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The Britt Woods:

Survey of a Remnant Tract of Old-growth Forest

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Virginia Louise Baker

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THE BRITT WOODS:
SURVEY OF A REMNANT TRACT OF OLD-GROWTH FOREST

By

Virginia Louise Baker

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ABSTRACT

The Britt Woods:
Survey of a remnant tract of old-growth forest

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Old-growth forests differ in dynamics, structure, and composition from second-growth successional forests (Davis 1993). This study provides a quantitative and qualitative survey of a 15 acre tract of old-growth hemlock-hardwood located in southern Iosco County, Michigan. The old-growth stand is bordered by a second-growth community on the western side. A composite chronology of the hemlocks was constructed by cross-dating tree cores. The age of the oldest hemlock core indicates the stand is old-growth. Current population demographics suggest the stand is succeeding from a mixed hardwood-hemlock complex currently composed of *Acer saccharum, Acer rubrum, Fagus grandifolia, Tilia americana, Fraxinus americana,* and *Tsuga canadensis,* to a beech-maple association. The understory stratum species of the old-growth portion of the woods differ in abundance, composition, evenness, and diversity from the second-growth community on the west side.

M. B. 1993. Old-growth in the east, a survey. A Wild Earth Publication, Richmond, Vermont.

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Chapter 1

Introduction

Old-growth forests are unique and rare communities in the Great Lakes region. Only fragmented patches of old-growth have survived east of the Mississippi since the 19th century logging era. In State and National forests there are approximately 60,000-200,000 acres of the original forest remaining. This small fraction is < 1% of the original forest system (Davis 1993). Preservation of these remnants is important for research by the scientific community as well as being a part of the heritage of the region.

Little is known about forest development past 80-100 years (Frelich and Lorimer 1991*a*). There is still much knowledge to be gained on natural disturbance regimes, nutrient cycles, forest structure, gap phase replacements, soil and forest floor dynamics, species diversity, and composition within these ancient communities (Davis 1993, Nowacki and Abrams 1994).

The term "old-growth" does not have an exact definition. Professional foresters define forest stands according to the commercial viability of the timber. One-hundred to 150 year old trees are considered "old-growth" to the some foresters. To the ecologist, age alone is just one characteristic generally associated with old-growth. Traditionally, ecologists referred to old-growth forests as "virgin" or "climax" systems. Virgin implies there has been no anthropogenic disturbance. Even before the arrival of Europeans, forests in the United States were used by aboriginal populations for centuries (Berthrong 1974). Acid rain and other pollutants have influenced many of these natural systems in the lower 48 states (Davis 1993). Human activities have influenced the spread of diseases like the chestnut blight (*Endothisa parasitica*) and the Dutch elm disease (*Ceratostemella ulmi*)(Watkinson 1986). Human induced climatic changes have reached even the most pristine areas (Davis 1993).

Dr. Frederick Clements, an early plant community ecologist, described climax communities as "complex organisms" that were inseparable from their surrounding climate (Clements, 1916, 1928). "The inherent unity of climax rests upon the fact that it is not merely the response to a particular climate, but at the same time the expression and indicator of it." (Clements 1936). In 1916, Clements wrote "the unit or climax formation is an organismic entity.... as an organism the formation arises, grows, matures and dies.....Furthermore, each climax formation is able to reproduce itself, repeating with essential fidelity the stages of it's development." Clements views were misinterpreted as meaning climax communities are static and spatially invariable communities in which individual plants are always replaced by recruits of their own species (Crawley 1986). In actuality, Clements thought climax communities were in a state of dynamic equilibrium in which random changes in composition and age structure occurred (Barbour et al. 1987). Contemporary ecologists, likewise characterize these mature communities as dynamic and not static (Barden 1979, Shugart and West 1981, Bormann and Likens 1981, Runkle 1981, Frelich and Lorimer 1991*a,b*, Frelich and Graumlich 1994).

