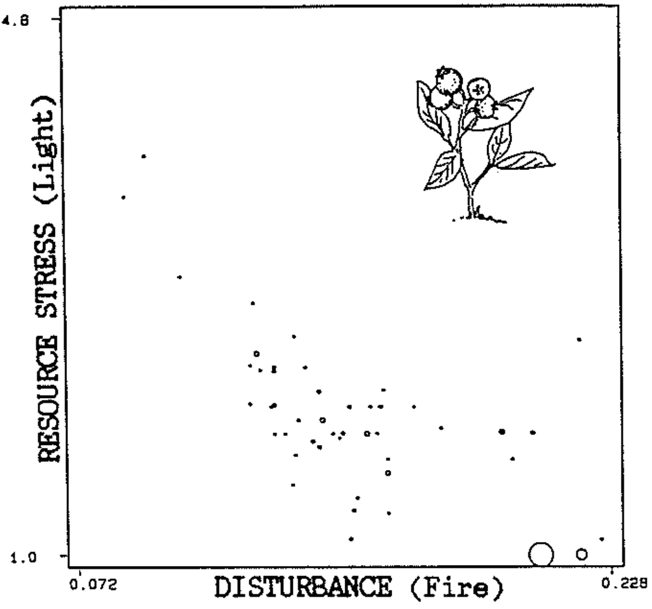


FIGURE 7-5 - RELATIVE ABUNDANCE OF SPECIES WITH NO STRONG ASSOCIATION FOR A PARTICULAR DISTURBANCE OR RESOURCE STRESS CONDITION

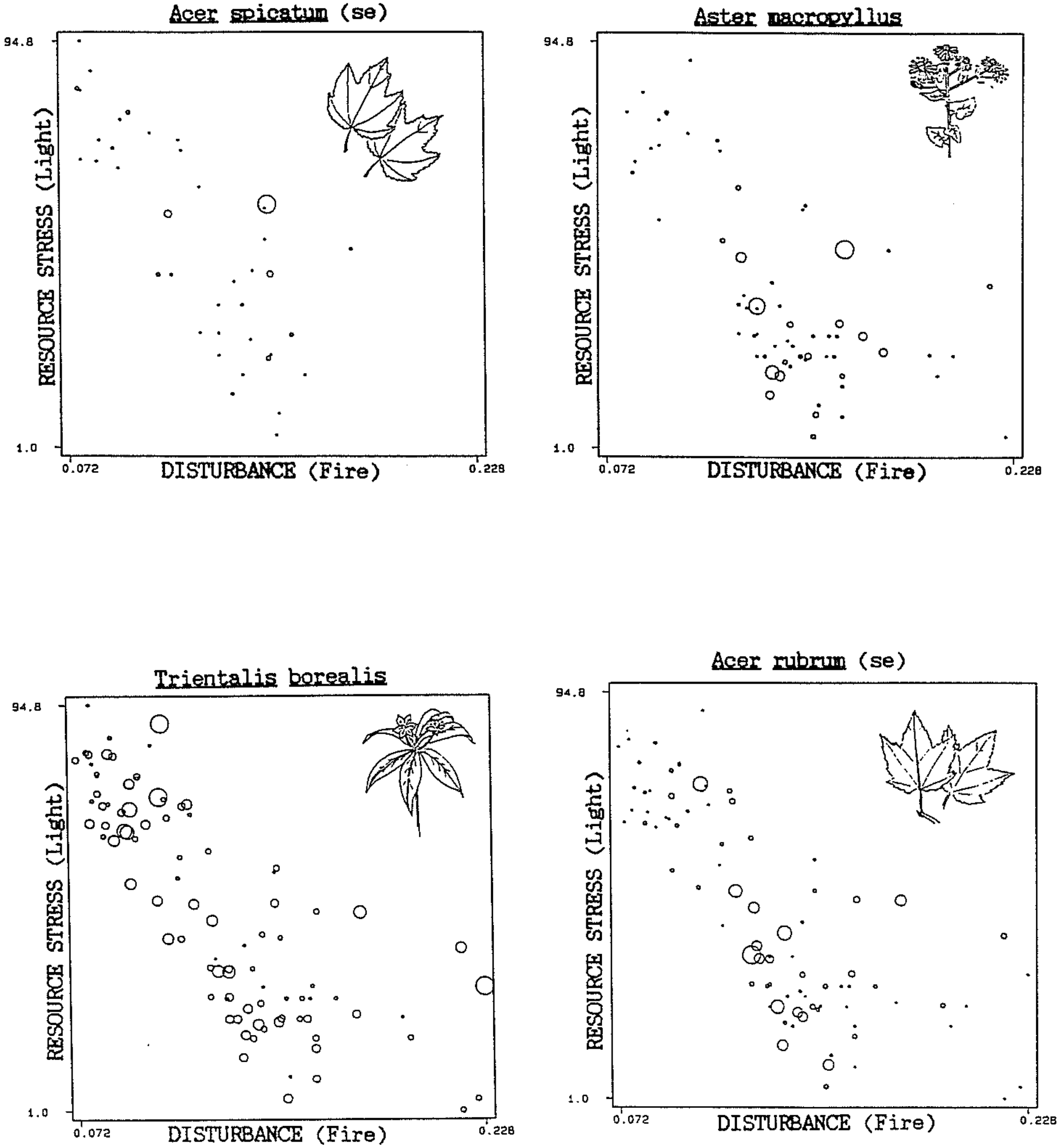
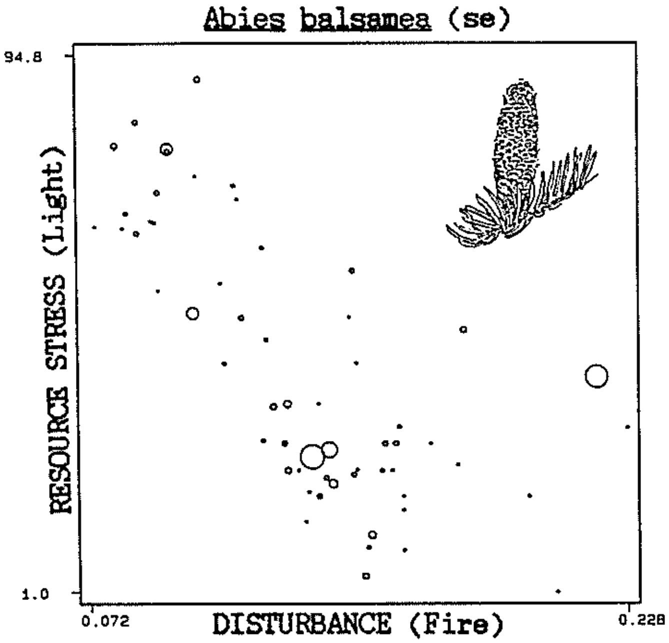


FIGURE 7-5 (CON'T)



Figures 7-2 through 7-4 show that the more abundant understory species are clearly associated with one of three major portions of the light-fire gradient. Taking this one step further, Table 7-9 classifies all the understory species into one of three growth strategy categories according to their relative abundance along the complex gradient. The stress tolerators/avoiders are most abundant at the high stress/low disturbance end of the gradient, the generalists are most abundant in the middle portion of the gradient (medium stress/medium disturbance), and the ruderals/endurers are most abundant at the low stress/high disturbance end of the gradient.

The stress tolerators/avoiders category includes 33 species dominated mainly by trees (*Acer saccharum*, *Acer pennsylvanicum*, *Fagus grandifolia*, *Ostrya virginiana*, *Prunus serotina*, and *Betula lutea*), ferns (*Dryopteris spinulosa*) and Lycopods (*Lycopodium obscurum* and *Lycopodium lucidulum*). The generalist category includes 47 species dominated mainly by trees (*Acer rubrum*, *Quercus rubra*, *Acer spicatum*, and *Populus tremuloides*), shrubs (*Viburnum alnifolium*, *Lonicera villosa*, and *Rubus pubescens*), and summer herbs (*Trientalis borealis*, *Streptopus amplexifolius*, *Tiarella cordifolia*, and *Medeola virginiana*). The ruderals/endurers category includes 45 species dominated mainly by shrubs (*Corylus cornuta*, *Vaccinium angustifolium*, *Lonicera canadensis*, and *Amelanchier sanguinea*) and summer herbs (*Aralia nudicaulis*, *Maianthemum canadense*, *Aster macrophyllus*, *Gaultheria procumbens*, *Cornus canadensis*, and *Clintonia borealis*).

TABLE 7-9 - UNDERSTORY SPECIES AND THEIR ABUNDANCES GROUPED BY GROWTH STRATEGIES AND STRESS/DISTURBANCE CATEGORIES (Values are presented as average % cover per stand; species are ordered within each growth strategy group according to decreasing total abundance in study area; see end of table for growth strategy and stress/disturbance grouping criteria)

GROWTH STRATEGY GROUP/SPECIES	ABUNDANCE WITHIN STAND STRESS/DISTURBANCE CATEGORIES		
	High Stress/ Low Disturbance Stands (38)	Medium Stress/ Medium Disturbance Stands (24)	Low Stress/ High Disturbance Stands (38)
Stress Tolerators/Avoiders			
Acer saccharum (se)	37.36	9.30	0.43
Acer saccharum (sa)	21.78	9.31	0.48
Dryopteris spinulosa	6.87	3.34	0.35
Acer pennsylvanicum (sa)	4.59	3.54	1.18
Lycopodium obscurum	2.77	2.27	1.03
Acer pennsylvanicum (se)	2.93	2.72	0.20
Fagus grandifolia (sa)	3.61	0.81	0.37
Ostrya virginiana (sa)	1.74	0.76	0.70
Lycopodium lucidulum	1.52	0.78	0.03
Ostrya viginiana (se)	0.80	0.48	0.23
Fagus grandifolia (se)	0.85	0.28	0.05
Prunus serotina (sa)	0.78	0.18	0.21
Betula lutea (sa)	0.63	0.46	0.00
Betula lutea (se)	0.43	0.32	0.03
Rubus strigosus	0.48	0.23	0.04
Galium triflorum	0.18	0.18	0.03
Prunus serotina (se)	0.31	0.04	0.04
Thelypteris noveboracensis	0.29	0.06	0.00
Lycopodium annotinum	0.22	0.12	0.01
Trillium erectum	0.26	0.01	0.00
Tilia americana (sa)	0.12	0.00	0.00
Ribes glandulosum	0.07	0.01	0.00
Cinna latifolia	0.04	0.02	0.01
Viola incognita	0.06	0.00	0.00
Trillium undulatum	0.04	0.02	0.00
Athyrium Felix-femina	0.04	0.01	0.00
Viola selkerkii	0.03	0.02	0.00
Brachyelytrum erectum	0.04	0.01	0.00
Viola pubescens	0.03	0.00	0.01
Trillium grandiflorum	0.04	0.00	0.00
Carex arctata	0.01	0.01	0.00
Impatiens capensis	0.01	0.01	0.00
Milium effusum	0.01	0.00	0.00

TABLE 7-9 (CON'T)

	High Stress/ Low Disturbance Stands (38)	Medium Stress/ Medium Disturbance Stands (24)	Low Stress/ High Disturbance Stands (38)
Generalists			
Acer rubrum (sa)	2.02	9.32	7.43
Acer rubrum (se)	1.94	5.88	3.77
Trientalis borealis	2.26	2.85	1.68
Viburnum alnifolium	2.95	3.55	0.00
Quercus rubra (sa)	0.72	0.81	1.38
Acer spicatum (se)	0.29	1.91	0.30
Streptopus amplexifolius	0.79	1.13	0.22
Tiarella cordifolia	0.35	1.75	0.03
Medeola virginiana	0.70	0.86	0.11
Viola spp.	0.51	0.89	0.21
Oxalis montana	0.18	1.10	0.00
Lonicera villosa	0.28	0.33	0.54
Thelypteris phegopteris	0.10	0.95	0.01
Rubus pubescens	0.14	0.67	0.15
Populus tremuloides (sa)	0.29	0.15	0.46
Kalmia angustifolia	0.22	0.25	0.41
Tsuga canadensis (sa)	0.06	0.68	0.00
Tsuga canadensis (se)	0.06	0.59	0.00
Mitchella repens	0.16	0.12	0.31
Pyrola rotundifolia	0.11	0.20	0.21
Smilacina racemosa	0.09	0.35	0.03
Coptis groenlandica	0.00	0.37	0.09
Lycopodium clavatum	0.00	0.28	0.08
Polygonatum biflorum	0.13	0.08	0.09
Polygala pauciflora	0.07	0.13	0.10
Betula papyrifera (sa)	0.03	0.13	0.10
Populus tremuloides (se)	0.05	0.09	0.08
Gymnocarpium dryopteris	0.06	0.14	0.01
Populus grandidentata (se)	0.08	0.05	0.05
Viola cucullata	0.07	0.10	0.01
Ribes lacustre	0.00	0.16	0.01
Rubus spp.	0.00	0.09	0.08
Polygonum cilinode	0.03	0.14	0.00
Fragaria virginiana	0.05	0.02	0.08
Betula papyrifera (se)	0.01	0.09	0.04
Viburnum cassinoides	0.02	0.06	0.02
Onoclea sensibilis	0.01	0.05	0.00
Alnus rugosa (sa)	0.00	0.06	0.00

TABLE 7-9 (CON'T)

	High Stress/ Low Disturbance Stands (38)	Medium Stress/ Medium Disturbance Stands (24)	Low Stress/ High Disturbance Stands (38)
Equisetum scirpoides	0.00	0.04	0.00
Sambucus canadensis	0.00	0.03	0.00
Goodyera repens	0.00	0.03	0.00
Sanicula marilandica	0.00	0.02	0.01
Circaea alpina	0.01	0.00	0.01
Pyrola elliptica	0.01	0.00	0.01
Habenaria orbiculata	0.00	0.01	0.01
Viola septentrionalis	0.01	0.01	0.00
Monotropa uniflora	0.00	0.01	0.00
Ruderals/Endurers			
Pteridium aquilinum	6.77	5.37	14.34
Aralia nudicaulis	2.95	9.33	13.11
Corylus cornuta	2.46	5.60	13.29
Maianthemum canadense	2.19	4.56	9.00
Abies balsamea (sa)	1.40	2.33	6.90
Aster macrophyllus	0.35	4.26	4.45
Vaccinium angustifolium	1.75	1.03	3.93
Abies balsamea (se)	0.90	2.22	2.48
Pinus strobus (sa)	1.33	0.96	2.84
Gaultheria procumbens	0.03	1.06	2.71
Gramineae spp.	0.31	0.81	2.58
Lonicera canadensis	0.64	1.36	1.49
Cornus canadensis	0.03	0.68	2.68
Clintonia borealis	0.29	1.27	1.60
Carex spp.	0.18	0.43	2.09
Amelanchier sanguinea	0.70	0.39	1.57
Linnaea borealis	0.46	0.05	1.17
Waldsteinia fragariodes	0.43	0.15	1.03
Picea glauca (sa)	0.17	0.40	0.88
Pinus strobus (se)	0.35	0.15	0.82
Quercus rubra (se)	0.13	0.34	0.66
Comptonia peregrina	0.17	0.04	0.42
Vaccinium myrtilloides	0.03	0.03	0.48
Cypripedium candidum	0.01	0.00	0.48
Populus gradidentata (sa)	0.07	0.04	0.37
Acer spicatum (sa)	0.00	0.17	0.25
Chimaphila umbellata	0.10	0.06	0.23
Viburnum acerifolium	0.01	0.12	0.26
Melampyrum lineare	0.09	0.03	0.21
Lycopodium complenatum	0.07	0.03	0.18
Picea glauca (se)	0.00	0.07	0.16
Apocynum androsaemifolium	0.06	0.02	0.15
Pinus banksiana (sa)	0.05	0.00	0.13
Prunus pumila	0.05	0.00	0.13
Cornus rugosa	0.01	0.07	0.09

TABLE 7-9 (CON'T)

	High Stress/ Low Disturbance Stands (38)	Medium Stress/ Medium Disturbance Stands (24)	Low Stress/ High Disturbance Stands (38)
Actaea pachypoda	0.04	0.00	0.09
Botrychium virginianum	0.02	0.03	0.08
Viola renifolia	0.01	0.05	0.06
Pinus resinosa (sa)	0.03	0.00	0.08
Epigaea repens	0.03	0.02	0.06
Hepatica americana	0.00	0.00	0.06
Aster umbellatus	0.00	0.01	0.04
Fragaria vesca	0.01	0.00	0.03
Solidago squarrosa	0.01	0.00	0.03
Carex deweyana	0.01	0.00	0.03

STRESS/DISTURBANCE CATEGORY CRITERIA: "High Stress/Low Disturbance" -light (stress) range: 63.5-94.8, mean: 74.2, fire (disturbance) range: .072X10^{-3}-.115X10^{-3}, mean: .090X10^{-3} (38 stands); "Medium Stress/Medium Disturbance" - light range: 33.2-61.0, mean: 44.8, fire range: .092X10^{-3}-.219X10^{-3}, mean: .133X10^{-3} (24 stands); "Low Stress/High Disturbance" - light range: 0-29.8, mean: 19.8, fire range: .122X10^{-3}-.228X10^{-3}, mean: .159X10^{-3} (38 stands).

GROWTH STRATEGY GROUPING CRITERIA: "Stress Tolerators/Avoiders" - abundance in the High Stress/Low Disturbance category was higher than both the other two categories and at least 2X greater than abundance in the Low Stress/High Disturbance category; "Ruderals/Endurers" - abundance in the Low Stress/High Disturbance category was higher than both the other two categories and at least 2X greater than the abundance in the High Stress/Low Disturbance category; "C-S-R Strategists" - abundance in the Medium Stress/Medium Disturbance category was higher than both the other two categories, or abundance in the High Stress/Low Disturbance category was higher than the other two categories but less than 2X the abundance in the Low Stress/High Disturbance category, or abundance in the Low Stress/High Disturbance category was higher than the other two categories but less than 2X the abundance in the High Stress/Low Disturbance category.

Only species that occurred in two or more stands were included in this table

DISCUSSION

The success of plant populations is dependent upon their growth and reproductive adaptations to variations in resource stress and disturbance (Grime, 1979). Light, which supplies energy for photosynthesis, is one of the more critical resources required for plant growth (Kimmins, 1987; Woodward, 1987). Many species have adapted to varying light conditions through the processes of germination, establishment, growth and reproduction (Grime, 1965; Whigham, 1974; Clough et al., 1979; Ernst, 1979; Barkham, 1980; Morgan and Smith, 1981). For understory vegetation, the nature of the canopy and the creation of canopy gaps have the greatest effect on the condition of light that eventually reaches the forest floor (MacLean and Wein, 1977; Barbour et al., 1980; Spurr and Barnes, 1980; Collins et al., 1985).

Studies have shown that overstory composition and density are significantly related to forest understory composition (Outcalt and White, 1981; Woods and Whittaker, 1981; Carleton, 1984; Carleton et al., 1985; Moloney, 1986). Variation in understory light was considered the most important effective influence on understory composition within a New Jersey deciduous forest (Davison and Forman, 1982), a Wisconsin hardwood forest (Menges, 1986), and a southern Appalachian hardwood forest (Bratton, 1976).

The results of this study indicate that light, evaluated by the sugar maple canopy variable and percent canopy opening, is considered to have the greatest influence on variation in understory composition. The dominance of sugar maple in the canopy severely reduces the amount of light reaching the forest floor relative to the pine and intolerant hardwood dominance-types. In addition to affecting understory light, however, overstory sugar maple may also affect understory plants through processes such as allelochemistry and seed production. These additional influences could not be assessed for this study. Disturbance, in the form of fire, was also found to be highly correlated with understory species composition. Through destruction of the forest canopy fire may drastically affect the intensity of light reaching the forest floor. It may also result in the release of other resources such as water and soil nutrients which then become available for plant growth.

There are two main mechanisms by which this may occur (Canham and Marks, 1985). First, resource use is reduced immediately following the destruction of biomass. An obvious example is the increase in light intensity at the forest floor due to the creation of canopy gaps. Secondly, disturbance causing increased insolation at the soil surface may increase nutrient availability by increasing the rate at which soil organic matter is decomposed (Bormann and Likens, 1979b).

Generally, the larger and more intense the disturbance, the greater the resulting availability of resources for plant growth (Canham and Marks, 1985). As a result of the immediate stimulation in growth, this resource availability is transient in nature. Variations in resource availability are more characteristic of disturbed areas and result in greater morphological and physiological plasticity in the resident plant species (Bradshaw, 1965; Bazzaz, 1979) allowing them to accumulate resources quickly upon their availability (Marks, 1975; Vitousek, 1977). Thus, by affecting competition for resources the frequency, intensity, and spatial distribution of disturbance has played a major role in the evolutionary selection of plant regeneration strategies (Grime, 1979).

In general, the understories of the pine dominance-types in Algonquin Park tend to be characterized by greater amounts of light compared to the intolerant hardwood dominance-types. These in turn have greater light levels than the understories of the tolerant hardwood dominance-types. This light gradient corresponds to an associated variation in the presence of understory plant species.