During the summer of 1994, a remnant stand of relatively undisturbed old-growth hemlock-hardwood was located in Iosco County, 25.3 km northeast of Standish, Michigan. The woods, hereafter referred to as the Britt Woods, was originally purchased by the Britt family in 1905, and passed down through three generations to Warren and Howard Britt (H. and W. Britt, pers.comm. 1995). Britt Woods is a prime example of old-growth mesic forest and is the only old-growth remnant known to exist in this area of Michigan. The woods has had relatively little disturbance which makes it an unparalleled area for research. The purpose of this thesis is to provide a quantitative and qualitative description of the vascular flora in the Britt Woods and to determine whether, in fact, the Britt Woods is "old-growth". To resolve this question, sampling was conducted during 1995 and 1996 to examine the composition, spatial distribution, and age of the canopy dominants. Observations were also made on soil characteristics, microtopography, evidence of past disturbance, storm damage, and accumulated coarse woody debris. The first part of this introductory chapter provides a brief description of the Great Lakes forest associations in which successional communities are contrasted with mature forests. Disturbance regimes, dynamic processes, structure, environmental factors, physiography, soil pedogenesis, and other general characteristics associated with old-growth systems are discussed. The second part gives a site description and presents historical information on Britt Woods and surrounding area.

Hemlock-White Pine-Northern Hardwood Region

The deciduous forest formations of eastern North America are composed of several differing associations of dominant and codominant trees (Braun 1950). The focus of this study will be within the Great Lakes Division of the Hemlock-White Pine-Northern Hardwood region as defined by Braun. This region extends from northern Minnesota and southeast Manitoba eastward across Wisconsin, Michigan, southern Ontario, New York, northern Pennsylvania, and southern New England. The Beech-Maple region lies just south the Hemlock-White Pine-Hardwood region. The boundaries of the two regions merge forming a tension zone (Braun 1950). The tension zone contains elements of both regions where many species reach either their northern or southern distributional limits. The Hemlock-White Pine-Northern

Hardwoods region is divided into two sub-regions: the Great Lakes Region--the focus of this study and the Northern Appalachian Highland region (Braun 1950). The Great Lakes region, as defined by Braun (1950), includes northern lower Michigan, eastern upper Michigan, and southern Ontario.

Glaciation and the Effects on Vegetation

Glaciation sculpted a low relief topography, deposited parent material, and altered the shorelines of the Great Lakes. Four major ice advances occurred during the Pleistocene Epoch; the Nebraskan, Kansan, Illinoisan, and Wisconsin (Leverett 1917, Hough 1958, Dorr and Eschman 1971). The effects of the latest, the Wisconsin, are the best preserved. The movements of the strongly lobate ice sheets of the Wisconsin period were influenced by the Great Lakes basins (Hough 1958). In the northeastern part of the Lower Penninsula, the Laurentide icesheet receded and readvanced several times forming the superficial topograghy observed today during the Port Bruce and Port Huron substages (Burgis 1977). These glaciers deposited unsorted and unstratified till which formed ridge-like terminal and lateral moraines or covered large areas with ground moraines. Glacial meltwaters left sorted and stratified outwash material in the form of outwash plains, valley trains, pitted outwash plains, kames, kame terraces, eskers, and ice-channel fillings over much of the region (Dorr and Eschman 1971). Repeated glacial advancement and retreat altered the Great Lakes shorelines through changing lake levels and uplift. Crustal rebound or uplift occurred as the Wisconsin glacier melted. Uplift was greater in the northern parts of the region since the ice sheet was thicker. In the northern part of the Lower Penninsula, the Nippissing and Algonquin "hinge lines" (regions of zero uplift) were created during readvancement stages of the Wisconsin period. Elevational changes, due to uplift, are most evident around the northern shorelines (Hough 1958, Dorr and Eschman 1971). Changing lake levels formed lacustrian deposits composed mostly of quartz sand, gravels derived from metamorphic and igneous rocks, and intercalated lacustrine clay. Wind action covered lacustrine beaches locally with discontinuous sets of sandy dunes (Burgis and Eschman 1981).

The varied glacially derived topography affects drainage regimes, soil horizon development, microclimates, fire frequency, and vegetation establishment (Braun 1950, Barnes and Wagner 1981, Host et. al. 1987). Well drained swells, moderately drained flat areas, poorly drained depressions, and organic peat bogs are located throughout the Great Lakes region. Moderately leached podzolic soils cover the lower Hemlock-White Pine-Northern Hardwoods region while more "strongly" leached podzols cover the northern area (Braun 1950). The results of some studies in the region suggest that forest patterns of colonization are associated with till and outwash deposits (Brubaker 1975, Burgis 1977, and Burgis and Eschman 1981, Kotar and Coffman 1984).

Glacial till soils retain sufficient moisture and nutrients to promote the establishment of hardwood communities (Barnes and Wagner 1981). Studies in the Upper Peninsula and Northern Wisconsin showed hemlock (*Tsuga canadensis* (L.) Carriere) and sugar maples (*Acer sacharum* Marshall) communities occurred on till (morainal swells and ridges) while pine (*Pinus*) and oak (*Quercus*) occurred on outwash. A similar study in the northeastern lower penninsula did not show as clear a relationship between forest patterns and glacially derived land forms (Padley 1989). Other studies suggest that forest patterns are a result of landform mediated fire frequency (Whitney 1986, 1987) or microclimate conditions (Host et. al. 1987).

Forest Community Associations in the Great Lakes Region

Little is known about the exact species ratios and distribution patterns that occurred during the last glacial retreat. Pollen samples, taken from the Vestaburg bog of Moncalm County, located in the central part of the Michigan's Lower Penninsula, showed patterns of taxa establishment and dominance. The first post glacial association was most likely an open parklike habitat consisting of spruce (*Picea glauca* (Moench) Voss and *P. mariana* (Miller) Britton). As the climate warmed, the spruce and less dominant fir (*Abies balsamea* (L.) Miller) decreased and pines (*Pinus strobus* (L.) and *Pinus resinosa* Aiton) increased. Oaks and other hardwoods (*Ulmus americana* (L.), *U. rubra* Mulh., *Acer, Carpinus caroliniana* Walter, *Ostrya virginiana* (Miller) K. Koch) followed the pines. Soon after hardwood establishment, pines decreased in dominance but remained steady in the canopy while the spruces disappeared. The the last trees to migrate into the area were the beech (*Fagus grandifolia* Ehrh.) and hemlock (Gilliam et al. 1967). Deforestation of this area resulted in the decrease of many these species (Hushen et. al. 1966).

Most of the Great Lakes region is now covered with secondary forests (Braun 1950). Old-growth forest stands are significantly older than the average catastrophic disturbance interval for the region in which they are located (Davis 1993). After catastrophic wind storms and fire, old-growth forests naturally revert to earlier successional stages (Dunn 1982, Kelty 1986). Windstorms leave low-lying understory trees, saplings, and shrubs intact. A severe canopy fire can burn tree crowns, as well as remove the humus layer, leaving exposed mineral soil. Less damaging surface fires are more common than raging canopy fires. Surface fires burn along the soil surface, removing accumulated litter and part of the humus layer (Aber and Mellilo 1991). Varying conclusions exist on the frequency of catastrophic disturbances (Frelich and Lorimer 1991*b*). Some ecologist have hypothesized that natural disturbances were so frequent that late successional stages rarely developed (Graham 1941, Maissurow 1941, Raup 1957, Henry and Swan 1974, Heinselman 1981). There are different techniques used for reconstructing forest disturbance; fire scar analysis, field disturbance chronologies, historical land survey records, contemporary records, and computer simulations based on recorded data. In the Porcupine Mountains of Michigan's Upper Peninsula, tree cores and wedges were used to reconstruct the forest disturbance chronology in 70 0.5 ha plots. The disturbance chronology results were used to simulate disturbance rotation periods (or turnover time). The rotation period due to wind disturbace increased exponentially as percent canopy removal increased. The rotation periods ranged from 69 years for $\geq$10% canopy removal to 1920 years for $\geq$60% canopy removal. The rotation period was 566 years for surface fires and 2797 years for canopy fires. Natural disturbance regimes create a mosaic of different successional stage patches on the landscape (Frelich and Lorimer 1991*b*).