Within the study area, the understories of the tolerant hardwood dominance-types are dominated mainly by trees, ferns and Lycopods. Typical dominant tree species such as Acer saccharum and Acer pennsylvanicum have developed adaptations to carry out efficient photosynthesis at low light levels (Woods and Whittaker, 1981). Ferns such as Dryopteris spinulosa and Lycopods such as Lycopodium obscurum and Lycopodium lucidulum are also shade tolerant. Because of their semi-evergreen nature, they are able to commence photosynthesis prior to canopy leaf-out and before most other species of the understory. In general, trees and ferns are also more competitive in a low light environment due to their greater height growth relative to other understory growth forms, enabling them to minimize the effect of shade from other plants (Horn, 1975; Givnish, 1982). Shade tolerant species have been classified as "shade plants" by Collins et al. (1985) and "stress tolerators" by Grime (1979).

With respect to disturbance, however, most understory species which are typical of the tolerant hardwood forest do not generally possess anatomical and reproductive adaptations that enable them to survive the effects of fire or to effectively exploit those environmental conditions created by such disturbance. Thus, these species have been called "avoiders" (of fire) by Rowe (1983).

Within the study area, the highest light intensities at the forest floor are found in the pine dominance-types which are dominated mainly by shrubs and summer herbs. Because these understory species are not well suited to shaded conditions, they may be classified as "sun plants" (Collins et al., 1985). They are, however, well adapted to the destructive as well as the environmental changes that result from fire. Thus, this group of species may also be called "endurers" (Rowe, 1983).

Sprouting of various species including Corylus cornuta (Van Wagner, 1963) and Vaccinium (Trevett, 1962; Smith and Sparling, 1966; Boerner, 1981) may occur as a result of increased soil temperature that results from fire. Pteridium aquilinum also shows rapid regrowth following fire (McMinn, 1951; Boener, 1981) due to the ability of its extensive underground rhizome system to survive fire (Martin, 1955). Other species that reappear rapidly following fire due to their adaptations to post-fire conditions, include Maianthemum canadense (Ahlgren, 1960; Sidhu, 1973), Aralia nudicaulis (Cayford et al., 1967; Ahlgren, 1974), and Aster macrophyllus (Methven, 1973). The increased growth of certain shrubs and herbs following fire may also be due to seed germination stimulated by heat and/or an increase in available nutrients due to organic matter combustion (Ahlgren and Ahlgren, 1960; Cushwa et al., 1968).

Some plants are able to exploit a wide variety of light conditions but seem to be best adapted to intermediate levels. These species are called "light flexible plants" by Collins et al. (1985) and "C-S-R strategists" by Grime (1979) who defines them as species that are "restricted by moderate intensities of both stress and disturbance". These generalist species are represented by all the major growth forms including trees, shrubs, and summer herbs. They tend to be most abundant at intermediate levels of light and fire incidence showing greatest abundances in the intolerant hardwood forests.

In addition to light, plant growth is also affected by water and nutrient supply (Chapin et al., 1987). The greater amounts of soil moisture on the Park's west side relative to the east side are typical due to the combined conditions of higher rainfall and a finer soil texture. This difference in soil moisture has probably also contributed to variation in forest understory species composition in Algonquin Park. Although the response of northern temperate understories to moisture has been little studied (Collins et al., 1985), a few studies have shown that species such as Dryopteris spinulosa and Acer saccharum are associated with mesic to moist conditions and species such as Pteridium aquilinum and Vaccinium angustifolium are associated with dry to dry-mesic conditions (Maycock and Curtis, 1960; Pregitzer and Barnes, 1984). Other studies have shown soil moisture to be generally important in determining understory composition (Siccama, 1974; Hicks, 1980).

A nutrient gradient, represented by a variation in soil nitrogen is also associated with variation in understory composition in Algonquin. Nutrient gradients are related to understory composition within the boreal forests of Ontario (Carleton and Maycock, 1980; Carleton et al., 1985) and southern Appalachian forests (Graves and Monk, 1982; Rheinhardt and Ware, 1984; Graves and Monk, 1985).

Through the products of decomposition, the carbon:nitrogen balance of the upper soil layer (which was measured in this study) is a direct reflection of the carbon:nitrogen balance in the vegetation (Alban et al., 1978). In addition to determining features of resource aquisition in plants, the plant carbon:nitrogen balance determines its susceptibility to herbivores and pathogens that in turn affect the trophic dynamics of the ecosystem (Chapin et al., 1987). Under resource limitations, some plants may accumulate carbon in order to support the synthesis of secondary metabolites (Bryant et al., 1983) such as lignin, tannin, and phenolics. This may deter herbivores and prolong the life of the plant (Chapin et al., 1987).

Finally, to understand fully the responses of understory species to resource gradients, the interaction of competition for light, water and nutrients must be addressed (Schulze and Chapin, 1987). The results obtained from this study do not allow for the identification of these interactions. However, a review of the variation in strategies used by plants to acquire and allocate resources with respect to above- and below-ground plant parts may help to shed light on these interactions

(Caldwell, 1987). Below-ground competition may be just as intense as above-ground competition and is of greater importance in low moisture/nutrient environments (Schulze and Chapin, 1987). Thus in the tolerant hardwood forest, where fire incidence is relatively low, light is most limiting, and water and nutrients are in good supply, understory species generally maximize the efficiency of their above-ground parts to capture light. The best example is the sugar maple which can attain height dominance in a few years because of its perennial woody nature and its ability to photosynthesize efficiently at low light levels. Few understory plants can outcompete it or survive in its shade.

In contrast, plant species in the pine forest must maximize the efficiency of and carbohydrate storage in their below-ground parts in order to survive and reproduce quickly after fire and to capture limited amounts of water and nutrients which are relatively less abundant than light. A good example is the perennial herb Clintonia borealis which has a rhizome system that may remain physiologically active for up to 15 years (Angevine and Handel, 1986) enduring the stress of fire and low levels of moisture and nutrients.

A focus on the role of above-and below-ground plant parts with respect to resource acquisition and allocation will contribute to a better understanding of the influence of primary producers on higher trophic levels and the movement of nutrients into the community. These studies would benefit from the use of controlled conditions in order to determine the interactive effects of competition for light, water, and nutrients.

In the long term, continued fire suppression in Algonquin Park will result in a shift in species composition towards the stress tolerators/avoiders (tolerant hardwood forest species) which are competitive on all but the driest sites at comparatively low levels of fire incidence. This shift in understory species composition is expected to translate eventually into changes in overstory composition in view of the importance of tree seedlings in the tolerant hardwood vegetation.

CHAPTER 8 - GENERAL DISCUSSION AND SYNTHESIS

The overstory analysis indicated that the fire regime was most strongly related to canopy composition within the Algonquin uplands. The understory analysis indicated that the light climate and the fire regime respectively were the most strongly related factors to compositional variation within the upland understory. However, the light climate in the understory is primarily determined by the density, structure, and composition of the overstory. Therefore, the disturbance regime emerges as the pre-eminent influence upon the composition of the upland forest complex as a whole.

At the high-disturbance end of this gradient, even-aged stands dominated by jack pine, red pine, white birch, and white pine prevail (see Figure 6-5). These tree species characteristically regenerate well following forest fire or are resistant to fire due to various silvical characteristics and adaptations (Fowells, 1965). They are also well adapted to moisture and nutrient stress which characterize their habitats. The understory of such stands is dominated by perennial herbs such as *Pteridium aquilinum*, *Aralia nudicaulis*, *Corylus cornuta*, *Maianthemum canadense*, *Gaultheria procumbens*, grasses, *Cornus canadensis*, *Clintonia borealis* and various sedges. These are geographically widespread taxa with the capacity to regenerate rapidly from persistent, below-ground parts especially following forest fire (Ahlgren, 1976).

In the mid-region of the fire-disturbance gradient, intolerant hardwoods dominated by poplar, red oak and to a lesser extent yellow birch predominate in the overstory (see Figure 6-5). These species possess some resprouting capability following all but severe forest fire, but are less tolerant of moisture and nutrient stress than those species at the high end of the disturbance gradient. The understory vegetation of such stands is characterized by a mixture of trees, shrubs and herbs including Acer rubrum, Trientalis borealis, Viburnum alnifolium, Acer spicatum, Streptopus amplexifolius, Tiarella cordifolia, and Mediola virginiana. These taxa are all capable of rapid regeneration after destruction of above-ground parts but may not be able to withstand the extreme thermal stress occasionally associated with forest fire. In addition, they are less tolerant of moisture and nutrient stress than those plants which typify the high end of the fire regime gradient. However, all species appear to be able to withstand moderate shade which may confer some competitive advantage over species which are more light-demanding.

The overstory of stands at the low end of the fire disturbance gradient are characterized by sugar maple and eastern hemlock. These species are extremely shade tolerant and can regenerate beneath an existing tree canopy. However, they are also intolerant of moisture stress and to a lesser extent nutrient stress (Fowells, 1965). Whereas sugar maple can actively resprout following canopy removal, eastern hemlock must establish by seed following disturbance. The understory of such stands is typified by woody vegetation, especially the saplings and seedlings of sugar maple stands. In addition, gap phase species such as Acer pennsylvanicum, Fagus grandifolia, and Ostrya virginiana frequently occur. The herbaceous understory in these stands is sparse and typified by extremely shade tolerant plants such as Dryopteris spinulosa and species of Lycopodium. Other taxa are more typical of spring flora, including Trillium and Viola.

With a decline in the fire incidence index the stands change from a primarily even-aged structure to an uneven-aged condition. This may be associated with differences in total stand age but is most likely to be related to the qualitative differences between disturbance by fire versus disturbance by windthrow and dominant tree death. In the tolerant hardwoods, sugar maple and other tree species form a "seedling bank" on the forest floor. In the event of gap formation from windthrow and tree death those seedlings which encounter increased irradiance enter a stage of increased or "release" growth and compete to fill the gap. In this way the tolerant hardwood canopy is rapidly filled to maximum capacity resulting in a reasonably uniform, deep shade beneath.

In contrast, postfire establishment in the pine stands is dependent on the availability and germination of viable seed. Maximum tree density may not be achieved by this method of regeneration. The result is likely to be an understocked stand in which gaps or a low canopy density prevails. In addition, the canopy characteristics of the pine and intolerant hardwood stands are such that relatively large amounts of diffuse radiation pass through. This is in contrast to the tolerant hardwoods with determinate growth patterns and highly efficient light interception characteristics in the canopy. An associated trend in the understory vegetation is the notable shift from a primarily herbaceous cover in the pine forest to one dominated by tree seedlings and saplings in the tolerant hardwood forest. It should be noted, however, that maple stands do have a significant herbaceous component, but this has been excluded from the main portion of the growing season and persists only as spring flora.

Clearly associated trends in canopy and understory characteristics emerge from this study and these have been related primarily to the incidence of fire. However, it is equally clear that the fire incidence index is also linked to the soil moisture regime (Figure 6-5) and to the available light in the understory (Figures 7-2 to 7-4). Thus the upland forest vegetation complex in Algonquin Park varies in relation to a complex primary gradient in which the type of disturbance, light and soil moisture all play a linked role. This single, complex gradient implies that plants adapted to one environmental feature must of necessity be adapted to other associated environmental constraints in order to survive. For example, Vaccinium angustifolium in the pine forest understory can regenerate following forest fire, but is also quite drought tolerant.

On a fundamental level, the models developed from this work provide a basic framework for making general predictions for overstory vegetation composition based on changes in soil moisture and fire; and for understory based on changes in light and fire. For the overstory model, a reduction in soil moisture drives upland overstory composition towards the pine communities and a reduction in fire incidence drives the overstory towards the tolerant hardwood composition. For the understory model, an increase in the amount of light reaching the forest floor drives the upland understory composition towards the pine understory types and a reduction in fire incidence results in a shift towards the tolerant hardwood understory vegetation.

Simple univariate effects of environmental variables on vegetation composition, however, do not account for the effects of numerous interactions among environmental variables. To account for these interactions, data on the spatial and temporal nature of environmental change in disturbed forest patches are required. Of particular importance are the effects of resource combinations and resource change on plant resource acquisition and allocation.

To understand the effects of resource combinations on vegetation composition using survey data such as that collected in this study, a multiple regression approach could be used. As the dependent variable, ordination axis scores would be predicted from a set of significant interacting environmental variables. The large amount of variance explained by the first ordination axis for overstory composition in this study suggests that criterion data set editing of a few sample outliers would suffice to obtain groups of stand scores, each of which would represent a homogeneous community type. Continuous ranges of stand scores on the primary ordination axis would then be used to represent a specific forest composition type.

On a more practical level, the results of this work provide the most detailed and comprehensive consideration of forest site influence upon upland forest composition in Algonquin Park. Assuming that timber harvesting and fire suppression have not significantly affected the composition of the stands sampled, the relationships established from this work can serve to refine long-term forest management objectives on sites defined by specific environmental conditions. If a reasonable regression model can be developed, forest management scenarios could be examined with a known degree of error and a continuous cycle of hypothesis generation, hypothesis testing, and hypothesis refinement could be initiated.

The results of this study, however, represent only a single snapshot in time of a very dynamic system. Thus the study findings can only be confirmed through a detailed analysis of forest ecosystem development over time. These ecosystem development studies should begin with the use of chronosequences, or spatially distinct stands chosen to represent various stages of ecosystem development within various community and site types. When plots are established within these stands they should be permanently marked within nature reserves or other protected areas so that they can be easily relocated and continuously remeasured.

Long-term studies of permanent plots that are selected to represent the variety of forest ecosystem types and successional stages will yield the knowledge necessary to understand and predict natural forest succession. Finally, by applying this approach to represent the variety of forest management practices that occur within a number of forest types in Algonquin Park it will be possible to develop a more reliable science of forest resource management.

CHAPTER 9 - SUMMARY

The development of the index to fire incidence allowed for examination of the relative influence of fire upon forest vegetation composition within upland forests in Algonquin Park. In the process of developing this index it was shown, using historical data, that forest types in Algonquin differ significantly in terms of fire incidence. For example, the data show that red pine and jack pine have a significantly higher fire incidence than poplar, hemlock, and sugar maple. As well, it was found that the tolerant hardwood forest as a unit has a significantly lower fire incidence than the intolerant hardwood and pine forest. The data for both species and forest types also form a smooth gradient from low to high fire incidence probability.

The importance of this fire gradient in relation to present forest composition in Algonquin Park was verified through multivariate studies which related both overstory and understory vegetation to environmental conditions. An environmental complex consisting of 13 factors was identified as having a significant influence upon the composition of the forest overstory. The variation in forest overstory composition is best explained by a fire-soil moisture gradient in which (1) the two influences are inversely related and (2) fire is most likely of greater importance in maintaining current overstory composition.

At the low fire-high moisture end of the gradient the landscape is dominated by species characteristic of the tolerant hardwood forest. At the high fire-low moisture end of the gradient the landscape is dominated by the pine forest and occurring at an intermediate position along the gradient are the intolerant hardwood communities. The relationship between fire and overstory composition in Algonquin is influenced by variations in foliage flammability, tree and stand structure, reproductive strategies, anatomical features, and natural firebreaks. Although they are affected to some degree by vegetation, the variation in total soil nitrogen, soil organic matter, and soil pH also plays a role in the distribution of overstory species.

Relative to the variation explained in overstory species composition by the ordination (87%), less of the variation in understory species composition was explained through ordination (38%). This is most likely because (1) there were over five times more species in the understory compared to the overstory which complicates ordination, and (2) the overstory was sampled more subjectively than the understory. An environmental complex consisting of nine factors was identified as having a significant influence upon the composition of the forest understory. Unlike the overstory composition of upland forests in Algonquin Park, the variation in understory composition is most highly correlated with light, and with fire as a secondary factor.

Given the methods and objectives of this study only broad understory-overstory associations could be addressed. The major feature of these associations in Algonquin is the unique quality of the understory composition within the tolerant hardwood forest type and the sugar maple dominance-type relative to the other forest and dominance-types. Also, biomass of the sugar maple canopy was found to be directly related to understory composition variation. This most likely is due to the effect of the sugar maple canopy on the amount of light reaching the forest floor.

Aside from human influence, the single most important factor influencing the future of Algonquin's upland forest composition is the occurrence of naturally-caused fire. It is particularly important in maintaining overstory composition within the pine communities and, to a lesser extent, the poplar communities. This, however, is not to discount the importance of fire within the understory of these communities. Those understory species which are known to be associated with the incidence of fire (e.g. _Corylus cornuta_, _Vaccinium angustifolium_, _Pteridium aquilinum_, _Maianthemum canadense_, and _Aster macrophyllus_) are most abundant in those overstory dominance types in Algonquin which are also most highly associated with fire, namely the pine and poplar dominance-types. Assumming that the effects of fire render a competitive advantage to these understory species, fire suppression in Algonquin Park may also significantly alter the composition of the understory within the pine and poplar forest ecosystems.

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APPENDIX I - FIRE INFORMATION

Fire #	Township	Date	Longitude	Latitude	Size (m^2)
1	Anglin	19/09/30	45 55	78 17	1
2	Anglin	30/07/42	45 53	78 15	450
3	Anglin	29/07/46	45 53	78 17	20,000
4	Anglin	26/08/49	45 52	78 13	4,000
5	Anglin	05/07/55	45 54	78 16	10
6	Anglin	17/09/55	45 55	78 18	8,000
7	Anglin	28/07/61	45 51	78 24	10
8	Anglin	24/06/64	45 50	78 22	12
9	Anglin	24/06/64	45 54	78 13	10
10	Anglin	28/07/64	45 55	78 20	12,000
11	Barron	17/05/31	45 53	77 53	36
12	Barron	17/06/41	45 55	77 56	16,000
13	Barron	17/06/41	45 55	77 56	16,000
14	Barron	05/07/41	45 51	77 50	1,200,000
15	Barron	23/06/43	45 52	77 52	12,000
16	Barron	15/07/43	45 53	77 58	4,000
17	Barron	24/07/43	45 54	77 51	18
18	Barron	02/06/44	45 53	77 58	4,000
19	Barron	17/07/48	45 52	77 49	80,000
20	Barron	05/08/49	45 52	77 52	16,000
21	Barron	26/06/52	45 53	77 52	10
22	Barron	03/10/52	45 54	77 59	2,000
23	Barron	23/08/53	45 51	77 55	81
24	Barron	20/06/55	45 54	77 57	18
25	Barron	11/05/58	45 52	77 49	140,000
26	Barron	13/07/59	45 55	77 51	1,500
27	Barron	22/05/64	45 56	77 51	4,000
28	Biggar	25/07/39	45 49	78 52	28,000
29	Biggar	19/08/45	45 53	78 58	10,000
30	Biggar	06/07/50	45 54	78 56	1,000
31	Biggar	09/05/53	45 54	78 55	6,000
32	Biggar	31/08/53	45 53	78 54	1,000
33	Biggar	31/08/53	45 52	78 50	32,000
34	Biggar	31/08/53	45 53	78 56	1,000
35	Biggar	27/06/55	45 52	78 56	4,000
36	Biggar	03/08/58	45 52	78 57	4,000
37	Biggar	07/07/59	45 57	78 52	135
38	Biggar	23/05/62	45 53	78 51	27
39	Bishop	20/06/31	45 49	78 39	68
40	Bishop	16/07/34	45 51	78 40	2,000
41	Bishop	07/08/38	45 49	78 39	7,000
42	Bishop	24/07/40	45 07	78 45	10
43	Bishop	11/07/46	45 47	78 37	10
44	Bishop	11/07/46	45 47	78 37	10
45	Bishop	11/07/46	45 46	78 36	10
46	Bishop	14/08/53	45 49	78 41	108
47	Bishop	04/09/53	45 51	78 40	10