Native Americans in the Great Lakes region were known to use fire to make hunting grounds more attractive to wild game. Ground fires leave behind an open and park like forest. Exactly how much this activity or practice altered the forest ecosystem in comparison to natural disturbance regimes in unknown (Berthrong 1974).

The aspen association is the most important secondary forest type in the Great Lakes region (Gates 1930). In mesic conditions, this secondary community colonizes burned over areas. The aspen association is composed of big-toothed aspen (*Populus grandidentata* Michaux), trembling aspen (*P.*

tremuloides Michaux), pin cherry (*Prunus pensylvanica* L.), and paper birch (*Betula papyrifera* Marshall) with bracken fern (*Pteridum aquilinum* (L.) Kuhn) and sweetfern (*Comptonia peregrina* (L.) Coulter) commonly growing in the understory. Post-fire communities dominated by jack-pine (*Pinus banksiana* Lambert) with interspersed scrub oaks develop on drier, sandier soils. Studies show that post-blowdown communities show that they are successionally more advanced than post-fire communities. Windstorms leave saplings, stumps, and short snags behind. Hardwoods have the capacity to sprout from stumps and they respond quickly to release (Braun 1950, Hix and Barnes 1984). The before and after windstorm study of a 61 ha Wisconsin old-growth hemlock-hardwood stand revealed a 94% reduction of the original canopy. Although, sugar maple continued to dominate in the sapling layer, a dense shrub layer of elder berry (*Sambucus pubens* Michaux) developed (Dunn 1982). Hardwoods are more proficient at repopulating disturbance areas than hemlocks or red and white pines (Hix and Barnes 1984).

Throughout much of the northern Great Lakes forests, after 1840 logging and human induced slash-burn fires drastically modified dominant vegetation associations. As with catastrophic disturbances, old-growth systems subject to intense anthropogenic disturbance may revert to an early successional stage. Hardwood stumps, left behind from logging, produce coppice stands (Braun 1950). In old fields, where stumps have been removed to create agricultural fields, the establishment of red and white pine may occur (Braun 1950). An old-growth Michigan Upper Peninsula hemlock-hardwood stand that was clearcut and surveyed after 46 years was found to be composed of sugar maple, red maple (*Acer rubrum* Linnaeus), yellow birch (*Betula alleghaniensis* Britt), and balsam fir while hemlock was essentially eliminated from the canopy (Hix and Barnes 1984). There are some distinct differences between the early successional stages of post blowdown and post logging communities even though species composition may be initially similar. Blowdowns disturb the soil and leave logs behind which act as safe sites for hemlock seedling establishment (Barnes and Wagner 1981, Dunn 1982). Post-logging coummunities can have fewer sites when only stumps are left behind, however this only sometimes occurs. Decomposition rates are higher in communities where fallen logs and snags remain (Gorham et. al. 1979).