48	Bishop	09/06/55	45	50	78	44	16,000
49	Bishop	03/07/62	45	48	78	38	10
50	Bishop	08/05/64	45	49	78	38	101,000
51	Bishop	19/05/65	45	49	78	38	4,000
52	Bishop	10/05/68	45	49	78	38	81,000
53	Bishop	15/07/77	45	49	78	38	2,000
54	Bishop	15/07/79	45	49	78	38	800
55	Bronson	13/06/44	46	03	77	46	240,000
56	Bronson	18/09/48	46	03	77	52	36,000
57	Bronson	10/08/50	46	03	77	48	16,000
58	Bronson	01/08/52	46	01	77	49	4,000
59	Bronson	18/08/53	46	02	77	49	8,000
60	Bronson	24/08/53	46	00	77	50	1,000
61	Bronson	24/08/53	46	04	77	51	2,000
62	Bronson	25/08/53	46	03	77	53	1,000
63	Bronson	27/06/55	45	59	77	44	68
64	Bronson	29/06/55	46	00	77	48	6,000
65	Bronson	07/08/58	46	01	77	45	36
66	Bronson	31/07/62	46	04	77	44	8,000
67	Bronson	13/09/62	46	00	77	51	36
68	Bronson	19/06/64	46	01	77	47	8,000
69	Bronson	03/07/64	46	01	77	49	1,000
70	Bronson	28/07/64	45	58	77	47	240
71	Bronson	08/08/64	46	01	77	48	12,000
72	Butt	24/08/53	45	46	79	00	3,000
73	Butt	24/05/62	45	41	78	57	10
74	Deacon	23/05/30	46	01	78	17	16,000
75	Deacon	02/07/31	46	01	78	26	10
76	Deacon	02/07/31	46	01	78	26	72
77	Deacon	13/07/34	46	02	78	20	2,000
78	Deacon	29/06/46	46	01	78	23	10
79	Deacon	11/07/46	46	03	78	27	16
80	Deacon	05/09/47	45	58	78	26	468
81	Deacon	12/07/48	46	06	78	23	900
82	Deacon	27/09/48	45	57	78	25	4,000
83	Deacon	24/08/53	46	06	78	24	2,000
84	Deacon	24/08/53	46	05	78	23	2,000
85	Deacon	25/08/53	46	07	78	21	6,000
86	Deacon	25/08/53	46	04	78	19	1,000
87	Deacon	25/08/53	46	03	78	21	2,000
88	Deacon	25/08/53	46	04	78	19	1,000
89	Deacon	18/09/55	46	06	78	22	4,000
90	Deacon	26/09/55	45	05	78	20	4,000
91	Deacon	12/06/61	45	59	78	28	10
92	Deacon	16/05/65	46	04	78	26	80,800
93	Deacon	27/07/66	46	04	78	23	4,400
94	Deacon	09/05/68	46	04	78	23	1,600
95	Deacon	09/05/68	46	04	78	23	400
96	Deacon	29/07/74	46	04	78	23	400
97	Devine	09/07/38	45	45	78	55	54
98	Devine	07/08/41	45	42	78	50	1,320
99	Devine	02/06/43	45	44	78	46	10

100	Devine	01/06/44	45	47	78	55	18
101	Devine	30/07/45	45	45	78	54	24,000
102	Devine	09/07/52	45	44	78	47	29
103	Devine	09/05/53	45	47	78	49	80,000
104	Devine	31/07/64	45	48	78	51	40
105	Devine	08/05/65	45	41	78	53	8,100
106	Devine	19/05/65	45	41	78	53	16,200
107	Devine	17/06/65	45	49	78	53	400
108	Devine	22/07/68	45	49	78	53	24,200
109	Devine	02/07/75	45	49	78	53	400
110	Devine	19/05/77	45	41	78	53	400
111	Devine	13/07/78	45	49	78	53	2,000
112	Devine	19/08/78	45	41	78	53	400
113	Edgar	06/05/42	45	59	77	57	140,000
114	Edgar	16/08/43	46	02	77	58	10
115	Edgar	26/08/47	46	03	78	00	80,000
116	Edgar	06/08/49	45	58	77	59	16,000
117	Edgar	24/08/53	46	02	78	04	1,000
118	Edgar	26/08/53	46	06	77	56	2,000
119	Edgar	03/09/53	46	01	78	03	270
120	Edgar	04/07/55	46	00	78	01	12,000
121	Edgar	12/07/55	45	58	77	55	4,000
122	Edgar	12/05/56	46	01	78	58	12,000
123	Edgar	11/06/59	46	01	78	02	2,000
124	Edgar	13/07/59	45	58	78	01	86
125	Edgar	24/06/62	46	00	78	00	3,000
126	Edgar	19/06/64	45	59	77	54	760
127	Edgar	23/06/64	46	01	77	53	4,000
128	Edgar	24/05/77	46	04	77	53	12,100
129	Fitzgerald	02/07/31	46	04	78	17	1,000
130	Fitzgerald	25/07/31	46	03	78	09	4,000
131	Fitzgerald	26/08/33	46	06	78	07	80,000
132	Fitzgerald	23/08/42	46	09	78	10	23
133	Fitzgerald	29/06/46	46	06	78	07	36,000
134	Fitzgerald	08/09/54	46	03	78	08	10
135	Fitzgerald	01/07/55	46	03	78	17	4,000
136	Fitzgerald	16/08/68	46	04	78	08	400
137	Fitzgerald	29/06/75	46	04	78	08	4,000
138	Fitzgerald	08/07/75	46	04	78	08	400
139	Fitzgerald	08/07/75	46	04	78	08	400
140	Fitzgerald	08/07/75	46	04	78	08	2,000
141	Freswick	02/07/31	45	51	78	32	22,000
142	Freswick	24/08/31	45	50	78	35	216
143	Freswick	21/08/32	45	48	78	30	630
144	Freswick	06/07/34	45	53	78	25	10
145	Freswick	14/07/36	45	53	78	26	6,000
146	Freswick	10/07/37	45	47	78	33	10
147	Freswick	07/08/41	45	51	78	26	12,000
148	Freswick	07/06/46	45	49	78	32	10
149	Freswick	20/07/48	45	51	78	26	10
150	Freswick	04/07/55	45	51	78	33	6,000
151	Freswick	06/07/55	45	52	78	31	2,000

152	Freswick	13/07/55	45	51	78	29	4,000
153	Freswick	26/07/56	45	50	78	28	10
154	Freswick	31/07/57	45	51	78	34	225
155	Freswick	16/08/57	45	52	78	30	54
156	Freswick	01/07/64	45	54	78	33	40
157	Freswick	15/07/79	45	49	78	23	1,200
158	Lister	02/07/31	45	57	78	27	1,000
159	Lister	10/05/34	45	56	78	32	10
160	Lister	04/08/36	45	59	78	34	12,000
161	Lister	12/07/39	46	00	78	36	10
162	Lister	08/08/39	45	57	78	27	252
163	Lister	26/07/40	45	59	78	37	10
164	Lister	26/07/40	45	59	78	38	10
165	Lister	25/08/42	46	01	78	34	12,000
166	Lister	05/07/44	46	00	78	30	10
167	Lister	07/07/44	46	01	78	31	6,000
168	Lister	15/08/44	46	00	78	34	2,000
169	Lister	30/07/45	45	57	78	38	4,000
170	Lister	02/08/45	45	57	78	38	12,000
171	Lister	10/08/46	46	01	78	31	18
172	Lister	28/07/48	46	00	78	33	1,800
173	Lister	22/08/48	46	00	78	33	675
174	Lister	09/07/52	46	00	78	34	6,000
175	Lister	31/08/53	45	58	78	34	8,000
176	Lister	31/08/53	45	58	78	34	8,000
177	Lister	31/08/53	46	00	78	32	1,000
178	Lister	06/07/55	45	57	78	29	1,000
179	Lister	31/08/58	46	00	78	31	14
180	Lister	11/17/66	45	56	78	38	2,000
181	Lister	07/07/75	45	56	78	38	800
182	Lister	08/07/75	45	56	78	38	800
183	Osler	02/07/31	45	55	78	44	600
184	Osler	12/07/39	45	58	78	46	10
185	Osler	07/08/41	46	00	78	42	1,000
186	Osler	25/08/42	46	00	78	42	225
187	Osler	19/08/44	45	59	78	44	8,000
188	Osler	11/07/46	45	56	78	44	27
189	Osler	10/08/46	45	59	78	45	36
190	Osler	18/08/47	45	58	78	47	2,000
191	Osler	18/08/47	45	57	78	46	16
192	Osler	24/08/55	45	53	78	47	1,000
193	Osler	27/08/55	45	56	78	46	2,000
194	Osler	03/08/58	45	51	78	46	4,000
195	Osler	31/08/62	45	55	78	41	8,000
196	Paxton	22/07/46	45	54	79	04	14,000
197	Paxton	19/08/53	45	54	79	06	8,000
198	Paxton	07/07/55	45	51	79	00	100,000
199	Stratton	09/08/30	45	53	77	42	10,000
200	Stratton	20/06/32	45	56	77	48	4,000
201	Stratton	21/06/32	45	52	77	43	20,000
202	Stratton	02/09/33	45	56	77	49	4,000
203	Stratton	02/09/33	45	56	77	39	100,000

204	Stratton	09/08/34	45	51	77	40	16,000
205	Stratton	04/08/36	45	52	77	40	8,000
206	Stratton	18/06/38	45	55	77	41	10
207	Stratton	13/07/42	45	58	77	46	1,000,000
208	Stratton	27/07/42	45	52	77	46	126
209	Stratton	01/09/47	46	00	77	39	12,000
210	Stratton	24/07/48	45	56	77	49	12,000
211	Stratton	30/07/52	45	56	77	36	1,000
212	Stratton	03/10/52	45	54	77	43	8,000
213	Stratton	03/10/52	45	52	77	40	54
214	Stratton	03/10/52	45	52	77	40	10
215	Stratton	09/05/53	45	58	77	37	72,000
216	Stratton	24/08/53	45	54	77	47	8,000
217	Stratton	24/08/53	45	58	77	44	10,000
218	Stratton	24/08/53	45	54	77	43	1,000
219	Stratton	20/08/55	45	56	77	38	2,000
220	Stratton	16/06/56	45	56	77	44	4,000
221	Stratton	09/08/58	45	59	77	40	51
222	Stratton	01/09/60	45	52	77	46	79
223	Stratton	07/07/63	45	56	77	45	2,000
224	Stratton	12/07/63	45	52	77	39	40,000
225	Stratton	30/08/63	45	52	77	44	225
226	Stratton	24/05/64	45	51	77	47	10
227	Stratton	26/06/64	45	56	77	47	2,000
228	Stratton	28/07/64	45	51	77	47	2,000
229	Stratton	23/09/64	45	53	77	36	1,000
230	Stratton	10/09/74	45	56	77	38	400
231	Stratton	21/07/75	45	56	77	38	36,000
232	Stratton	15/06/76	45	56	77	38	12,100
233	Stratton	28/06/76	45	56	77	38	3,200
234	Stratton	19/06/78	45	56	77	38	18,200
235	White	06/07/31	46	00	78	07	8,000
236	White	09/07/36	45	54	78	12	10
237	White	04/07/41	45	53	78	09	40,000
238	White	03/08/41	46	00	78	09	12,000
239	White	09/07/42	45	55	78	12	1,000
240	White	31/08/47	46	00	78	08	28,000
241	White	31/07/48	45	59	78	12	24,000
242	White	25/08/48	45	57	78	13	27
243	White	29/07/49	45	56	78	08	16,000
244	White	03/08/41	46	00	78	09	12,000
245	White	28/08/62	45	57	78	03	225
246	White	09/06/64	45	58	78	10	360
247	White	28/07/64	45	58	78	05	160
248	White	02/07/65	45	56	78	08	400
249	White	28/07/66	45	56	78	03	33,100
250	White	16/08/69	45	56	78	08	400
251	White	20/05/75	45	56	78	08	5,700
252	White	14/06/76	45	56	78	08	400

APPENDIX II - FRI MAP SURVEY RESULTS

Sampling Unit	Stand Type	% Cover	No. Stands Needed	No. Stands Obtained
Paxton-Butt	Mh	75.4	5.3	8
	By	18.0	1.3	1
				9
Biggar-Devine	Mh	76.1	9.9	11
	By	17.9	2.3	1
				12
Osler-Bishop	Mh	55.4	7.2	5
	He	14.5	1.9	2
	Pw	9.5	1.2	1
	Po	7.5	1.0	1
	By	7.2	.9	1
	Bw	5.0	.7	1
				11
Lister-Freswick	Mh	54.7	7.1	9
	He	15.5	2.0	1
	Pw	8.8	1.1	1
	By	8.2	1.1	1
	Po	10.2	1.3	3
				15
Deacon-Anglin	Pw	29.9	3.9	3
	Po	23.8	3.1	3
	Mh	19.3	2.5	3
	Bw	8.8	1.1	1
	By	5.9	.8	1
	Pr	4.8	.6	1
	He	4.3	.6	1
				13
Fitzgerald-White	Po	44.9	5.8	6
	Pw	17.6	2.3	3
	Bw	13.2	1.7	1
	Pr	10.5	1.4	1
	Mh	8.0	1.0	1
	Pj	2.7	.4	1
				13

Edgar-Barron	Pw	40.0	5.2	5
	Po	32.8	4.3	4
	Mh	8.3	1.1	1
	Or	8.1	1.1	1
	Pr	5.0	.7	1
				12
Bronson-Stratton	Pw	52.8	6.9	6
	Po	20.0	2.6	2
	Or	13.0	1.7	2
	Mh	8.7	1.1	2
	Pj	1.9	.2	1
	Pr	1.7	.2	2
				15

Total = 100

APPENDIX III - STAND INFORMATION

Stand No.	Dominant Species	Township	FRI Stand No.	Size (ha)	Substrate Type
1	Mh	Butt	8	21	B&BD
2	Mh	Butt	79	28	T
3	Mh	Butt	33	20	B&BD
4	Mh	Butt	97	11	T
5	Mh	Butt	48	24	B&BD
6	Mh	Paxton	392	16	B&BD
7	Mh	Butt	78	24	GF
8	Mh	Butt	42	14	B&BD
9	Pr	Stratton	613	38	GF
10	Pj	Stratton	607	50	GF
11	Pw	Stratton	579	54	T
12	Pw	Stratton	624	15	B&BD
13	Pr	Stratton	512	43	B&BD
14	Po	White	398	10	GF
15	Pj	White	188	30	GF
16	Po	Fitzgerald	578	45	T
17	Pr	Deacon	565	11	GF
18	Po	Deacon	541	38	T
19	Bw	Deacon	491	19	B&BD
20	Po	Fitzgerald	535	39	T
21	Pw	Fitzgerald	559	10	GF
22	Or	Stratton	461	57	B&BD
23	Pw	Stratton	485	37	B&BD
24	Pw	Stratton	20	10	T
25	Mh	Lister	433	28	B&BD
26	Po	Lister	417	34	B&BD
27	Po	Lister	437	24	B&BD
28	Mh	Lister	521	30	B&BD
29	Mh	Lister	350	17	GF
31	Po	Deacon	397	83	GF
32	Mh	Lister	475	43	GF
33	Po	Lister	508	18	B&BD
34	Pw	Stratton	639	21	T
35	Pw	Stratton	371	42	GF
36	Mh	Stratton	732	28	B&BD
37	Mh	Stratton	492	24	T
38	Po	Stratton	714	35	B&BD
39	Or	Stratton	715	40	B&BD
40	Po	Stratton	452	20	B&BD
41	Po	Edgar	490	22	GF
42	Pw	Edgar	547	20	B&BD
43	Po	Edgar	457	29	GF
44	Pw	Edgar	274	10	B&BD
45	Mh	Barron	363	10	T
46	Or	Edgar	553	30	B&BD
47	Po	White	378	39	GF

48	Pr	White	408	9	GF
49	Po	Barron	540	16	T
50	Po	Barron	527	30	GF
51	Pw	Barron	212	10	B&BD
52	Pr	White	449	8	GF
53	Mh	Fitzgerald	401	32	B&BD
54	Bw	Fitzgerald	419	28	B&BD
55	Pw	White	385	10	GF
56	Po	White	401	19	B&BD
57	Pw	Barron	329	34	B&BD
58	Mh	Deacon	460	36	GF
59	Pw	Lister	419	20	B&BD
60	Pw	Deacon	513	10	B&BD
61	By	Lister	523	18	B&BD
62	Mh	Anglin	317	14	T
63	Pw	Anglin	35	46	GF
64	Po	Osler	646	10	GF
65	He	Lister	526	65	B&BD
66	Mh	Lister	392	19	B&BD
67	Mh	Lister	385	60	B&BD
68	Bw	Bishop	626	16	B&BD
69	He	Bishop	622	22	GF
70	Mh	Bishop	596	20	B&BD
71	Mh	Bishop	628	10	B&BD
72	Mh	Freswick	308	21	T
73	By	Bishop	310	4	B&BD
74	Mh	Bishop	322	32	GF
75	He	Bishop	166	17	T
76	Mh	Bishop	164	12	T
77	Mh	Bishop	154	20	B&BD
78	Po	Fitzgerald	556	18	T
79	Mh	Devine	433	14	B&BD
80	Mh	Devine	424	14	GF
81	Mh	Devine	484	32	GF
82	Mh	Devine	511	14	GF
83	Mh	Devine	428	17	B&BD
84	Mh	Devine	612	8	GF
85	Mh	Devine	317	8	GF
86	Mh	Devine	586	25	GF
87	By	Devine	429	6	B&BD
88	Mh	Devine	805	18	B&BD
89	Mh	Devine	877	16	B&BD
90	Mh	Devine	838	30	B&BD
91	By	Butt	439	11	B&BD
92	Mh	Deacon	13	46	B&BD
93	Po	Deacon	352	30	T
94	He	Deacon	206	12	T
95	Pw	Deacon	191	62	T
96	Mh	Lister	104	38	B&BD
97	Mh	Deacon *	42	24	B&BD
98	By	Lister #	136	20	B&BD
99	Pw	Osler	451	14	GF

100	Pw	Fitzgerald	400	62	GF
101	Pw	Bronson @	220	14	GF

* for Lister, # for Deacon, @ for Edgar
B&BD - bedrock and bedrock drift; T - till; GF - glacial fluvial

APPENDIX IV - BASAL AREA FOR OVERSTORY SPECIES BY STAND
(stands and species are arranged according to their
positions on the first DCA axis)

SPECIES	STANDS																							
	069	075	094	065	073	098	087	074	077	091	061	072	080	001	085	084	067	071	092	079	088	083	089	090
Tsuga canadensis	48.89	47.06	50.03	31.36	11.17	5.30	1.85	11.34	15.25	1.58	0.00	11.43	0.00	0.00	1.23	5.36	1.70	4.36	4.61	0.00	0.00	0.00	0.00	0.00
Betula lutea	4.31	1.07	0.02	0.00	35.23	35.17	36.79	4.21	3.30	40.78	24.61	2.53	17.09	11.26	9.14	0.63	6.50	1.64	0.50	6.17	11.44	4.17	9.20	3.16
Prunus serotina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acer saccharum	0.00	1.62	3.40	4.62	8.77	6.63	9.00	25.58	25.22	9.19	9.61	30.23	23.23	15.37	31.79	25.25	25.79	35.31	30.12	32.92	19.72	29.86	27.76	28.62
Tilia americana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.72	0.00	0.00	0.00	0.00	0.00
Fraxinus nigra	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fagus grandifolia	0.00	0.00	0.00	0.05	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
Ostrya virginiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.29	0.03	0.66	0.00	0.00	0.12	0.00	0.41	0.00
Thuja occidentalis	0.00	1.54	0.00	0.00	0.00	1.07	2.74	0.00	0.23	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acer pennsylvanicum	0.00	0.04	0.36	0.21	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.02	0.00	0.00	0.00	0.00
Abies balsamea	0.37	1.28	0.00	0.60	0.00	0.00	0.08	0.03	0.00	1.05	0.79	0.00	0.09	0.00	0.00	0.00	0.31	0.00	0.00	0.23	1.62	0.00	0.00	0.00
Acer rubrum	0.00	0.00	0.00	3.84	0.00	0.00	0.14	0.00	0.00	3.07	0.00	0.00	0.17	0.64	0.00	1.43	0.00	0.00	0.00	0.00	1.34	0.00	0.00	0.00
Betula papyrifera	0.00	0.00	2.16	0.00	0.00	0.00	0.00	0.00	2.01	0.00	1.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Picea glauca	0.00	0.04	0.00	0.00	0.05	0.00	0.76	0.08	0.00	0.25	0.05	0.04	0.80	0.06	0.05	0.00	0.93	0.32	0.76	0.04	0.16	0.00	1.84	0.00
Quercus rubra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alnus rugosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Populus grandidentata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pinus strobus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Populus tremuloides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acer spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Picea mariana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pinus resinosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pinus banksiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

SPECIES	STANDS																							
	004	086	081	002	003	006	070	096	008	076	097_	028	005	037	007	036	062	045	032	053	058	066	082	025
Tsuga canadensis	0.00	0.00	0.00	0.00	1.30	0.00	0.00	2.20	0.00	0.00	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Betula lutea	2.44	3.44	7.95	3.40	0.00	3.40	2.74	0.20	11.55	3.06	7.24	5.65	0.00	3.45	2.70	0.00	0.00	1.56	1.23	3.03	2.84	2.59	4.65	0.60
Prunus serotina	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	3.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acer saccharum	24.62	23.15	28.34	23.83	18.98	24.11	26.87	33.34	26.01	30.20	28.08	28.64	31.34	28.19	21.78	28.24	30.17	17.47	28.63	16.96	24.42	24.20	24.53	18.59
Tilia americana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.05	0.00	11.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fraxinus nigra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00
Fagus grandifolia	0.04	0.01	0.00	0.02	1.80	3.08	0.66	5.46	0.00	0.00	0.61	0.00	1.75	2.07	0.00	0.00	6.66	11.57	2.62	5.36	2.02	0.00	0.00	10.22
Ostrya virginiana	0.26	0.10	0.00	0.00	0.08	0.00	0.00	0.66	0.14	0.00	0.69	0.05	0.04	0.82	0.17	0.00	0.25	0.00	0.21	0.34	0.61	0.00	0.00	0.25
Thuja occidentalis	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acer pennsylvanicum	0.03	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.16	0.00	0.11	0.00	0.24	0.01	0.00	0.00	0.01	0.18	0.00	0.11	0.01	0.00	0.00	0.15
Abies balsamea	0.00	0.41	0.44	0.00	0.00	0.22	0.00	0.00	0.05	3.45	0.00	0.25	0.00	0.45	0.00	0.00	0.02	0.58	0.00	0.28	2.14	2.09	0.00	0.15
Acer rubrum	0.00	0.30	1.68	1.06	0.28	0.00	0.00	0.00	0.01	0.00	0.98	0.94	2.01	0.16	3.48	0.00	0.00	0.00	0.00	0.00	2.73	0.00	6.49	0.47
Betula papyrifera	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.23	0.00	0.00	0.00	2.02	0.00	0.00	0.00	4.38	0.00	0.00	0.00	4.05	1.06	0.00	0.00	2.29
Picea glauca	0.02	0.18	0.17	0.17	0.00	0.25	0.00	0.00	0.97	0.00	0.58	0.05	0.00	0.85	0.32	0.00	0.00	0.18	0.00	1.04	0.49	2.16	0.06	0.23
Quercus rubra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.68	0.00	0.00	1.39	0.00	0.00	3.07	0.00	0.00	0.00	0.00	0.00	0.00	1.77
Alnus rugosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Populus grandidentata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00
Pinus strobus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.14	0.00	0.00	1.14	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.67	1.68	2.94	0.00
Populus tremuloides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.53	0.00	0.00	0.00	0.00	0.00
Acer spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Picea mariana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pinus resinosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00
Pinus banksiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

SPECIES	STANDS																							
	054	029	068	026	093	039	046	022	095	031	019	016	049	014	023	038	027	033	064	042	018	100	051	099
Tsuga canadensis	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Betula lutea	0.08	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00
Prunus serotina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acer saccharum	10.73	18.70	0.34	9.43	8.89	0.00	0.49	0.00	4.32	4.46	0.00	3.00	1.77	0.00	1.93	0.25	1.24	0.40	0.21	0.00	0.01	1.07	0.00	0.71
Tilia americana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fraxinus nigra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fagus grandifolia	1.44	0.03	0.00	0.02	0.04	0.00	1.83	0.00	0.00	0.21	0.00	0.90	0.01	0.00	0.93	0.00	0.14	0.02	0.07	0.00	0.00	0.00	0.00	0.00
Ostrya virginiana	0.20	0.32	0.41	0.14	0.30	0.00	0.77	0.00	0.28	0.32	0.00	0.10	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
Thuja occidentalis	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.31	0.59	0.00
Acer pennsylvanicum	0.01	0.07	0.00	0.01	0.29	0.00	0.04	0.03	0.02	0.01	0.12	0.00	0.15	0.00	0.25	0.52	0.41	0.26	0.00	0.02	0.04	0.04	0.06	0.00
Abies balsamea	1.99	0.45	11.06	0.08	0.59	0.00	0.00	0.00	0.00	0.04	0.08	0.00	0.00	1.26	0.86	0.00	1.08	1.32	0.72	0.00	0.54	1.53	0.73	0.09
Acer rubrum	0.00	0.03	0.00	0.01	0.72	0.03	2.10	0.99	0.52	1.07	3.98	1.19	1.64	2.08	0.70	3.25	0.89	3.59	0.23	2.03	3.74	0.60	0.18	2.47
Betula papyrifera	14.41	3.63	24.44	3.96	0.89	0.00	0.00	0.37	6.74	3.69	14.22	1.03	1.43	2.71	0.49	1.41	1.16	0.50	3.76	1.27	0.56	0.00	0.00	0.45
Picea glauca	0.81	0.29	0.00	0.69	0.12	0.00	0.28	0.00	0.00	0.08	0.64	0.00	0.00	4.63	1.60	0.00	0.36	3.61	4.67	0.11	3.46	4.41	2.70	3.52
Quercus rubra	0.00	0.00	0.00	0.00	0.99	23.10	16.23	15.67	1.97	0.00	1.72	0.05	1.27	0.00	5.30	1.70	0.00	0.00	0.00	11.05	0.00	0.00	5.39	0.90
Alnus rugosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Populus grandidentata	0.00	2.27	0.00	29.76	25.72	0.00	4.17	0.00	3.04	28.11	1.15	17.40	38.05	18.23	2.72	26.56	33.22	38.90	28.73	5.51	13.15	0.00	6.98	7.69
Pinus strobus	0.95	3.99	0.00	0.03	5.54	2.25	9.99	4.32	21.27	1.88	1.29	4.91	0.12	5.65	19.62	0.37	4.61	6.21	6.28	20.64	5.94	35.54	20.24	27.50
Populus tremuloides	0.00	2.49	0.00	0.00	0.00	0.00	0.00	1.88	0.00	0.00	0.00	5.56	0.00	2.68	0.88	0.00	0.00	2.64	5.78	0.00	6.33	0.00	0.00	3.72
Acer spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Picea mariana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
Pinus resinosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.11	0.00	0.00	0.98	2.74	1.45	0.41	0.08	0.00	1.40	1.38	2.46	0.72	0.00
Pinus banksiana	0.00	0.00	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00	5.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

SPECIES	STANDS																							
	040	012	021	055	078	050	059	058	044	024	060	020	041	057	034	063	101	011	043	047	035	017	009	052
Tsuga canadensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Betula lutea	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prunus serotina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acer saccharum	0.03	0.00	0.82	0.23	0.00	0.63	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tilia americana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fraxinus nigra	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fagus grandifolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ostrya virginiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thuja occidentalis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.00	0.00	0.00	0.00	1.52	0.00	0.00	0.06	0.00	0.00
Acer pennsylvanicum	0.00	0.00	0.00	0.00	0.00	0.20	0.12	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Abies balsamea	0.05	0.44	0.77	2.85	0.49	2.38	0.14	0.22	0.33	2.86	0.03	0.00	0.54	0.81	0.00	2.24	0.98	0.23	0.24	0.00	0.10	2.33	0.00	0.57
Acer rubrum	2.10	0.00	1.37	0.26	3.17	1.00	0.81	1.92	0.31	0.78	1.06	3.38	0.47	0.57	2.75	0.03	1.27	1.27	0.13	0.94	0.00	0.01	0.65	0.17
Betula papyrifera	0.06	3.74	0.00	0.50	0.98	0.82	0.00	0.39	2.28	0.75	0.20	0.00	0.63	1.37	1.27	2.35	1.08	0.64	1.80	0.55	0.00	0.53	0.00	0.00
Picea glauca	0.20	0.86	4.55	0.30	1.01	0.46	0.47	0.28	0.00	2.05	2.12	0.10	1.29	0.16	0.38	1.31	1.12	3.22	0.79	0.61	0.31	0.44	0.00	0.13
Quercus rubra	0.11	0.00	0.00	0.00	0.00	0.64	5.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alnus rugosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Populus grandidentata	41.96	0.23	0.00	0.34	25.13	16.76	3.93	38.05	9.38	6.34	0.94	28.21	0.00	3.91	4.73	1.82	1.05	3.41	22.02	32.52	0.00	7.14	7.23	2.77
Pinus strobus	7.92	26.26	37.64	28.69	11.15	5.67	25.66	2.32	25.72	28.99	31.94	6.08	4.05	28.72	26.38	25.99	31.79	27.40	4.22	1.15	32.96	1.07	10.63	11.63
Populus tremuloides	0.00	0.00	12.17	0.00	2.03	9.34	0.00	0.00	0.00	6.45	3.78	0.73	18.32	0.00	0.00	4.51	0.00	0.00	0.00	0.00	6.55	6.82	0.00	2.66
Acer spicatum	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Picea mariana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.18	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.09	0.00	0.05	0.00
Pinus resinosa	0.22	0.33	0.00	0.30	3.39	3.92	2.34	4.62	1.83	4.17	1.23	6.09	0.00	4.45	5.90	4.36	4.21	5.76	11.43	9.18	1.35	21.68	28.14	30.60
Pinus banksiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.71	0.00	0.00	0.00	1.01	3.55	0.00	0.00	0.00

SPECIES	STANDS			
	013	048	015	010
Tsuga canadensis	0.00	0.00	0.00	0.00
Betula lutea	0.00	0.00	0.00	0.00
Prunus serotina	0.00	0.00	0.00	0.00
Acer saccharum	0.00	0.00	0.00	0.00
Tilia americana	0.00	0.00	0.00	0.00
Fraxinus nigra	0.00	0.00	0.00	0.00
Fagus grandifolia	0.00	0.00	0.00	0.00
Ostrya virginiana	0.00	0.00	0.00	0.00
Thuja occidentalis	0.00	0.00	0.00	0.00
Acer pennsylvanicum	0.00	0.00	0.00	0.00
Abies balsamea	0.23	0.00	0.00	0.00
Acer rubrum	0.00	0.00	0.00	0.00
Betula papyrifera	0.00	0.00	0.00	0.00
Picea glauca	0.21	0.27	0.03	0.40
Quercus rubra	0.00	0.00	0.00	0.00
Alnus rugosa	0.00	0.00	0.00	0.00
Populus grandidentata	0.00	0.00	0.00	0.00
Pinus strobus	11.04	0.84	0.08	2.20
Populus tremuloides	2.35	0.00	7.14	0.00
Acer spicatum	0.00	0.00	0.00	0.00
Picea mariana	0.24	0.00	0.27	0.00
Pinus resinosa	28.17	28.83	0.00	4.43
Pinus banksiana	0.00	7.47	19.28	15.35

APPENDIX V - SOIL PROFILE DESCRIPTORS (CM)

Stand	LFH	A1	A2	A	B	DC *	DM *
001	2.75	5.08	2.44	07.51	53.45	59.69	60.02
002	6.14	1.48	7.84	09.31	64.35	72.39	73.29
003	4.45	3.81	2.87	06.67	47.32	55.25	60.96
004	7.20	2.33	5.72	08.05	51.01	60.11	68.58
005	6.99	4.02	1.91	05.93	46.99	53.34	58.42
006	5.93	3.60	3.07	06.66	47.41	53.34	58.88
007	6.77	1.91	5.35	07.25	53.18	67.73	67.73
008	6.99	3.60	9.74	13.34	39.16	59.27	59.69
009	5.50	1.69	2.86	04.55	68.26	73.24	74.02
010	5.29	1.06	2.55	03.60	66.47	70.28	73.66
011	5.72	2.33	7.62	09.95	63.71	73.66	76.20
012	3.81	1.69	2.22	03.91	51.97	55.88	58.42
013	4.66	1.06	3.39	04.45	48.89	52.49	63.50
014	5.50	0.64	3.92	04.56	45.83	50.38	51.22
015	5.29	2.12	1.91	04.02	36.63	43.87	43.87
016	3.39	1.06	5.61	06.67	48.47	55.88	55.88
017	4.02	1.06	6.19	07.25	43.87	48.26	48.26
018	4.02	2.33	3.92	06.24	46.26	52.49	52.49
019	5.50	1.91	4.13	06.04	37.44	40.64	40.64
020	5.08	0.85	3.71	04.56	47.10	51.65	54.19
021	5.29	1.27	4.24	05.50	49.11	53.34	53.34
022	5.72	1.27	3.71	05.30	33.13	39.37	48.68
023	5.50	0.64	5.61	06.25	41.59	55.88	56.30
024	2.22	0.95	7.31	08.26	53.35	61.60	66.04
025	3.81	1.69	5.08	06.76	45.72	52.49	54.19
026	5.50	1.06	5.30	06.35	51.44	58.00	58.42
027	3.60	0.85	4.56	05.40	53.03	58.42	61.81
028	4.66	1.06	4.87	05.92	55.46	61.38	65.19
029	4.45	0.85	3.70	04.55	51.33	55.88	59.27
031	4.02	1.27	5.08	06.35	46.57	52.92	57.79
032	5.50	1.17	5.08	06.25	50.06	56.30	59.27
033	2.94	1.06	4.77	05.82	58.45	59.27	63.50
034	4.45	1.91	6.78	08.68	45.31	53.34	64.35
035	5.50	2.33	2.54	05.29	37.89	42.33	45.72
036	4.45	1.27	6.35	07.62	44.45	52.07	57.15
037	5.08	2.54	7.73	10.27	46.46	55.88	65.19
038	2.96	1.27	3.07	04.33	37.36	56.73	56.73
039	3.49	0.85	2.81	03.65	50.49	50.00	57.15
040	4.23	1.27	7.94	09.21	39.06	48.26	58.42
041	5.29	3.81	2.54	06.35	40.22	46.14	46.14
042	4.66	1.91	5.41	07.31	49.01	56.30	56.30
043	5.72	2.75	7.20	09.94	45.94	55.88	55.88
044	4.45	1.48	2.81	04.28	39.79	46.57	46.57
045	5.93	2.17	5.08	07.24	38.52	45.72	45.72
046	4.66	2.17	5.32	07.48	37.07	44.45	50.80
047	4.23	3.39	1.27	04.66	38.10	46.57	48.26
048	5.72	3.18	3.39	06.56	39.07	45.72	47.41
049	4.02	1.48	2.76	04.23	42.34	46.57	46.57

050	3.81	2.54	6.78	09.31	35.56	44.03	44.03
051	2.96	2.12	5.19	07.30	37.58	45.30	45.30
052	3.81	2.96	3.39	06.35	34.29	40.64	40.64
053	3.81	3.18	1.91	05.09	45.72	50.80	50.80
054	5.08	3.60	3.17	06.77	23.64	45.72	45.72
055	4.45	2.96	1.91	04.87	40.85	45.72	46.99
056	3.81	1.27	2.44	03.71	39.48	45.72	45.72
057	5.50	2.12	2.54	04.67	39.37	48.26	48.26
058	5.08	2.75	7.20	09.94	38.32	52.49	52.49
059	4.66	2.54	3.60	06.14	38.10	50.84	50.84
060	4.02	2.33	3.50	05.83	37.15	47.41	47.41
061	5.08	2.17	4.45	06.61	37.90	46.14	46.14
062	3.81	2.12	3.07	05.19	49.85	51.65	51.65
063	6.35	1.27	4.02	05.29	42.96	48.26	49.11
064	4.02	1.69	4.56	06.24	32.71	41.49	43.18
065	5.72	1.48	5.51	06.98	43.82	50.80	50.80
066	6.14	2.17	5.19	07.36	33.34	42.33	43.18
067	3.81	1.27	2.54	03.81	37.67	45.72	47.41
068	2.96	2.75	4.23	06.98	37.88	44.87	49.53
069	9.95	2.54	8.26	10.79	34.93	45.72	45.72
070	1.69	2.54	5.62	08.15	49.44	59.27	60.54
071	5.08	1.91	4.87	06.78	50.80	57.57	57.57
072	4.45	1.91	7.52	09.42	35.04	48.68	54.19
073	3.81	1.27	7.20	08.46	49.95	58.42	58.42
074	5.50	1.27	9.52	10.79	44.24	55.03	55.03
075	5.93	1.48	7.42	08.89	36.83	44.03	45.72
076	4.02	2.12	7.41	09.53	35.35	44.87	44.87
077	4.23	5.29	6.25	11.53	38.43	49.95	49.95
078	4.23	1.91	6.57	08.47	37.68	47.84	47.84
079	5.50	2.33	5.93	08.26	44.66	50.38	50.38
080	5.50	2.54	5.71	08.25	41.70	49.95	49.95
081	4.66	1.91	5.51	07.41	43.40	50.80	50.80
082	5.29	4.23	3.07	07.30	37.57	53.34	55.88
083	4.66	5.50	3.18	07.19	42.12	50.80	52.49
084	5.08	3.81	3.50	07.30	40.55	47.84	50.38
085	1.96	1.48	4.24	05.71	40.01	49.53	53.34
086	5.93	2.54	3.18	05.72	47.62	53.34	55.03
087	5.93	0.85	5.08	05.93	43.61	51.22	51.22
088	5.08	2.12	7.52	09.63	41.18	50.80	52.49
089	4.66	2.12	4.02	08.26	46.34	52.49	52.49
090	3.81	1.91	4.24	06.14	39.16	45.30	46.99
091	4.66	2.12	4.87	06.99	47.20	54.19	54.19
092	4.23	2.54	4.98	07.51	44.78	52.07	52.07
093	4.23	1.91	4.02	04.83	41.91	47.87	51.22
094	5.70	1.91	9.94	11.85	39.37	53.34	53.34
095	5.50	2.33	6.99	07.70	31.73	46.57	48.26
096	4.45	1.48	7.20	07.19	45.52	54.19	54.19
097	4.23	2.12	6.98	07.48	35.77	44.87	44.87
098	6.35	3.81	5.62	09.42	40.11	49.53	49.53
099	4.87	1.91	5.08	06.99	30.51	45.09	45.09
100	4.66	2.33	4.77	07.10	41.81	48.68	48.68
101	4.45	1.27	3.18	04.45	38.74	47.63	47.63

* depth from mineral soil surface, all others are thickness measurements

APPENDIX VI - PHYSIOGRAPHY, CLIMATE, FIRE

Stand No.	Elev (m)	Lat *	Long *	Prcp (mm)	Temp (C)	Light Index	Fire Index
001	463	06	01	907	18.6	13.8	.111
002	458	07	04	900	18.6	13.8	.082
003	493	06	02	904	18.6	13.8	.074
004	458	06	04	901	18.6	13.8	.078
005	473	06	03	903	18.6	13.8	.072
006	478	07	01	906	18.6	13.8	.084
007	458	07	04	898	18.6	15.0	.083
008	463	07	03	901	18.6	15.0	.105
009	183	14	89	734	19.3	25.0	.196
010	168	15	89	742	19.3	41.0	.207
011	234	15	87	742	19.3	21.7	.160
012	229	14	87	735	19.3	21.7	.170
013	249	14	82	743	19.2	25.0	.205
014	259	19	60	819	18.9	23.3	.136
015	259	20	58	821	18.9	43.3	.219
016	325	21	55	824	18.9	11.7	.123
017	290	20	48	828	18.8	24.3	.178
018	305	19	47	828	18.8	16.7	.129
019	320	19	44	831	18.8	13.3	.219
020	305	20	51	826	18.8	16.7	.138
021	285	21	54	825	18.9	23.3	.141
022	264	13	78	743	19.1	21.7	.142
023	285	13	80	740	19.1	21.7	.128
024	244	17	75	784	19.0	25.0	.149
025	427	18	32	845	18.7	05.0	.103
026	412	18	31	846	18.7	06.7	.122
027	402	18	33	843	18.7	18.3	.125
028	422	16	29	848	18.7	05.0	.104
029	427	16	28	850	18.7	08.3	.114
031	427	17	38	836	18.7	21.7	.129
032	427	18	36	839	18.7	11.7	.080
033	397	17	31	845	18.7	21.7	.122
034	259	14	85	739	19.3	20.0	.161
035	229	15	78	760	19.1	25.0	.156
036	259	11	79	725	19.1	08.3	.100
037	259	14	80	748	19.1	10.0	.086
038	229	12	77	738	19.0	21.7	.129
039	336	12	77	738	19.0	23.3	.143
040	229	13	76	747	19.0	15.0	.124
041	259	17	64	813	18.9	25.0	.129
042	274	18	06	814	18.9	21.7	.151
043	213	18	62	816	18.9	25.0	.159
044	229	20	62	819	18.9	21.7	.157
045	335	14	69	775	18.9	11.7	.091
046	305	17	07	813	18.9	13.3	.135
047	229	16	59	816	18.8	25.0	.146
048	213	18	61	817	18.9	38.3	.225
049	351	10	67	750	18.8	18.3	.122