Succession to Old-Growth

Biomass, species composition and diversity, nutrient cycles, soil pedogenesis, physiography, forest structure, and internal dynamic processes change as a community succeeds into an old-growth hemlock-hardwood association (Braun 1950, Gorham et. al. 1979, Bormann and Likens 1981, Runkle 1981, Hix and Barnes 1984, Kelty 1986, Hunter 1989, Schaetzl 1990, Schaetzl and Follmer 1990, Frelich and Lorimer 1991*ab*, Davis 1993, Mlaidenoff et. al. 1993, Graumlich and Frelich 1994, Tyrell and Crow 1994). Two different models have been proposed that describe the developmental phases of a forest system. According Odum, 1969, biomass increases steadily at first and then levels off during later stages of succession. According to Bormann and Likens, 1981, there are 4 distinct phases of succession involving biomass accumulation. There is an immediate decrease in biomass during the first and shortest "reorganization" phase due to clearcutting. The trees start to re-establish and grow which increases biomass during the second "aggradation phase". As the forest ages, older trees die due to mortality and natural disturbances which slowly decreases biomass during the third "transition" phase. In the last "shifting steady-state mosaic" phase (i.e. growth and death of forest patches are nonsynchronous), biomass levels oscillate slightly according to interior forest dynamics such as gap formation and replacement. During the last stage, the forest has reached an age in which the annual net growth rate is close to zero and the current annual growth rate is less than the average life time growth rate (Hunter 1989). JABOWA computer simulation models suggest it takes a few hundred years after clearcutting to reach the steady-state shifting mosaic phase (Bormann and Likens 1981).

Immediately after clearcutting, in areas where hardwoods replaced hemlock dominated communities, soil acidity decreases which accelerates the nitrogen cycle and decomposition rates. In addition, thickness, mass, and nutrients (such as K, Mg, and Ca) of the forest floor have been shown to significantly decrease after clearcuts (Hix and Barnes 1984). In later successional stands, hemlock acidifies the soil which decreases decomposition rates until the stand reaches a mature age. During advanced stages of succession, some nutrient cycle models suggest that accumulated woody debris causes decomposition rates to accelerate. (Gorham et. al. 1979).

Continuous random tree falls in older mesic forest disrupts and diversifies soil horizons. Uprooting causes "floralturbation" or "the mixing of soil by action of plants". Masses of uprooted soils can cause the inversion of the original soil profile, especially in steeper areas. In flatter sites, large amounts of the mound soil wash back into the pits, creating less inversion and soil mixing (Schaetzl and Follmer 1990). The pit and mound microtopography causes varied rates of soil profile development. Pedogenesis (horizon formation) occurs at the following comparable rates: "pit>undisturbed>mound". Higher moisture content and fewer periods of freezing expedites leaching within pits. Pits have greater insulation than mounds due to snow and leaf litter build up. In pits, the litter build up creates thicker acidic organic horizons with higher levels of acid leaching. Increased concentrations of Fe and Al within eluvial zones of mound indicates slow soil pedogenesis; while thick eluvial (E) horizons and the presence of a B_{hs} illuvial zone (a horizon that accumulates humus and sesquioxides (-oxides and hydroxides of Fe and Al)) within pits indicates rapid soil pedogenesis. The resulting soil mosaic caused by the pit and mound microtopography, affects plant diversity (Schaetzl 1990).

Species composition and diversity change during succession in forest communities in the Great Lakes region (Braun 1950, Scheiner and Teeri 1981, Mlaidenoff et. al. 1993). There is an increase in diversity immediately after disturbance or agricultural field abandonment. Post-fire studies have shown diversity can peak from 10-25 years after a severe fire (Gates 1926, Scheiner and Teeri 1981). Red maple and white pine replaced a bigtooth aspen population 53 years after fire in a stand located in the Upper Peninsula (Scheiner and Teeri 1981). Red and white pines will also replace jack pines in sandier soils (Braun 1950). Hardwoods and hemlocks eventually replace pine during later successional stages (Braun 1950). Hemlocks are shade-tolerant and grow slower than hardwoods and pines (Barnes and Wagner 1981, Kelty 1986). Kelty (1986) studied the re-establishment patterns of hardwoods in logged and windblown stands that had previously been dominated by hemlock in New England. In both types of stands, the colonizing hemlocks were limited by terminal shoot breakage caused by abrasion with the previously established hardwood canopy trees. Some research suggests deer browsing and recent climatic warming trends have negative affects on hemlock regeneration

(Anderson and Loucks 1979, Alverson et al. 1988, Frelich and Lorimer 1985, Mlaidenoff and Stearns 1993).