050	305	11	67	757	18.8	28.3	.135
051	259	15	71	777	18.9	26.7	.142
052	229	17	60	798	19.0	28.3	.199
053	366	23	56	826	18.9	08.3	.115
054	381	23	55	827	18.9	18.3	.180
055	213	18	60	818	18.9	33.3	.153
056	229	19	61	818	18.9	25.0	.132
057	335	12	69	760	18.9	28.3	.162
058	412	18	42	833	18.8	15.0	.092
059	427	18	32	845	18.7	35.0	.152
060	305	20	45	831	18.8	38.3	.151
061	396	15	29	848	18.7	10.0	.148
062	427	13	40	829	18.7	18.3	.080
063	366	15	42	829	18.7	35.0	.162
064	417	13	21	863	18.6	31.7	.134
065	427	15	29	849	18.7	10.0	.102
066	396	17	30	847	18.7	20.0	.086
067	396	17	29	849	18.7	20.0	.090
068	396	10	28	848	18.6	20.0	.228
069	412	09	28	848	18.6	11.7	.111
070	427	08	26	852	18.6	21.7	.086
071	412	09	29	846	18.6	16.7	.076
072	396	10	30	844	18.6	11.7	.084
073	412	10	25	855	18.6	20.0	.142
074	412	10	24	857	18.6	16.7	.089
075	412	11	24	858	18.6	13.3	.106
076	412	11	24	857	18.6	15.0	.080
077	417	11	23	859	18.6	18.3	.098
078	305	20	53	825	18.8	28.3	.138
079	457	06	08	893	18.6	11.7	.085
080	457	06	09	891	18.6	13.3	.112
081	442	05	11	889	18.6	21.7	.092
082	473	05	12	887	18.5	20.0	.094
083	473	05	09	893	18.6	08.3	.081
084	473	07	17	874	18.5	18.3	.077
085	462	07	16	876	18.5	18.3	.092
086	457	07	16	876	18.5	18.3	.082
087	457	05	08	895	18.6	15.0	.147
088	457	03	12	888	18.5	11.7	.106
089	457	03	12	888	18.5	13.3	.095
090	457	03	09	895	18.5	11.7	.078
091	457	01	05	907	18.5	10.0	.147
092	407	23	35	843	18.8	11.7	.077
093	335	21	40	837	18.8	15.0	.116
094	320	21	36	841	18.8	05.0	.110
095	320	22	36	841	18.8	16.7	.163
096	346	22	32	846	18.8	06.7	.077
097	396	24	37	842	18.8	13.3	.095
098	320	20	34	843	18.8	18.3	.149
099	427	14	23	859	18.6	26.7	.140
100	351	23	56	826	18.9	26.7	.148
101	198	22	76	816	19.1	30.0	.162

* converted to cartesian coordinate system

APPENDIX VII - REAL AND INTERPOLATED PRECIPITATION VALUES FOR 39 WEATHER STATIONS IN THE ALGONQUIN REGION

Weather Station	Precipitation (in) Real	Interpolated
Algonquin Park	32.68	36.45
Algonquin Park West	36.10	40.46
Bancroft	31.90	34.64
Bark Lake Dam	28.10	30.95
Barrett Chute	29.31	31.28
Beatrice	40.71	42.28
Big Chute	39.20	38.72
Bingham Chute	35.33	35.21
Burk's Falls	37.83	41.96
Chalk River AEC	30.88	31.98
Chenaux	28.00	31.23
Coe Hill	33.73	35.72
Combermere	28.45	31.35
Des Joachims	32.23	34.00
Dorset	36.50	43.39
Dwight	36.24	45.63
Foymount	28.54	29.72
Haliburton A	35.09	38.24
Huntsville MOE	38.18	38.22
Killaloe	25.54	26.55
Lake Traverse	31.75	29.04
La Cave	33.60	34.89
Madawaska	27.78	31.46
Magnetawan	37.74	40.36
Milford Bay	40.96	42.09
Minden	35.89	38.22
Muskoka A	38.91	39.73
North Bay	34.82	36.61
North Bay A	34.66	36.57
Pembroke E. M.	28.25	30.33
Petawawa A	29.36	31.50
Purdy	28.86	32.57
PNF	30.18	32.35
Ragged Rapids	40.32	40.55
Renfrew	27.79	30.72
Scotia	37.58	39.93
South Falls	39.46	39.47
Utterson Ontario Hydro	40.62	43.46
West Guilford	35.87	46.89

APPENDIX VIII - REAL AND INTERPOLATED TEMPERATURE VALUES FOR 34 WEATHER STATIONS IN THE ALGONQUIN REGION

Station	Temperature (C) Real	Interpolated
Algonquin Park	18.3	18.4
Algonquin Park West	17.5	18.6
Bancroft	18.6	18.8
Bark Lake Dam	18.5	18.8
Beatrice	18.2	18.9
Big Chute	20.3	19.4
Bingham Chute	18.6	18.9
Burk's Falls	17.4	18.8
Chalk River AEC	19.6	19.7
Chenaux	20.7	20.0
Coe Hill	17.9	19.1
Combermere	18.7	18.8
Des Joachims	19.4	19.3
Dorset	17.7	18.7
Dwight	17.3	18.5
Haliburton A	18.4	18.8
Huntsville MOE	19.1	18.7
Killaloe	18.5	19.3
Lake Traverse	18.6	18.9
La Cave	18.3	19.0
Madawaska	18.1	18.4
Magnetawan	17.9	18.9
Milford Bay	18.5	19.0
Minden	18.1	18.4
Muskoka A	18.3	19.0
North Bay	19.4	19.0
North Bay A	18.3	18.9
Pembroke E. M.	20.2	20.0
Petawawa A	18.7	19.8
PNF	19.0	19.7
Ragged Rapids	18.8	19.3
Renfrew	19.7	20.0
Utterson Ontario Hydro	18.0	18.8
West Guilford	18.2	18.7

APPENDIX IX - SOIL TEXTURE

Stand	Sand (%)	Silt (%)	Clay (%)	OM (%)
001	42.4	53.0	04.6	07.8
002	53.0	41.4	05.6	05.8
003	39.8	55.6	04.6	14.0
004	54.8	41.1	04.1	06.7
005	59.0	36.9	04.1	11.2
006	43.4	53.0	03.6	12.0
007	48.0	47.4	04.6	07.5
008	40.8	55.3	03.9	10.0
009	74.0	20.4	05.6	03.0
010	86.5	09.4	04.1	03.3
011	50.2	44.2	05.6	02.5
012	57.0	36.9	06.1	03.8
013	76.4	18.0	05.6	04.0
014	71.0	23.9	05.1	03.5
015	84.5	10.4	05.1	02.3
016	56.8	35.2	08.0	04.5
017	70.8	24.2	05.0	03.0
018	65.3	28.5	06.2	05.5
019	71.7	23.6	04.7	03.2
020	73.6	20.4	06.0	04.5
021	52.5	39.7	07.8	06.0
022	54.3	39.4	06.0	07.0
023	52.4	40.4	07.2	04.0
024	55.1	36.6	08.3	04.3
025	56.9	35.1	08.0	06.2
026	39.1	50.9	10.1	05.7
027	60.8	32.9	06.3	04.8
028	50.8	42.4	06.8	06.0
029	39.3	54.9	05.8	06.7
031	67.4	25.4	07.2	04.2
032	54.2	40.2	05.6	07.0
033	58.0	33.6	08.4	06.0
034	47.0	45.8	07.2	05.0
035	77.0	17.6	05.4	04.8
036	56.6	34.8	08.6	05.8
037	60.5	31.9	07.6	06.0
038	38.0	49.9	12.1	07.3
039	40.8	49.0	10.2	09.5
040	67.4	27.0	05.6	03.2
041	67.0	30.2	02.8	04.6
042	61.7	32.5	05.8	06.8
043	71.6	21.9	06.5	06.7
044	69.0	26.1	04.9	04.2
045	65.0	30.0	05.0	05.4
046	56.5	36.7	06.8	05.2
047	56.5	36.5	07.0	04.9
048	83.2	11.1	05.7	03.0
049	62.4	30.6	07.0	03.8

050	67.0	28.2	04.8	03.4
051	52.5	40.7	06.8	04.2
052	84.0	11.0	05.0	03.5
053	49.0	45.0	06.0	06.3
054	50.0	45.0	05.0	09.2
055	63.3	30.3	06.4	08.4
056	78.4	17.8	03.8	03.3
057	55.7	35.8	08.6	06.8
058	63.5	30.0	06.5	06.2
059	54.5	38.7	06.8	10.4
060	63.0	29.0	08.0	06.1
061	45.6	46.4	08.0	06.9
062	50.5	44.3	05.2	07.6
063	63.2	34.2	02.6	03.2
064	52.7	42.2	05.2	05.0
065	56.5	37.7	05.8	12.0
066	53.5	38.5	08.0	05.5
067	48.5	47.2	04.3	09.4
068	56.5	37.8	05.7	05.6
069	52.8	40.0	07.2	06.2
070	77.7	18.6	03.7	05.5
071	42.1	52.9	05.0	07.9
072	50.8	42.6	06.6	08.7
073	43.5	49.9	06.6	06.5
074	47.4	46.0	06.6	07.1
075	31.7	53.9	14.4	07.3
076	46.7	45.3	08.0	02.0
077	49.4	42.6	08.0	12.1
078	54.1	37.2	08.7	03.9
079	57.0	39.3	03.7	10.8
080	53.4	39.3	07.3	05.9
081	68.4	27.6	04.0	07.5
082	59.8	36.5	03.7	22.0
083	42.7	49.3	08.0	08.8
084	57.1	37.8	05.2	12.3
085	52.0	44.3	03.7	11.3
086	56.2	40.0	03.7	15.4
087	64.1	29.3	06.6	07.5
088	64.1	29.3	06.6	08.6
089	52.0	42.9	05.2	13.2
090	56.7	37.9	05.4	09.1
091	60.7	34.9	04.4	11.7
092	58.0	34.2	07.9	08.5
093	57.7	35.8	06.6	05.1
094	63.4	28.6	08.0	01.9
095	85.8	10.3	03.9	03.4
096	63.5	31.5	05.0	06.6
097	41.4	50.6	08.0	05.3
098	60.9	31.9	07.2	06.7
099	69.8	22.9	07.3	03.3
100	77.1	17.7	05.2	03.1
101	66.4	26.8	06.9	07.3

APPENDIX X - SOIL CHEMISTRY

Stand No.	PH	TOTN (%)	P (ppm)	K (ppm)	CA (ppm)	MG (ppm)	CN (ratio)
001	4.4	0.22	10	36	0225	025	035.5
002	4.5	0.19	11	40	0225	027	030.5
003	4.4	0.26	08	36	0225	027	053.8
004	4.5	0.29	10	44	0350	031	023.1
005	4.3	0.35	07	56	0325	033	032.0
006	4.0	0.35	09	48	0250	027	034.3
007	4.4	0.21	06	36	0300	025	035.7
008	4.5	0.26	05	40	0200	020	038.5
009	4.5	0.06	06	28	0175	020	050.0
010	4.6	0.06	24	16	0150	017	055.0
011	5.2	0.07	21	28	0400	042	035.7
012	5.2	0.07	62	40	0375	031	054.3
013	4.7	0.07	15	28	0200	022	057.1
014	4.8	0.07	61	36	0250	022	050.1
015	4.9	0.05	08	20	0200	017	046.0
016	5.1	0.10	27	52	0350	027	045.0
017	4.5	0.08	22	40	0300	029	037.5
018	5.3	0.11	25	60	0650	072	050.0
019	4.9	0.06	19	44	0275	033	053.3
020	4.6	0.10	35	40	0225	022	045.0
021	4.8	0.14	62	40	0550	038	042.9
022	4.4	0.11	14	48	0125	017	063.6
023	5.0	0.08	12	28	0225	020	050.0
024	4.8	0.08	07	44	0425	042	053.8
025	4.7	0.15	39	72	0325	033	041.3
026	5.1	0.09	07	36	0400	038	063.3
027	4.9	0.09	31	52	0175	020	053.3
028	5.0	0.17	53	52	0525	042	035.3
029	5.2	0.18	41	48	0525	031	037.2
031	4.6	0.09	15	52	0300	031	046.7
032	4.9	0.17	27	48	0400	029	041.2
033	4.5	0.11	27	72	0275	027	054.5
034	4.7	0.06	19	44	0275	027	083.3
035	4.4	0.09	14	32	0200	022	053.3
036	5.4	0.13	33	48	1200	069	044.6
037	5.3	0.17	13	48	1025	060	035.3
038	5.1	0.14	20	80	0575	055	052.1
039	4.7	0.17	04	36	0150	022	055.9
040	4.9	0.06	33	28	0150	015	053.3
041	4.9	0.09	43	27	0064	037	051.1
042	4.5	0.15	13	49	0085	044	045.3
043	4.1	0.11	16	67	0174	053	060.9
044	5.1	0.10	45	68	0135	045	042.0
045	5.0	0.13	22	37	0203	043	041.5
046	5.1	0.09	16	35	0122	039	057.8
047	5.4	0.12	15	57	0251	047	040.8
048	5.4	0.07	12	28	0086	033	042.9

049	5.4	0.09	36	40	0129	040	042.2
050	5.4	0.08	07	44	0255	057	042.5
051	4.9	0.03	19	49	0155	038	041.0
052	4.9	0.08	09	31	0113	037	043.8
053	5.2	0.17	30	40	0126	039	037.1
054	5.0	0.24	17	61	0226	045	038.3
055	4.5	0.23	12	68	0365	054	036.5
056	5.3	0.08	57	51	0102	034	041.3
057	4.9	0.13	10	69	0355	105	052.3
058	4.5	0.11	12	48	0187	041	056.4
059	4.7	0.17	15	51	0083	041	061.2
060	4.7	0.13	14	75	0148	045	046.9
061	5.0	0.22	22	44	0341	059	031.4
062	4.9	0.22	12	47	0100	041	034.5
063	5.1	0.07	35	60	0107	038	045.7
064	5.0	0.12	19	41	0091	038	041.7
065	4.9	0.20	08	35	0135	038	060.0
066	4.7	0.19	17	41	0163	041	028.9
067	4.9	0.23	16	38	0109	040	040.9
068	5.7	0.16	40	60	1135	062	035.0
069	4.2	0.14	06	24	0057	024	044.3
070	4.8	0.20	08	42	0445	061	027.5
071	4.1	0.22	10	38	0157	033	035.9
072	4.2	0.26	07	35	0171	031	033.5
073	4.5	0.15	13	29	0090	025	043.3
074	4.8	0.27	14	41	0510	049	026.3
075	4.8	0.15	07	29	0347	028	048.7
076	4.7	0.22	14	53	0137	038	010.0
077	4.3	0.67	07	48	0241	039	018.1
078	4.9	0.27	09	43	0145	039	014.4
079	4.4	0.43	07	42	0167	052	025.1
080	4.3	0.17	17	32	0162	045	034.7
081	4.6	0.22	07	33	0074	039	034.1
082	4.8	0.63	05	64	0062	043	034.9
083	4.1	0.37	10	50	0128	045	023.8
084	4.4	0.35	07	39	0091	038	035.1
085	4.5	0.35	06	44	0151	038	032.3
086	4.7	0.37	05	49	0110	043	041.6
087	4.4	0.22	07	34	0081	035	034.1
088	4.2	0.38	07	34	0156	037	022.6
089	4.3	0.35	06	46	0093	037	037.7
090	4.3	0.32	07	44	0107	034	028.4
091	4.5	0.40	05	41	0087	032	029.3
092	4.9	0.39	10	50	0402	072	021.8
093	5.1	0.13	43	61	0356	048	039.2
094	4.5	0.13	12	45	0152	024	014.6
095	4.9	0.09	22	46	0209	028	037.8
096	4.5	0.22	10	60	0259	040	030.0
097	4.6	0.17	24	45	0265	057	031.2
098	4.7	0.19	04	25	0680	082	035.3
099	4.7	0.09	39	38	0181	039	036.7
100	4.8	0.09	09	22	0250	066	034.4
101	4.7	0.18	11	39	0163	053	040.6

APPENDIX XI - OVERSTORY STAND ORDINATION SCORES FOR AXES 1 AND 2

Axis 1

Stand No.	Stand Type	Score
069	*Tsuga canadensis*	588
075	*Tsuga canadensis*	575
094	*Tsuga canadensis*	574
065	*Tsuga canadensis*	546
073	*Betula lutea*	529
098	*Betula lutea*	522
087	*Betula lutea*	505
074	*Acer saccharum*	501
077	*Acer saccharum*	500
091	*Betula lutea*	499
061	*Betula lutea*	496
072	*Acer saccharum*	496
080	*Acer saccharum*	482
001	*Acer saccharum*	481
085	*Acer saccharum*	476
084	*Acer saccharum*	473
067	*Acer saccharum*	470
071	*Acer saccharum*	469
092	*Acer saccharum*	469
079	*Acer saccharum*	466
088	*Acer saccharum*	466
083	*Acer saccharum*	465
089	*Acer saccharum*	464
090	*Acer saccharum*	463
004	*Acer saccharum*	461
086	*Acer saccharum*	460
081	*Acer saccharum*	459
002	*Acer saccharum*	458
003	*Acer saccharum*	457
006	*Acer saccharum*	456
070	*Acer saccharum*	456
096	*Acer saccharum*	454
008	*Acer saccharum*	451
076	*Acer saccharum*	448
097	*Acer saccharum*	448
028	*Acer saccharum*	445
005	*Acer saccharum*	444
037	*Acer saccharum*	443
007	*Acer saccharum*	441
036	*Acer saccharum*	435
062	*Acer saccharum*	432
045	*Acer saccharum*	430
032	*Acer saccharum*	426
053	*Acer saccharum*	426

Axis 2

Stand No.	Stand Type	Score
039	*Quercus rubrum*	311
022	*Quercus rubrum*	280
046	*Quercus rubrum*	227
055	*Pinus strobus*	227
035	*Pinus strobus*	226
012	*Pinus strobus*	220
021	*Pinus strobus*	217
060	*Pinus strobus*	216
100	*Pinus strobus*	216
059	*Pinus strobus*	210
042	*Pinus strobus*	208
101	*Pinus strobus*	204
015	*Pinus banksiana*	200
023	*Pinus strobus*	199
041	*Populus* spp	194
063	*Pinus strobus*	194
051	*Pinus strobus*	193
057	*Pinus strobus*	186
011	*Pinus strobus*	181
095	*Pinus strobus*	180
024	*Pinus strobus*	179
010	*Pinus banksiana*	178
099	*Pinus strobus*	175
034	*Pinus strobus*	167
044	*Pinus strobus*	162
068	*Betula papyrifera*	134
019	*Betula papyrifera*	133
025	*Acer saccharum*	131
045	*Acer saccharum*	124
087	*Betula lutea*	123
062	*Acer saccharum*	121
098	*Betula lutea*	119
013	*Pinus resinosa*	117
054	*Betula papyrifera*	117
097	*Acer saccharum*	117
091	*Betula lutea*	116
061	*Betula lutea*	115
073	*Betula lutea*	115
053	*Acer saccharum*	114
008	*Acer saccharum*	113
029	*Acer saccharum*	113
066	*Acer saccharum*	110
037	*Acer saccharum*	109
052	*Pinus resinosa*	108

058	Acer saccharum	425
066	Acer saccharum	425
082	Acer saccharum	417
025	Acer saccharum	415
054	Betula papyrifera	357
029	Acer saccharum	354
068	Betula papyrifera	305
026	Populus spp	257
093	Populus spp	249
039	Quercus rubrum	243
046	Quercus rubrum	243
022	Quercus rubrum	235
095	Pinus strobus	234
031	Populus spp	230
019	Betula papyrif.	220
016	Populus spp	214
049	Populus spp	205
014	Populus spp	204
023	Pinus strobus	203
038	Populus spp	200
027	Populus spp	199
033	Populus spp	199
064	Populus spp	199
042	Pinus strobus	198
018	Populus spp	195
100	Pinus strobus	194
051	Pinus strobus	192
099	Pinus strobus	189
040	Populus spp	185
012	Pinus strobus	183
021	Pinus strobus	182
055	Pinus strobus	180
078	Populus spp	180
050	Populus spp	179
059	Pinus strobus	178
056	Populus spp	174
044	Pinus strobus	171
024	Pinus strobus	170
060	Pinus strobus	169
020	Populus spp	168
041	Populus spp	167
057	Pinus strobus	166
034	Pinus strobus	165
063	Pinus strobus	164
101	Pinus strobus	163
011	Pinus strobus	161
043	Populus spp.	152
047	Populus spp	151
035	Pinus strobus	143
017	Pinus resinosa	102
009	Pinus resinosa	084
052	Pinus resinosa	079
013	Pinus resinosa	071
048	Pinus resinosa	017
015	Pinus banksiana	016
010	Pinus banksiana	000

075	Pinus strobus	108
069	Tsuga canadensis	105
080	Acer saccharum	105
001	Acer saccharum	103
058	Acer saccharum	103
088	Acer saccharum	103
006	Acer saccharum	102
032	Acer saccharum	102
094	Tsuga canadensis	102
096	Acer saccharum	102
089	Acer saccharum	101
076	Acer saccharum	100
028	Acer saccharum	099
067	Acer saccharum	099
081	Acer saccharum	098
077	Acer saccharum	097
085	Acer saccharum	097
074	Acer saccharum	096
003	Acer saccharum	095
065	Tsuga canadensis	095
079	Acer saccharum	095
082	Acer saccharum	095
018	Tsuga canadensis	094
048	Pinus resinosa	094
070	Acer saccharum	094
072	Acer saccharum	094
086	Acer saccharum	094
071	Acer saccharum	093
083	Acer saccharum	093
004	Acer saccharum	092
036	Acer saccharum	092
090	Acer saccharum	092
092	Acer saccharum	092
002	Acer saccharum	091
084	Acer saccharum	090
005	Acer saccharum	089
050	Populus spp	089
009	Pinus resinosa	088
007	Acer saccharum	086
017	Pinus resinosa	082
014	Populus spp	076
016	Populus spp	073
078	Populus spp	068
064	Populus spp	067
093	Populus spp	050
043	Populus spp	046
033	Populus spp	039
020	Populus spp	033
027	Populus spp	022
040	Populus spp	022
031	Populus spp	020
026	Populus spp	019
038	Populus spp	012
047	Populus spp	011
056	Populus spp	004
049	Populus spp	000

APPENDIX XII - UNDERSTORY SPECIES COVER BY STAND (stands and species arranged according to their positions on the first DCA axis)

SPECIES	STANDS													
	083	079	088	080	003	089	090	084	098	008	006	070	087	096
Milium effusum	0	5	5	0	0	0	0	0	0	0	0	0	0	0
Thelypteris noveboracensis	0	20	100	0	0	0	0	0	0	100	0	0	30	0
Viola cucullata	0	0	40	0	0	0	0	0	45	0	0	0	0	0
Viola septentrionalis	0	0	0	0	0	0	5	0	5	0	0	0	0	0
Impatiens capensis	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyelytrum erectum	0	5	0	0	0	0	0	0	0	0	0	0	5	0
Viola selkerkii	15	0	0	0	0	0	0	0	10	0	0	0	0	0
Carex arctata	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Trillium erectum	10	0	25	10	0	10	40	10	0	0	5	5	0	5
Trillium grandiflorum	0	0	0	0	20	0	0	0	0	0	0	0	0	0
Ribes glandulosum	0	0	0	0	0	50	0	0	0	0	0	0	0	0
Monotropa uniflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola incognita	0	0	20	30	0	0	0	0	0	0	0	0	0	0
Prunus serotina (sa)	5	0	10	0	10	0	0	70	0	25	25	0	10	0
Betula lutea (se)	50	35	25	10	5	15	0	35	0	0	0	0	10	0
Oxalis montana	0	5	0	0	0	15	0	0	70	0	0	0	210	0
Cinna latifolia	5	5	0	0	0	0	0	5	10	0	0	5	0	0
Viburnum alnifolium	30	0	100	0	60	300	5	0	0	160	160	0	735	20
Betula lutea (sa)	30	20	20	0	15	10	0	10	5	0	10	5	10	0
Gymnocarpium dryopteris	0	0	0	0	0	5	0	0	70	0	0	0	0	5
Equisetum scirpoides	0	0	0	0	0	0	0	0	15	0	0	0	0	0
Sambucus canadensis	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Polygonum cilinode	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Goodyera repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (se)	20	0	10	10	10	10	40	35	0	10	5	0	5	0
Lycopodium lucidulum	5	10	150	100	150	30	0	0	15	115	120	5	40	20
Trillium undulatum	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Tiarella cordifolia	0	25	0	175	0	5	0	0	790	0	0	0	70	0
Cicaea alpina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryopteris spinulosa	340	330	270	175	140	360	265	80	40	220	180	65	250	55
Rubus strigosus	15	40	10	0	10	75	5	65	0	0	10	0	5	0
Tsuga canadensis (se)	0	0	0	0	0	0	0	20	0	0	0	0	5	0
Ribes lacustre	0	0	0	0	0	0	0	0	80	0	0	0	0	0
Onoclea sensibilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (sa)	570	270	380	560	155	225	445	360	625	115	110	610	215	375
Lycopodium annotinum	0	0	100	0	0	0	0	0	0	0	0	0	45	0
Thelypteris phegopteris	0	0	5	0	0	0	0	0	75	0	0	0	0	0
Actaea pachypoda	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Acer saccharum (se)	1270	1400	1115	1170	220	885	1230	1085	475	590	690	1050	285	1250
Tsuga canadensis (sa)	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Athyrium Felix-femina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (se)	40	0	5	0	80	5	0	65	0	50	75	45	75	195
Viola spp.	10	5	10	60	30	0	5	0	15	50	10	10	0	0
Streptopus amplexifolius	0	10	60	65	0	40	25	5	30	0	20	30	25	30
Galium triflorum	0	0	0	0	0	0	0	0	45	0	0	0	0	10
Tilia americana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus spp.	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Acer pennsylvanicum (sa)	40	50	0	0	195	0	0	80	0	50	60	55	145	85
Lycopodium obscurum	10	60	205	60	10	30	0	0	10	10	10	0	155	5
Ostrya virginiana (sa)	0	0	0	0	0	20	45	60	0	0	10	0	0	35
Smilacina recemosa	0	0	0	0	0	0	0	0	0	10	0	0	0	0
Ostrya virginiana (se)	0	0	0	0	0	0	5	20	10	0	0	20	0	10
Acer spicatum (se)	5	0	0	0	0	0	0	5	150	0	5	0	5	60
Fagus grandifolia (sa)	0	0	0	20	10	10	0	0	0	25	35	30	30	140
Medeola virginiana	0	0	0	0	0	5	0	0	0	0	0	0	50	75
Fagus grandifolia (se)	0	0	0	0	0	10	0	0	0	0	25	0	0	110

SPECIES	STANDS													
	083	079	088	080	003	089	090	084	098	008	006	070	087	096
Carex deweyana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus pubescens	0	0	0	0	0	0	0	0	320	0	0	0	0	0
Botrychium virginianum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trientalis borealis	0	10	25	30	0	10	5	40	15	15	10	0	35	5
Polygonatum biflorum	0	0	0	0	0	0	0	0	0	0	0	10	0	0
Viola pubescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coptis groenlandica	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Habenaria orbiculata	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Lonicera canadensis	0	0	0	60	0	130	0	5	15	0	0	0	0	20
Aralia nudicaulis	0	0	40	0	0	0	0	30	100	20	0	0	45	10
Mitchella repens	0	0	10	0	0	0	0	0	0	0	0	5	0	5
Corylus cornuta	30	5	100	0	0	0	0	0	0	160	130	5	0	0
Maianthemum canadense	0	5	0	0	0	0	0	0	15	0	5	60	60	40
Sanicula marilandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer rubrum (se)	0	0	60	0	10	40	0	5	0	5	15	0	50	0
Abies balsamea (sa)	0	0	0	0	0	0	5	0	5	0	0	0	5	0
Aster umbellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abies balsamea (se)	0	0	0	0	5	40	0	0	15	0	0	0	5	0
Acer rubrum (sa)	0	0	115	0	0	10	0	0	0	0	35	0	35	0
Clintonia borealis	0	0	0	0	0	0	0	0	20	0	0	0	5	0
Carex spp.	0	0	0	0	5	5	5	0	0	0	0	5	0	0
Picea glauca (sa)	0	0	0	0	0	0	0	10	20	0	0	0	0	0
Betula papyrifera (sa)	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Viola renifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gramineae spp.	0	0	15	0	0	0	0	0	0	30	10	0	5	0
Fragaria virginiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus grandidentata (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornus rugosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola rotundifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium clavatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornus canadensis	0	0	0	0	0	0	0	0	5	0	0	0	5	0
Fragaria vesca	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Picea glauca (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aster macrophyllus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus tremuloides (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus rubra (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer spicatum (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alnus rugosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium myrtilloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum acerifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus grandidentata (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula papyrifera (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hepatica americana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaultheria procumbens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus rubra (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pteridium aquilinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygala pauciflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linnaea borealis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus tremuloides (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus strobus (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium angustifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum cassinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocynum androsaemifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus strobus (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lonicera villosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	083	079	088	080	003	089	090	084	098	008	006	070	087	096
Prunus pumila	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amelanchier sanguinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waldsteinia fragariodes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melampyrum lineare	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chimaphila umbellata	0	0	0	0	0	0	0	0	20	0	0	0	0	0
Epigaea repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium complenatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kalmia angustifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago squarrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Comptonia peregrina	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Pinus banksiana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus resinosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cypripedium candidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	082	072	085	074	077	005	091	004	076	094	081	007	092	002
Milium effusum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris noveboracensis	0	0	0	0	15	0	0	0	0	0	0	0	0	0
Viola cucullata	0	15	0	0	0	0	0	0	0	0	0	0	0	0
Viola septentrionalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Impatiens capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyelytrum erectum	15	0	5	5	0	0	0	0	0	0	0	0	0	0
Viola selkerkii	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex arctata	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Trillium erectum	10	0	10	0	20	0	5	0	0	0	0	0	20	5
Trillium grandiflorum	0	0	0	0	0	0	0	5	0	0	0	5	0	0
Ribes glandulosum	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Monotropa uniflora	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Viola incognita	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (sa)	60	0	5	0	0	30	0	15	0	0	0	65	0	65
Betula lutea (se)	0	0	40	15	35	10	10	10	10	25	5	5	5	0
Oxalis montana	0	5	5	60	10	0	60	0	0	0	0	35	0	0
Cinna latifolia	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum alnifolium	150	40	290	0	10	70	440	120	0	0	50	130	0	0
Betula lutea (sa)	10	0	20	0	20	0	10	80	0	10	10	20	10	30
Gymnocarpium dryopteris	0	10	5	20	5	0	0	0	0	0	0	0	0	0
Equisetum scirpoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sambucus canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum cilinode	0	0	0	0	0	0	0	0	0	0	50	0	0	0
Goodyera repens	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Prunus serotina (se)	10	0	0	10	0	5	0	5	0	0	0	25	0	40
Lycopodium lucidulum	5	70	5	0	0	100	50	65	0	20	30	50	0	0
Trillium undulatum	0	0	0	0	10	0	5	5	0	0	0	0	0	0
Tiarella cordifolia	0	0	20	0	0	0	20	30	0	0	0	0	0	0
Cicaea alpina	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Dryopteris spinulosa	200	110	295	100	150	120	225	320	150	75	190	260	80	210
Rubus strigosus	10	5	5	0	0	0	0	0	55	0	100	0	0	0
Tsuga canadensis (se)	0	0	0	0	10	0	0	0	0	115	0	0	0	0
Ribes lacustre	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Onoclea sensibilis	0	0	0	0	0	0	20	0	0	0	5	0	0	0
Acer saccharum (sa)	390	375	615	370	575	215	440	310	535	50	200	175	370	165
Lycopodium annotinum	0	0	0	0	0	0	0	0	75	0	0	0	0	0
Thelypteris phegopteris	0	10	0	0	0	0	50	0	0	0	0	0	0	0
Actaea pachypoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (se)	715	855	1145	715	860	790	425	230	1040	45	1005	260	1670	910
Tsuga canadensis (sa)	0	0	0	0	0	0	0	0	0	50	0	0	20	0
Athyrium Felix-femina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (se)	10	50	10	20	60	15	10	30	0	130	0	15	95	10
Viola spp.	40	0	10	30	5	5	20	20	0	5	35	0	0	10
Streptopus amplexifolius	15	10	10	10	30	5	40	0	0	25	15	25	20	5
Galium triflorum	0	10	0	0	20	0	0	0	0	0	0	0	0	0
Tilia americana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus spp.	0	0	0	0	0	0	25	0	0	10	0	0	0	0
Acer pennsylvanicum (sa)	70	45	0	30	140	45	5	85	0	25	40	10	155	0
Lycopodium obscurum	55	180	90	25	40	30	110	60	105	45	215	120	40	25
Ostrya virginiana (sa)	0	0	20	0	0	0	0	30	0	0	0	0	35	0
Smilacina recemosa	0	20	5	0	0	0	0	0	0	0	40	5	0	0
Ostrya virginiana (se)	0	0	0	0	0	0	10	20	0	0	0	0	25	0
Acer spicatum (se)	0	0	0	30	0	0	15	0	0	165	0	5	5	0
Fagus grandifolia (sa)	0	0	0	0	5	15	0	0	0	5	0	0	10	0
Medeola virginiana	0	30	0	15	30	0	0	5	10	0	10	5	20	0
Fagus grandifolia (se)	0	0	0	0	10	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	082	072	085	074	077	005	091	004	076	094	081	007	092	002
Carex deweyana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus pubescens	0	80	0	0	20	0	0	0	0	0	0	0	0	0
Botrychium virginianum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trientalis borealis	70	45	45	30	40	25	5	60	65	10	50	30	30	30
Polygonatum biflorum	0	5	0	0	5	5	0	10	0	0	0	0	10	0
Viola pubescens	0	0	0	0	0	0	0	0	0	0	0	0	25	0
Coptis groenlandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Habenaria orbiculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lonicera canadensis	10	0	0	0	0	0	20	5	0	45	0	10	0	20
Aralia nudicaulis	55	80	35	10	60	35	105	65	0	100	75	50	35	130
Mitchella repens	0	0	5	0	0	0	0	0	0	0	0	5	0	0
Corylus cornuta	80	45	25	15	20	0	0	120	0	50	15	70	0	70
Maianthemum canadense	60	65	20	5	30	15	5	10	15	35	30	130	30	25
Sanicula marilandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer rubrum (se)	110	0	50	0	40	5	90	40	0	5	45	65	0	35
Abies balsamea (sa)	0	0	5	0	10	0	0	10	20	50	5	20	10	0
Aster umbellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abies balsamea (se)	0	0	0	0	0	0	0	0	110	10	15	30	0	0
Acer rubrum (sa)	185	0	45	0	20	0	20	130	0	0	0	50	5	10
Clintonia borealis	0	0	0	0	5	0	25	0	0	0	50	70	0	0
Carex spp.	0	0	0	0	0	0	30	0	0	0	0	5	5	25
Picea glauca (sa)	0	0	0	0	0	10	10	25	0	5	20	0	0	0
Betula papyrifera (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola renifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gramineae spp.	10	0	0	5	0	10	5	20	0	0	15	25	5	45
Fragaria virginiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus grandidentata (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornus rugosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola rotundifolia	0	10	0	0	10	0	0	0	0	0	0	0	0	0
Lycopodium clavatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornus canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragaria vesca	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Picea glauca (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aster macrophyllus	0	0	5	5	0	0	0	0	0	0	5	10	0	0
Populus tremuloides (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus rubra (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer spicatum (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alnus rugosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium myrtilloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum acerifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus grandidentata (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula papyrifera (se)	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Hepatica americana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaultheria procumbens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus rubra (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pteridium aquilinum	50	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygala pauciflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linnaea borealis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus tremuloides (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus strobus (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium angustifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum cassinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocynum androsaemifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus strobus (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lonicera villosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	082	072	085	074	077	005	091	004	076	094	081	007	092	002
Prunus pumila	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amelanchier sanguinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waldsteinia fragariodes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melampyrum lineare	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chimaphila umbellata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epigaea repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium complenatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kalmia angustifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago squarrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Comptonia peregrina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus banksiana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus resinosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cypripedium candidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	001	086	069	071	062	073	028	061	036	067	075	097	045	053
Milium effusum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris noveboracensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola cucullata	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Viola septentrionalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Impatiens capensis	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Brachyelytrum erectum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola selkerkii	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Carex arctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium erectum	0	0	0	10	15	0	0	0	0	0	0	0	0	0
Trillium grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes glandulosum	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Monotropa uniflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola incognita	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (sa)	55	60	0	0	0	0	0	0	0	0	0	0	0	0
Betula lutea (se)	5	15	40	10	0	20	0	0	0	0	40	0	5	0
Oxalis montana	5	0	110	0	0	85	5	0	0	0	0	0	0	0
Cinna latifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum alnifolium	480	530	0	140	0	10	15	60	0	0	0	0	10	0
Betula lutea (sa)	0	20	30	0	0	20	0	0	0	10	20	0	0	0
Gymnocarpium dryopteris	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equisetum scirpoides	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Sambucus canadensis	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Polygonum cilinode	0	0	0	0	0	0	20	10	0	0	0	0	0	0
Goodyera repens	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (se)	15	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium lucidulum	55	120	10	25	0	45	0	10	0	0	120	5	0	15
Trillium undulatum	0	5	0	0	0	5	0	0	0	0	0	0	0	5
Tiarella cordifolia	0	15	0	0	0	0	0	0	0	0	0	0	0	0
Cicaea alpina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryopteris spinulosa	270	120	120	335	115	255	160	25	30	120	170	40	0	10
Rubus strigosus	0	5	0	0	0	0	60	5	5	10	0	0	0	0
Tsuga canadensis (se)	0	0	90	0	0	15	10	0	0	0	40	5	0	0
Ribes lacustre	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Onoclea sensibilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (sa)	160	230	0	180	300	110	585	495	810	520	80	160	45	150
Lycopodium annotinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris phegopteris	5	0	0	0	0	100	0	230	0	0	0	0	0	0
Actaea pachypoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (se)	350	955	30	725	500	215	970	605	870	1100	65	530	115	135
Tsuga canadensis (sa)	0	0	35	0	0	10	0	0	0	0	150	0	0	20
Athyrium Felix-femina	0	0	0	0	0	0	10	5	0	0	0	0	0	0
Acer pennsylvanicum (se)	0	45	105	50	155	85	110	80	5	95	40	145	240	95
Viola spp.	90	10	5	0	5	40	15	105	5	0	5	10	5	0
Streptopus amplexifolius	0	30	5	45	30	40	0	80	0	0	40	25	35	10
Galium triflorum	0	0	0	0	0	0	20	30	20	0	0	0	0	0
Tilia americana (sa)	0	0	0	0	0	0	0	0	30	0	0	0	0	0
Rubus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (sa)	0	60	20	20	210	145	25	155	30	15	5	240	85	105
Lycopodium obscurum	40	100	45	35	45	100	125	60	25	155	40	55	0	10
Ostrya virginiana (sa)	0	60	0	0	0	0	25	0	110	0	0	65	0	15
Smilacina recemosa	10	10	0	0	0	30	0	0	0	0	0	25	0	0
Ostrya virginiana (se)	0	15	0	0	40	10	0	0	10	10	0	100	15	10
Acer spicatum (se)	0	0	75	40	0	15	0	360	0	0	40	40	5	10
Fagus grandifolia (sa)	0	40	0	0	310	45	0	0	50	0	0	40	240	430
Medeola virginiana	0	80	0	5	10	110	10	10	0	35	0	25	35	45
Fagus grandifolia (se)	0	5	5	0	50	20	0	0	0	0	0	5	150	120

SPECIES	STANDS													
	001	086	069	071	062	073	028	061	036	067	075	097	045	053
Carex deweyana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus pubescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Botrychium virginianum	0	0	0	0	0	0	0	10	15	0	0	0	0	0
Trientalis borealis	15	65	25	20	75	20	150	75	5	120	50	25	115	60
Polygonatum biflorum	0	0	0	5	0	5	0	0	0	5	10	0	0	0
Viola pubescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coptis groenlandica	0	0	35	0	0	0	0	15	0	0	20	0	0	0
Habenaria orbiculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lonicera canadensis	10	20	0	60	0	10	10	5	40	0	90	20	20	0
Aralia nudicaulis	40	170	30	210	5	115	375	70	15	20	135	55	115	70
Mitchella repens	5	45	0	0	25	5	0	0	0	0	0	0	0	0
Corylus cornuta	30	125	0	45	0	25	0	10	10	10	50	20	30	65
Maianthemum canadense	0	50	35	0	50	45	10	70	25	305	50	75	90	70
Sanicula marilandica	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Acer rubrum (se)	45	50	10	5	30	40	15	0	0	55	0	65	5	145
Abies balsamea (sa)	30	0	90	5	0	0	40	55	35	0	50	120	200	40
Aster umbellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abies balsamea (se)	0	10	75	0	0	0	50	95	0	5	0	230	30	10
Acer rubrum (sa)	55	70	0	0	35	10	70	10	0	15	0	10	10	0
Clintonia borealis	0	0	0	20	0	10	0	0	0	0	55	25	5	5
Carex spp.	5	0	10	0	0	5	5	10	5	5	5	5	5	5
Picea glauca (sa)	0	10	0	20	0	0	0	0	0	0	0	0	10	0
Betula papyrifera (sa)	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Viola renifolia	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Gramineae spp.	70	5	5	0	0	5	5	15	5	0	0	10	0	0
Fragaria virginiana	5	0	0	0	0	0	25	0	0	0	0	0	0	0
Populus grandidentata (se)	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Pyrola elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornus rugosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola rotundifolia	0	0	0	0	5	0	0	5	0	0	0	0	0	0
Lycopodium clavatum	0	0	0	0	0	0	0	25	0	0	0	0	0	0
Cornus canadensis	0	0	15	0	0	0	5	5	0	0	25	0	0	0
Fragaria vesca	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Picea glauca (se)	0	0	0	0	0	0	0	10	0	0	5	0	0	0
Aster macrophyllus	5	30	0	0	0	0	10	40	0	0	0	115	0	10
Populus tremuloides (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus rubra (se)	0	0	0	0	0	10	0	0	0	0	0	25	0	5
Acer spicatum (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alnus rugosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium myrtilloides	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Viburnum acerifolium	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Populus grandidentata (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula papyrifera (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hepatica americana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaultheria procumbens	0	0	0	0	0	5	0	0	0	0	25	0	0	5
Quercus rubra (sa)	0	0	0	0	0	10	0	0	0	0	0	10	0	0
Pteridium aquilinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygala pauciflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linnaea borealis	0	0	0	0	0	0	0	0	0	0	10	0	5	0
Populus tremuloides (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus strobus (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium angustifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum cassinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocynum androsaemifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus strobus (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lonicera villosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	001	086	069	071	062	073	028	061	036	067	075	097	045	053
Prunus pumila	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amelanchier sanguinea	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Waldsteinia fragariodes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melampyrum lineare	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chimaphila umbellata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epigaea repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium complenatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kalmia angustifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago squarrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Comptonia peregrina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus banksiana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus resinosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cypripedium candidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	025	066	065	037	026	068	032	100	058	054	064	029	093	095
Milium effusum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris noveboracensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola cucullata	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Viola septentrionalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Impatiens capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyelytrum erectum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola selkerkii	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex arctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium erectum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes glandulosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monotropa uniflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola incognita	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula lutea (se)	5	0	0	0	5	0	0	0	0	0	20	0	0	0
Oxalis montana	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Cinna latifolia	0	5	0	0	0	5	0	0	0	0	5	0	0	0
Viburnum alnifolium	10	0	5	0	10	0	0	0	0	0	0	0	0	0
Betula lutea (sa)	15	0	35	0	15	0	0	0	5	0	0	0	0	0
Gymnocarpium dryopteris	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equisetum scirpoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sambucus canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum cilinode	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goodyera repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium lucidulum	10	25	0	0	0	0	0	0	15	0	0	0	0	0
Trillium undulatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tiarella cordifolia	0	0	0	5	0	0	0	15	0	0	0	0	0	0
Cicaea alpina	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Dryopteris spinulosa	0	20	15	20	40	90	10	35	10	10	0	15	0	0
Rubus strigosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tsuga canadensis (se)	0	0	25	0	0	0	0	0	0	0	0	0	5	0
Ribes lacustre	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Onoclea sensibilis	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Acer saccharum (sa)	155	80	20	395	310	95	200	60	50	155	55	285	10	130
Lycopodium annotinum	0	0	0	0	0	0	0	5	0	0	5	0	15	0
Thelypteris phegopteris	35	0	0	25	0	10	5	0	0	0	0	0	0	0
Actaea pachypoda	0	0	0	20	0	50	0	0	0	0	0	0	0	0
Acer saccharum (se)	140	910	35	575	218	90	150	45	100	535	45	895	195	60
Tsuga canadensis (sa)	0	0	65	0	0	0	0	0	0	0	0	0	15	0
Athyrium Felix-femina	0	0	0	25	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (se)	175	90	205	90	15	0	55	0	45	115	0	70	85	10
Viola spp.	5	0	0	25	20	65	5	5	0	20	25	15	40	0
Streptopus amplexifolius	0	15	10	0	25	0	0	40	25	90	50	0	25	45
Galium triflorum	0	50	0	15	5	15	0	5	0	5	0	0	5	0
Tilia americana (sa)	0	0	0	40	0	0	0	0	0	0	0	0	0	0
Rubus spp.	0	0	0	0	0	0	0	5	0	0	0	0	5	0
Acer pennsylvanicum (sa)	225	60	55	15	25	20	70	0	150	115	10	90	15	20
Lycopodium obscurum	0	135	0	95	35	275	105	45	95	10	40	60	30	60
Ostrya virginiana (sa)	0	0	0	170	15	0	300	0	0	0	0	0	35	50
Smilacina recemosa	0	0	0	0	10	0	0	0	0	0	0	0	0	75
Ostrya virginiana (se)	15	75	0	50	0	5	75	0	40	80	0	80	35	20
Acer spicatum (se)	10	0	0	10	15	0	0	105	0	30	20	5	0	0
Fagus grandifolia (sa)	145	5	30	45	0	0	285	0	170	30	0	0	0	5
Medeola virginiana	50	25	20	10	20	0	10	5	10	30	5	15	10	10
Fagus grandifolia (se)	35	0	30	10	0	0	85	5	60	35	0	0	5	0

SPECIES	STANDS													
	025	066	065	037	026	068	032	100	058	054	064	029	093	095
Carex deweyana	0	5	0	0	0	20	0	0	0	0	0	0	0	0
Rubus pubescens	0	0	0	0	0	0	0	70	0	0	0	0	0	0
Botrychium virginianum	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Trientalis borealis	145	100	95	30	70	150	55	45	120	110	85	95	45	70
Polygonatum biflorum	0	15	0	0	5	0	0	5	5	0	5	30	0	0
Viola pubescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coptis groenlandica	0	0	95	0	0	0	0	0	0	0	5	0	0	0
Habenaria orbiculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lonicera canadensis	15	10	85	25	5	30	0	10	10	55	20	20	25	95
Aralia nudicaulis	25	130	165	140	315	125	70	230	115	65	385	185	110	240
Mitchella repens	0	0	0	20	5	0	10	0	0	0	0	0	0	5
Corylus cornuta	185	5	50	170	270	0	55	295	185	30	330	185	40	270
Maianthemum canadense	115	170	275	20	125	220	60	50	65	180	240	125	100	100
Sanicula marilandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer rubrum (se)	290	20	105	105	130	10	30	45	135	225	215	115	260	155
Abies balsamea (sa)	25	25	35	0	15	65	0	330	225	115	240	0	80	15
Aster umbellatus	0	0	0	0	0	0	0	35	0	0	0	0	0	0
Abies balsamea (se)	15	90	180	35	25	60	5	45	35	50	55	20	95	0
Acer rubrum (sa)	135	20	40	10	330	5	25	35	85	10	160	60	115	65
Clintonia borealis	0	0	45	0	50	0	0	195	10	0	80	95	25	50
Carex spp.	5	5	25	30	0	25	5	40	10	0	0	0	0	0
Picea glauca (sa)	0	0	20	10	0	0	0	55	0	20	0	0	25	0
Betula papyrifera (sa)	0	5	0	0	0	5	0	0	0	0	0	0	0	0
Viola renifolia	0	0	0	0	0	25	0	0	5	0	5	0	15	0
Gramineae spp.	10	0	0	10	10	50	10	30	5	10	20	15	10	35
Fragaria virginiana	5	0	0	10	0	0	0	0	0	0	0	0	0	0
Populus grandidentata (se)	5	0	0	0	10	0	45	0	0	0	0	5	10	5
Pyrola elliptica	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Cornus rugosa	0	0	0	5	5	0	0	0	0	30	0	0	0	0
Pyrola rotundifolia	5	0	0	0	0	35	30	15	0	0	15	30	0	0
Lycopodium clavatum	0	0	0	0	0	30	0	0	0	0	0	0	15	0
Cornus canadensis	0	0	70	0	0	90	0	30	5	20	65	15	5	0
Fragaria vesca	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Picea glauca (se)	0	0	0	0	15	0	0	5	0	0	5	0	5	0
Aster macrophyllus	10	0	0	10	140	0	5	40	15	80	200	50	155	540
Populus tremuloides (se)	15	0	0	0	0	0	15	0	0	0	0	10	0	0
Quercus rubra (se)	5	0	0	65	10	0	0	0	0	15	0	0	5	20
Acer spicatum (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alnus rugosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium myrtilloides	0	10	0	0	0	0	0	10	10	0	15	0	0	0
Viburnum acerifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus grandidentata (sa)	40	0	0	0	0	0	0	0	0	0	0	0	5	10
Betula papyrifera (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hepatica americana	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Gaultheria procumbens	0	10	20	0	5	0	5	10	0	5	0	0	5	35
Quercus rubra (sa)	0	0	0	0	40	0	0	0	0	0	0	0	0	30
Pteridium aquilinum	0	10	10	5	120	300	0	30	0	0	275	15	5	80
Polygala pauciflora	0	0	0	0	0	5	0	0	10	20	0	0	30	0
Linnaea borealis	0	0	0	0	0	60	0	5	0	5	0	0	5	0
Populus tremuloides (sa)	0	0	0	0	25	0	45	0	0	0	0	75	0	0
Pinus strobus (sa)	0	0	10	15	0	0	0	0	10	0	20	0	10	5
Vaccinium angustifolium	0	5	5	0	0	0	0	5	10	0	30	0	0	0
Viburnum cassinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocynum androsaemifolium	0	0	0	0	0	35	0	0	0	0	10	0	0	0
Pinus strobus (se)	0	0	0	0	0	0	0	0	5	0	0	0	5	10
Lonicera villosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	025	066	065	037	026	068	032	100	058	054	064	029	093	095
Prunus pumila	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amelanchier sanguinea	0	0	0	20	0	0	0	0	0	5	0	0	0	0
Waldsteinia fragariodes	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Melampyrum lineare	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chimaphila umbellata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epigaea repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium complenatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kalmia angustifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago squarrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Comptonia peregrina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus banksiana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus resinosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cypripedium candidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	021	031	019	078	027	016	023	034	033	018	024	046	048	020
Milium effusum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris noveboracensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola cucullata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola septentrionalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Impatiens capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyelytrum erectum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola selkerkii	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex arctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium erectum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes glandulosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monotropa uniflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola incognita	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula lutea (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis montana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinna latifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum alnifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula lutea (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnocarpium dryopteris	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Equisetum scirpoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sambucus canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum cilinode	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goodyera repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium lucidulum	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Trillium undulatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tiarella cordifolia	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Cicaea alpina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryopteris spinulosa	135	0	0	10	0	0	0	0	0	0	0	0	0	0
Rubus strigosus	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Tsuga canadensis (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes lacustre	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Onoclea sensibilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (sa)	0	120	45	0	0	135	10	35	0	0	0	50	0	0
Lycopodium annotinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris phegopteris	0	0	0	0	0	0	0	0	0	0	0	0	0	20
Actaea pachypoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (se)	0	40	0	0	20	15	60	45	0	0	0	40	30	0
Tsuga canadensis (sa)	0	15	0	0	0	0	0	0	0	0	0	0	0	0
Athyrium Felix-femina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (se)	0	0	85	0	45	40	35	0	20	0	0	210	35	0
Viola spp.	5	0	5	10	0	0	0	0	0	35	10	0	5	0
Streptopus amplexifolius	5	5	15	5	15	30	0	5	0	0	15	0	5	5
Galium triflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tilia americana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (sa)	0	15	25	0	45	20	70	0	70	10	25	340	50	0
Lycopodium obscurum	100	75	0	40	0	15	0	25	25	40	0	0	0	35
Ostrya virginiana (sa)	0	155	0	0	0	10	65	165	0	0	55	0	0	10
Smilacina recemosa	0	10	0	0	0	0	0	0	0	0	0	0	0	0
Ostrya virginiana (se)	0	45	0	0	5	15	80	35	0	0	0	10	0	0
Acer spicatum (se)	5	0	0	10	0	0	0	0	10	60	15	0	0	30
Fagus grandifolia (sa)	0	15	25	0	45	10	55	15	0	10	10	30	0	10
Medeola virginiana	0	0	35	40	10	75	0	10	10	10	0	25	0	5
Fagus grandifolia (se)	0	0	0	0	0	0	15	5	0	0	10	25	0	10

SPECIES	STANDS													
	021	031	019	078	027	016	023	034	033	018	024	046	049	020
Carex deweyana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus pubescens	0	0	0	0	0	0	0	0	0	15	0	0	0	0
Botrychium virginianum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trientalis borealis	25	110	100	75	109	100	10	10	70	80	30	55	75	65
Polygonatum biflorum	0	10	0	0	0	0	15	5	5	0	0	10	0	0
Viola pubescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coptis groenlandica	0	0	0	0	0	0	0	0	0	5	0	0	0	10
Habenaria orbiculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lonicera canadensis	0	70	15	40	25	15	60	30	60	90	275	20	5	0
Aralia nudicaulis	280	380	520	355	420	285	235	465	320	400	200	285	325	320
Mitchella repens	0	5	0	0	25	0	0	5	10	10	5	0	0	0
Corylus cornuta	835	95	645	160	225	195	125	45	215	195	260	40	125	240
Maianthemum canadense	125	150	110	160	135	130	70	175	175	105	235	60	175	220
Sanicula marilandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer rubrum (se)	35	240	135	75	200	210	105	165	120	80	85	290	410	55
Abies balsamea (sa)	25	0	70	125	100	10	45	0	55	100	25	0	0	10
Aster umbellatus	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Abies balsamea (se)	190	10	290	90	105	25	35	25	20	115	60	0	0	10
Acer rubrum (sa)	175	255	135	85	360	250	135	435	130	95	10	430	990	100
Clintonia borealis	120	70	0	185	10	65	0	50	0	30	80	0	0	130
Carex spp.	25	15	5	0	10	5	40	10	0	5	0	10	25	40
Picea glauca (sa)	0	0	0	5	0	0	0	0	0	10	45	0	0	0
Betula papyrifera (sa)	0	0	0	0	15	20	0	0	0	10	0	0	0	0
Viola renifolia	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Gramineae spp.	5	35	15	25	10	20	40	55	5	10	20	10	80	25
Fragaria virginiana	0	0	0	0	0	0	5	0	0	5	15	0	0	0
Populus grandidentata (se)	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Pyrola elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornus rugosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola rotundifolia	0	5	15	5	10	15	0	5	0	5	0	0	5	20
Lycopodium clavatum	0	0	0	5	0	40	0	0	0	40	0	0	5	15
Cornus canadensis	5	35	35	30	25	0	5	65	10	45	90	0	0	40
Fragaria vesca	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Picea glauca (se)	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Aster macrophyllus	15	20	140	255	70	255	40	185	15	445	235	45	85	50
Populus tremuloides (se)	5	0	0	0	0	10	0	0	5	20	5	10	0	0
Quercus rubra (se)	0	5	0	0	0	0	35	5	0	0	0	65	25	0
Acer spicatum (sa)	90	0	0	0	0	0	0	0	15	60	30	0	0	0
Alnus rugosa (sa)	0	0	0	0	0	0	0	0	0	20	0	0	0	0
Vaccinium myrtilloides	0	0	0	15	0	0	0	0	0	0	0	15	0	0
Viburnum acerifolium	0	0	0	0	0	0	5	55	0	0	0	20	0	0
Populus grandidentata (sa)	0	0	0	0	0	0	0	0	90	0	0	0	0	0
Betula papyrifera (se)	0	0	0	0	0	0	0	0	5	0	0	0	30	5
Hepatica americana	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Gaultheria procumbens	0	55	35	10	85	40	30	130	90	10	15	35	50	50
Quercus rubra (sa)	0	0	140	0	15	25	80	55	0	0	10	15	15	0
Pteridium aquilinum	0	0	445	335	260	235	125	125	120	130	175	215	375	460
Polygala pauciflora	0	0	0	5	0	0	0	0	0	0	0	5	10	0
Linnaea borealis	40	0	0	0	0	0	0	0	0	0	5	5	0	0
Populus tremuloides (sa)	0	0	0	10	0	10	0	0	0	0	0	0	0	20
Pinus strobus (sa)	0	40	0	0	15	45	10	25	0	0	0	0	0	0
Vaccinium angustifolium	0	40	80	0	65	60	30	25	35	45	40	20	20	60
Viburnum cassinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	30
Apocynum androsaemifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Pinus strobus (se)	15	0	0	10	0	10	0	35	5	5	0	5	0	0
Lonicera villosa	185	5	0	15	0	20	0	5	0	25	0	0	0	90

SPECIES	STANDS													
	021	031	019	078	027	016	023	034	033	018	024	046	049	020
Prunus pumila	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amelanchier sanguinea	0	35	5	0	0	10	35	15	5	0	5	5	45	45
Waldsteinia fragariodes	0	0	0	0	0	0	10	0	0	0	135	0	0	0
Melampyrum lineare	0	5	0	0	0	0	0	0	0	0	0	0	10	0
Chimaphila umbellata	0	0	0	0	10	0	0	0	0	0	0	0	0	0
Epigaea repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium complenatum	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Kalmia angustifolia	0	0	0	0	0	0	0	0	0	5	0	10	0	0
Solidago squarrosa	0	0	0	0	0	0	0	0	0	0	0	20	0	80
Comptonia peregrina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus banksiana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	15
Pinus resinosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cypripedium candidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	050	017	059	060	051	057	014	056	041	099	055	038	044	011
Milium effusum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris noveboracensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola cucullata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola septentrionalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Impatiens capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyelytrum erectum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola selkerkii	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex arctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium erectum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes glandulosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monotropa uniflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola incognita	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula lutea (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis montana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinna latifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum alnifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula lutea (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnocarpium dryopteris	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equisetum scirpoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sambucus canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum cilinode	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goodyera repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (se)	0	10	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium lucidulum	0	0	0	15	0	0	0	0	0	0	0	0	0	0
Trillium undulatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tiarella cordifolia	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Cicaea alpina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryopteris spinulosa	0	5	0	0	0	5	0	0	0	0	0	0	0	0
Rubus strigosus	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Tsuga canadensis (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes lacustre	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Onoclea sensibilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (sa)	20	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium annotinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris phegopteris	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Actaea pachypoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (se)	40	0	10	0	0	0	0	0	0	10	0	0	0	0
Tsuga canadensis (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Athyrium Felix-femina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (se)	70	0	5	0	0	0	0	0	0	0	0	0	0	0
Viola spp.	0	5	0	0	0	25	0	0	0	0	0	5	0	0
Streptopus amplexifolius	0	0	15	0	10	0	0	15	0	10	0	0	5	0
Galium triflorum	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Tilia americana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (sa)	20	0	100	0	100	0	0	0	0	0	0	145	0	25
Lycopodium obscurum	0	0	0	20	0	0	55	30	100	0	5	0	0	20
Ostrya virginiana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Smilacina recemosa	0	0	0	0	0	0	0	0	0	5	0	0	5	0
Ostrya virginiana (se)	0	0	0	0	25	0	0	0	0	0	0	0	0	0
Acer spicatum (se)	0	0	15	10	0	5	0	0	5	0	0	0	40	0
Fagus grandifolia (sa)	0	0	70	0	0	0	0	20	0	0	0	0	0	20
Medeola virginiana	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Fagus grandifolia (se)	0	0	5	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	050	017	059	060	051	057	014	056	041	099	055	038	044	011
Carex deweyana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus pubescens	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Botrychium virginianum	0	0	0	0	60	0	0	0	0	0	0	0	0	0
Trientalis borealis	40	35	55	40	25	25	40	85	35	50	0	35	15	5
Polygonatum biflorum	0	0	0	0	5	0	0	20	0	5	0	5	0	0
Viola pubescens	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Coptis groenlandica	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Habenaria orbiculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lonicera canadensis	0	80	20	70	135	60	20	0	0	40	10	60	40	0
Aralia nudicaulis	490	640	290	415	145	300	245	375	190	395	390	490	345	620
Mitchella repens	0	30	0	0	0	0	0	0	0	0	0	0	0	50
Corylus cornuta	285	140	60	370	175	230	240	740	200	435	505	185	350	395
Maianthemum canadense	125	180	250	250	180	105	110	110	225	115	265	45	240	320
Sanicula marilandica	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Acer rubrum (se)	95	15	210	120	185	35	80	270	5	190	35	0	35	90
Abies balsamea (sa)	170	95	105	185	40	255	105	25	490	0	475	0	250	65
Aster umbellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abies balsamea (se)	55	65	30	110	140	60	325	15	105	45	130	0	90	40
Acer rubrum (sa)	95	65	85	280	300	15	105	145	5	190	85	30	120	110
Clintonia borealis	0	25	40	60	10	45	140	25	90	15	0	0	0	0
Carex spp.	25	5	0	15	15	40	50	60	0	45	60	10	20	0
Picea glauca (sa)	0	10	40	30	40	30	55	0	10	0	30	0	10	0
Betula papyrifera (sa)	0	10	0	0	0	0	0	0	0	5	0	0	0	0
Viola renifolia	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Gramineae spp.	55	10	45	45	45	5	20	45	45	40	45	20	35	60
Fragaria virginiana	0	10	0	0	0	15	0	0	0	0	0	0	0	0
Populus grandidentata (se)	0	0	0	20	0	0	5	0	0	0	0	0	0	0
Pyrola elliptica	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Cornus rugosa	0	0	0	40	0	0	0	0	0	0	0	25	10	0
Pyrola rotundifolia	0	5	5	5	5	5	0	0	0	0	10	5	0	0
Lycopodium clavatum	0	20	0	0	0	0	0	0	0	0	0	5	0	0
Cornus canadensis	75	65	115	55	0	50	5	15	95	0	0	10	0	41
Fragaria vesca	20	0	0	0	0	5	0	0	0	0	0	0	0	0
Picea glauca (se)	0	0	0	5	10	0	15	0	25	0	0	0	5	0
Aster macrophyllus	365	190	175	135	50	135	60	45	10	140	30	70	95	30
Populus tremuloides (se)	15	10	0	0	0	10	0	0	0	10	0	0	0	0
Quercus rubra (se)	10	0	75	0	40	0	0	0	0	5	0	0	5	0
Acer spicatum (sa)	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Alnus rugosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium myrtilloides	15	0	45	40	35	10	0	30	0	20	80	0	15	0
Viburnum acerifolium	0	0	0	0	5	0	0	0	0	0	0	55	0	0
Populus grandidentata (sa)	0	45	5	0	0	5	10	0	0	0	0	0	0	0
Betula papyrifera (se)	0	10	0	0	0	0	0	0	0	0	0	0	0	0
Hepatica americana	0	0	0	20	0	10	0	0	0	0	0	0	0	0
Gaultheria procumbens	15	20	100	25	80	85	85	70	20	65	55	95	20	55
Quercus rubra (sa)	0	0	270	0	85	5	0	0	0	10	0	25	5	0
Pteridium aquilinum	730	415	295	100	215	260	390	125	280	165	175	190	215	300
Polygala pauciflora	0	0	5	0	0	0	0	0	10	0	10	0	0	0
Linnaea borealis	10	35	45	10	35	45	0	0	0	50	20	5	5	45
Populus tremuloides (sa)	0	20	0	0	0	0	10	0	5	10	0	0	0	0
Pinus strobus (sa)	0	0	0	5	90	5	25	10	15	25	0	65	0	20
Vaccinium angustifolium	15	30	105	50	45	20	70	30	85	95	15	105	20	90
Viburnum cassinoides	0	0	0	0	0	0	0	0	0	0	0	15	0	0
Apocynum androsaemifolium	0	0	20	0	0	0	0	5	0	0	0	0	0	0
Pinus strobus (se)	5	0	5	15	45	0	10	0	0	10	5	0	10	5
Lonicera villosa	15	30	20	10	0	10	0	5	0	35	0	0	40	0

SPECIES	STANDS													
	050	017	059	060	051	057	014	056	041	099	055	038	044	011
Prunus pumila	0	0	0	0	0	90	0	0	0	10	0	0	0	0
Amelanchier sanguinea	0	30	10	35	15	10	0	80	20	90	25	0	10	10
Waldsteinia fragariodes	0	0	0	0	0	0	0	0	0	0	0	40	15	90
Melampyrum lineare	5	5	25	0	15	0	0	0	0	0	0	0	0	0
Chimaphila umbellata	0	0	0	0	0	5	0	10	0	0	0	10	5	65
Epigaea repens	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Lycopodium complenatum	0	0	0	0	0	0	5	15	0	0	0	0	0	0
Kalmia angustifolia	0	0	0	0	0	0	5	0	30	0	0	0	0	20
Solidago squarrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Comptonia peregrina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus banksiana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus resinosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cypripedium candidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	STANDS													
	043	035	101	063	022	047	040	042	009	052	012	039	015	013
Milium effusum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris noveboracensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola cucullata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola septentrionalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Impatiens capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyelytrum erectum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola selkerkii	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex arctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium erectum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes glandulosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monotropa uniflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola incognita	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula lutea (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis montana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinna latifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viburnum alnifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula lutea (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnocarpium dryopteris	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equisetum scirpoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sambucus canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum cilinode	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goodyera repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina (se)	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium lucidulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trillium undulatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tiarella cordifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cicaea alpina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryopteris spinulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus strigosus	0	5	0	0	0	0	0	0	10	0	0	15	0	0
Tsuga canadensis (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes lacustre	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Onoclea sensibilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium annotinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris phegopteris	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Actaea pachypoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer saccharum (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tsuga canadensis (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Athyrium Felix-femina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (se)	0	0	0	0	25	0	0	5	0	0	0	0	0	0
Viola spp.	0	0	0	0	5	0	5	0	0	0	0	0	0	10
Streptopus amplexifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galium triflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tilia americana (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus spp.	0	0	55	0	0	0	0	0	0	0	0	0	0	0
Acer pennsylvanicum (sa)	0	0	0	0	25	0	0	65	0	0	0	0	0	0
Lycopodium obscurum	10	0	0	10	0	15	25	0	0	0	5	0	0	5
Ostrya virginiana (sa)	0	0	0	0	115	0	0	0	0	0	0	0	0	0
Smilacina recemosa	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Ostrya virginiana (se)	0	0	0	0	40	0	0	0	0	0	0	0	0	0
Acer spicatum (se)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fagus grandifolia (sa)	0	20	0	0	0	0	0	0	0	0	0	0	0	0
Medeola virginiana	0	0	0	0	0	0	5	0	0	10	0	0	0	0
Fagus grandifolia (se)	0	0	0	0	0	0	10	0	0	0	0	0	0	0

SPECIES	STANDS													
	043	035	101	063	022	047	040	042	008	052	012	038	015	013
Carex deweyana	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus pubescens	0	0	40	0	0	5	0	0	0	0	0	0	0	0
Botrychium virginianum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trientalis borealis	30	20	35	80	5	0	52	60	5	20	10	0	70	0
Polygonatum biflorum	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Viola pubescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coptis groenlandica	0	0	0	65	0	0	0	0	0	0	0	0	0	0
Habenaria orbiculata	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Lonicera canadensis	0	5	15	80	0	0	5	0	10	0	0	5	0	0
Aralia nudicaulis	305	125	20	365	190	325	55	165	160	15	310	80	10	465
Mitchella repens	0	0	0	0	5	0	0	0	10	0	20	0	0	115
Corylus cornuta	385	475	390	330	100	305	220	370	220	320	570	0	0	465
Maianthemum canadense	185	155	230	325	145	190	90	205	330	590	155	55	305	165
Sanicula marilandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer rubrum (se)	10	0	115	5	140	145	185	115	120	15	100	5	5	10
Abies balsamea (sa)	5	40	0	260	0	10	0	0	0	210	125	0	0	80
Aster umbellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abies balsamea (se)	5	80	5	15	0	0	0	0	0	5	65	0	0	0
Acer rubrum (sa)	20	120	80	40	35	515	50	95	175	105	210	10	10	0
Clintonia borealis	0	25	0	70	5	0	0	0	0	5	0	0	0	10
Carex spp.	0	25	90	105	25	45	10	35	40	130	0	155	420	35
Picea glauca (sa)	30	30	5	30	0	20	10	0	0	0	25	0	0	0
Betula papyrifera (sa)	0	0	0	0	0	0	0	0	35	0	0	0	0	0
Viola renifolia	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Gramineae spp.	15	25	55	15	85	125	20	45	95	90	115	305	155	65
Fragaria virginiana	0	0	0	0	5	0	0	0	0	0	0	15	0	0
Populus grandidentata (se)	0	0	0	0	0	0	0	0	5	0	5	0	0	0
Pyrola elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornus rugosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola rotundifolia	0	20	0	0	5	0	20	0	20	0	0	0	10	0
Lycopodium clavatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornus canadensis	25	695	0	440	5	0	10	0	5	0	5	0	0	50
Fragaria vesca	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Picea glauca (se)	10	5	40	0	0	0	0	0	0	0	0	0	0	0
Aster macrophyllus	30	20	85	95	170	125	70	45	50	65	190	95	0	60
Populus tremuloides (se)	0	5	0	0	0	0	5	0	0	0	0	0	0	0
Quercus rubra (se)	0	0	10	0	25	0	15	55	5	0	80	180	0	0
Acer spicatum (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alnus rugosa (sa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium myrtilloides	0	0	0	15	0	0	0	0	0	25	0	0	0	0
Viburnum acerifolium	0	0	0	0	90	0	35	0	0	0	0	0	0	0
Populus grandidentata (sa)	0	0	0	0	45	0	0	0	0	0	0	0	0	10
Betula papyrifera (se)	0	0	10	0	0	0	10	0	0	0	0	0	0	0
Hepatica americana	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Gaultheria procumbens	15	85	55	25	115	70	75	65	65	35	70	40	105	90
Quercus rubra (sa)	0	40	0	0	30	0	0	5	10	0	40	105	0	10
Pteridium aquilinum	185	305	690	490	185	600	370	480	230	555	290	15	800	280
Polygala pauciflora	0	0	5	5	0	0	0	25	0	10	0	0	0	0
Linnaea borealis	15	5	75	110	5	35	0	5	55	30	20	0	0	115
Populus tremuloides (sa)	0	15	0	5	25	0	0	0	10	60	0	0	75	0
Pinus strobus (sa)	0	100	450	0	165	20	220	20	35	15	85	25	0	225
Vaccinium angustifolium	85	125	130	65	115	55	125	95	140	35	30	140	265	95
Viburnum cassinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocynum androsaemifolium	0	0	0	5	0	0	0	0	0	5	0	0	0	15
Pinus strobus (se)	5	75	95	0	5	0	40	15	10	25	20	0	0	125
Lonicera villosa	0	5	10	20	0	5	25	0	0	0	5	0	0	10

SPECIES	STANDS													
	043	035	101	063	022	047	040	042	008	052	012	039	015	013
Prunus pumila	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amelanchier sanguinea	30	60	10	0	65	105	45	125	100	70	45	130	15	10
Waldsteinia fragariodes	0	60	0	0	105	35	75	5	95	90	35	50	0	60
Melampyrum lineare	0	0	0	0	10	15	0	0	5	5	5	15	0	10
Chimaphila umbellata	5	0	0	5	0	0	0	0	0	0	15	0	0	25
Epigaea repens	0	10	10	10	0	0	5	0	0	0	0	0	0	10
Lycopodium complenatum	0	15	0	0	0	35	0	0	0	10	0	0	0	0
Kalmia angustifolia	5	0	0	0	35	0	25	10	40	0	35	0	15	0
Solidago squarrosa	0	0	0	10	0	0	0	10	0	0	0	0	0	0
Comptonia peregrina	0	0	0	0	10	0	0	0	5	0	0	45	135	50
Pinus banksiana (sa)	0	0	0	0	0	0	0	0	0	0	0	75	0	0
Pinus resinosa (sa)	0	0	0	0	0	0	0	5	0	0	0	0	20	0
Cypripedium candidum	0	0	0	0	0	0	0	0	0	0	0	0	0	5

SPECIES	STANDS	
	010	048
Milium effusum	0	0
Thelypteris noveboracensis	0	0
Viola cucullata	0	0
Viola septentrionalis	0	0
Impatiens capensis	0	0
Brachyelytrum erectum	0	0
Viola selkerkii	0	0
Carex arctata	0	0
Trillium erectum	0	0
Trillium grandiflorum	0	0
Ribes glandulosum	0	0
Monotropa uniflora	0	0
Viola incognita	0	0
Prunus serotina (sa)	120	0
Betula lutea (se)	0	0
Oxalis montana	0	0
Cinna latifolia	0	0
Viburnum alnifolium	0	0
Betula lutea (sa)	0	0
Gymnocarpium dryopteris	0	0
Equisetum scirpoides	0	0
Sambucus canadensis	0	0
Polygonum cilinode	0	0
Goodyera repens	0	0
Prunus serotina (se)	15	0
Lycopodium lucidulum	0	0
Trillium undulatum	0	0
Tiarella cordifolia	0	0
Cicaea alpina	0	0
Dryopteris spinulosa	0	0
Rubus strigosus	0	0
Tsuga canadensis (se)	0	0
Ribes lacustre	0	0
Onoclea sensibilis	0	0
Acer saccharum (sa)	0	0
Lycopodium annotinum	0	0
Thelypteris phegopteris	0	0
Actaea pachypoda	0	0
Acer saccharum (se)	0	0
Tsuga canadensis (sa)	0	0
Athyrium Felix-femina	0	0
Acer pennsylvanicum (se)	0	0
Viola spp.	0	0
Streptopus amplexifolius	0	0
Galium triflorum	0	0
Tilia americana (sa)	0	0
Rubus spp.	0	0
Acer pennsylvanicum (sa)	0	0
Lycopodium obscurum	0	0
Ostrya virginiana (sa)	0	0
Smilacina recemosa	0	0
Ostrya virginiana (se)	0	0
Acer spicatum (se)	0	0
Fagus grandifolia (sa)	0	0
Medeola virginiana	0	0
Fagus grandifolia (se)	0	0

SPECIES	STANDS	
	010	048
Carex deweyana	0	0
Rubus pubescens	0	0
Botrychium virginianum	0	0
Trientalis borealis	0	20
Polygonatum biflorum	0	0
Viola pubescens	0	0
Coptis groenlandica	0	0
Habenaria orbiculata	0	0
Lonicera canadensis	15	0
Aralia nudicaulis	0	0
Mitchella repens	0	0
Corylus cornuta	0	0
Maianthemum canadense	35	140
Sanicula marilandica	0	0
Acer rubrum (se)	0	5
Abies balsamea (sa)	0	30
Aster umbellatus	0	0
Abies balsamea (se)	10	0
Acer rubrum (sa)	0	0
Clintonia borealis	0	0
Carex spp.	0	80
Picea glauca (sa)	0	0
Betula papyrifera (sa)	0	0
Viola renifolia	0	0
Gramineae spp.	50	55
Fragaria virginiana	0	0
Populus grandidentata (se)	0	0
Pyrola elliptica	0	0
Cornus rugosa	0	0
Pyrola rotundifolia	0	0
Lycopodium clavatum	0	0
Cornus canadensis	0	0
Fragaria vesca	0	0
Picea glauca (se)	0	0
Aster macrophyllus	0	5
Populus tremuloides (se)	0	0
Quercus rubra (se)	0	0
Acer spicatum (sa)	0	0
Alnus rugosa (sa)	0	0
Vaccinium myrtilloides	0	10
Viburnum acerifolium	0	0
Populus grandidentata (sa)	0	0
Betula papyrifera (se)	0	5
Hepatica americana	0	0
Gaultheria procumbens	195	60
Quercus rubra (sa)	0	0
Pteridium aquilinum	880	310
Polygala pauciflora	0	0
Linnaea borealis	0	45
Populus tremuloides (sa)	0	15
Pinus strobus (sa)	155	10
Vaccinium angustifolium	740	80
Viburnum cassinoides	0	0
Apocynum androsaemifolium	25	0
Pinus strobus (se)	80	15
Lonicera villosa	0	5

SPECIES	STANDS	
	010	048
Prunus pumila	0	0
Amelanchier sanguinea	60	30
Waldsteinia fragariodes	0	0
Melampyrum lineare	0	55
Chimaphila umbellata	0	40
Epigaea repens	0	0
Lycopodium complenatum	25	35
Kalmia angustifolia	135	0
Solidago squarrosa	0	0
Comptonia peregrina	85	0
Pinus banksiana (sa)	0	0
Pinus resinosa (sa)	20	0
Cypripedium candidum	10	0

APPENDIX XIII - UNDERSTORY STAND ORDINATION SCORES FOR AXES 1 AND 2

Axis 1			Axis 2		
Stand No.	Stand Type	Score	Stand No.	Stand Type	Score
083	Acer saccharum	292	098	Betula lutea	211
079	Acer saccharum	283	061	Betula lutea	171
088	Acer saccharum	266	100	Pinus strobus	167
080	Acer saccharum	263	057	Pinus strobus	156
003	Acer saccharum	259	068	Betula papyrifera	146
089	Acer saccharum	256	063	Pinus strobus	141
090	Acer saccharum	251	078	Populus spp.	141
084	Acer saccharum	241	101	Pinus strobus	137
098	Betula lutea	235	060	Pinus strobus	136
008	Acer saccharum	233	047	Populus spp.	135
006	Acer saccharum	232	021	Pinus strobus	132
070	Acer saccharum	230	076	Acer saccharum	129
087	Betula lutea	229	018	Populus spp.	127
096	Acer saccharum	227	048	Pinus resinosa	125
082	Acer saccharum	226	064	Populus spp.	125
072	Acer saccharum	223	055	Pinus strobus	124
085	Acer saccharum	221	043	Populus spp.	119
074	Acer saccharum	220	036	Acer saccharum	117
077	Acer saccharum	220	056	Populus spp.	117
005	Acer saccharum	219	041	Populus spp.	115
091	Betula lutea	218	017	Pinus resinosa	114
004	Acer saccharum	218	072	Acer saccharum	114
076	Acer saccharum	218	035	Pinus strobus	111
094	Tsuga canadensis	212	037	Acer saccharum	111
081	Acer saccharum	209	052	Pinus resinosa	111
007	Acer saccharum	206	044	Pinus strobus	110
092	Acer saccharum	206	051	Pinus strobus	109
002	Acer saccharum	204	020	Populus spp.	106
001	Acer saccharum	203	013	Pinus resinosa	103
086	Acer saccharum	202	028	Acer saccharum	103
069	Tsuga canadensis	201	050	Populus spp.	103
071	Acer saccharum	198	014	Populus spp.	102
062	Acer saccharum	187	059	Pinus strobus	101
073	Betula lutea	187	066	Acer saccharum	101
028	Acer saccharum	181	093	Populus spp.	100
061	Betula lutea	181	090	Acer saccharum	099
036	Acer saccharum	178	038	Populus spp.	096
067	Acer saccharum	176	024	Pinus strobus	095
075	Tsuga canadensis	171	040	Populus spp.	095
097	Acer saccharum	158	091	Betula lutea	094
045	Acer saccharum	154	099	Pinus strobus	094
053	Acer saccharum	153	054	Betula papyrifera	092

025	*Acer saccharum*	151
066	*Acer saccharum*	150
065	*Tsuga canadensis*	149
037	*Acer saccharum*	147
026	*Populus* spp.	140
068	*Betula papyrifera*	136
032	*Acer saccharum*	135
100	*Pinus strobus*	131
058	*Acer saccharum*	129
054	*Betula papyrifera*	125
064	*Populus* spp.	124
029	*Acer saccharum*	123
093	*Populus* spp.	114
095	*Pinus strobus*	110
021	*Pinus strobus*	100
031	*Populus* spp.	098
019	*Betula papyrifera*	097
078	*Populus* spp.	090
027	*Populus* spp.	089
016	*Populus* spp.	084
023	*Pinus strobus*	084
034	*Pinus strobus*	083
033	*Populus* spp.	081
018	*Populus* spp.	074
024	*Pinus strobus*	074
046	*Quercus rubra*	069
049	*Populus* spp.	068
020	*Populus* spp.	066
050	*Populus* spp.	065
017	*Pinus resinosa*	064
059	*Pinus strobus*	062
060	*Pinus strobus*	061
051	*Pinus strobus*	058
057	*Pinus strobus*	056
014	*Populus* spp.	054
056	*Populus* spp.	054
041	*Populus* spp.	052
089	*Pinus strobus*	051
055	*Pinus strobus*	050
038	*Populus* spp.	048
044	*Pinus strobus*	048
011	*Pinus strobus*	042
043	*Populus* spp.	042
035	*Pinus strobus*	040
101	*Pinus strobus*	040
063	*Pinus strobus*	038
022	*Quercus rubra*	037
047	*Populus* spp.	034
040	*Populus* spp.	032
042	*Pinus strobus*	028
009	*Pinus resinosa*	026

075	*Tsuga canadensis*	091
012	*Pinus strobus*	089
016	*Populus* spp.	089
058	*Acer saccharum*	088
029	*Acer saccharum*	087
033	*Populus* spp.	086
080	*Acer saccharum*	085
019	*Betula papyrifera*	084
049	*Populus* spp.	084
081	*Acer saccharum*	084
011	*Pinus strobus*	083
027	*Populus* spp.	082
067	*Acer saccharum*	082
045	*Acer saccharum*	080
065	*Tsuga canadensis*	077
034	*Pinus strobus*	076
071	*Acer saccharum*	076
031	*Populus* spp.	075
069	*Tsuga canadensis*	074
074	*Acer saccharum*	074
026	*Populus* spp.	072
092	*Acer saccharum*	071
046	*Quercus rubra*	069
022	*Quercus rubra*	068
079	*Acer saccharum*	068
023	*Pinus strobus*	066
077	*Acer saccharum*	066
015	*Pinus banksiana*	065
025	*Acer saccharum*	065
032	*Acer saccharum*	064
083	*Acer saccharum*	064
094	*Tsuga canadensis*	062
009	*Pinus resinosa*	062
039	*Quercus rubra*	061
053	*Acer saccharum*	061
085	*Acer saccharum*	061
097	*Acer saccharum*	059
096	*Acer saccharum*	058
070	*Acer saccharum*	057
042	*Pinus strobus*	056
001	*Acer saccharum*	053
062	*Acer saccharum*	053
095	*Pinus strobus*	051
010	*Pinus banksiana*	049
087	*Betula lutea*	047
089	*Acer saccharum*	046
073	*Betula lutea*	045
002	*Acer saccharum*	043
082	*Acer saccharum*	041
088	*Acer saccharum*	041
086	*Acer saccharum*	039

052	*Pinus resinosa*	024
012	*Pinus strobus*	020
039	*Quercus rubra*	012
015	*Pinus banksiana*	005
013	*Pinus resinosa*	004
010	*Pinus banksiana*	000
048	*Pinus resinosa*	000

007	*Acer saccharum*	035
005	*Acer saccharum*	034
084	*Acer saccharum*	034
004	*Acer saccharum*	031
006	*Acer saccharum*	013
008	*Acer saccharum*	003
003	*Acer saccharum*	000