Early and late successional stands differ structurally. Early successional stands are even-aged and have a dense shrub and sapling layer. Older age classes dominate with forest maturity and the shrub/sapling layer thins (Hunter 1989). Less competition for light and time allows a rich herbaceous stratum to develop. Moss growing in dense matts intermixed with diverse herbs and fungi is often an indicator of old-growth (Davis 1993). Old-growth forest stands are characterized as having reached an age in which the annual net growth rate is close to zero (Hunter 1989). The oldest dominant trees have reached their life time expectancy and a sizeable percent of the trees are advanced in age in an old-growth stand (Davis 1993). Tyrell and Crow (1994) studied structural characteristics of 25 late successional Great Lakes stands ranging in age from 177 to 374 years. During the later stages of succession there is a generally continuous increase of gap size, coarse woody debris (including stumps, snags, and logs) and snag basal area. Certain characteristics appeared at a "threshold age" of 275-300 years; live tree and snag density decreases (especially evident in hemlocks), the volume of well decayed hemlock logs significantly increases, canopy gaps cover >10% of the stand, and age-diameter correlations are more likely to be significant from 275-300 years.

In northern Wisconsin, spatial heterogenity of a disturbed landscape composed of second-growth forest intermixed with old-growth patches was compared to an intact old-growth landscape. The 2 landscapes had similar topography and soil types. Table 1.1 illustrates patch size and type found in both landscapes. The disturbed landscape, Border Lakes in Northern Wisconsin, had a finer grained patch structure and higher number of patch types than the old-growth landscape, Sylvania Wilderness in Ottawa National Forest, Michigan. The patches within the old-growth landscape were more complex in shape and occurred in more size classes than the disturbed landscape. The diverse patch type, simple shape, and high patch count per ha resulted in poor connectivity of similar patch types within the disturbed landscape. Poor connectivity of patches isolates wildlife habitats. In pristine homogenous old-growth landscapes, patch connectivity builds habitat cooridoors and decreases habitat isolation (Mlaidenoff 1993).

Table 1.1 Patch size (ha) and type for Sylvania Wilderness and Border Lakes. Border Lakes are the more disturbed of the two sites (Maidenoff 1993).

	Patch size (in ha) mean±1SD		Patch number	
Type	Bord	Syl	Bord	Syl
	<u>Old-growth</u>			
Lakes	15.5±47.7	21.6±58.3	105	71
Wetland	3.0±6.5	2.0±16.3	140	43
Bog	2.1±2.3	1.0±31.6	100	107
Lowland conifer	3.9±8.2	2.9±5.9	350	206
Hemlock	11.7±16.0	21.6±101.1	19	113
Northern hardwood	6.0±5.2	10.1±16.3	19	84
Hemlock hardwood	...	13.0±31.6	...	95
	<u>Second-growth</u>			
Northern hardwood	7.8±18.5	...	238	...
Mixed hardwood	8.7±18.2	...	154	...
Hardwood/conifer	7.3±15.0	...	56	...
Hardwood over conifer	5.3±10.0	...	261	...
Mixed conifer	3.0±5.4	...	206	...
Upland openings	3.8±4.2	4.4±10.0	37	14
	<u>Total</u>			
	5.7±16.9	9.8±46.2	1711	14

(Syl)-Sylvania Wilderness, (Bord)-Border Lakes

An established old-growth hemlock-hardwood forest exhibits dynamic processes (Runkle 1981, Frelich and Lorimer 1991*b*, Frelich and Graumlich 1994). Forest trees have the capacity to reproduce and replace themselves and mortality is balanced by reproductive capacity (Hett and Loucks 1971). In Wisconsin, the average canopy turnover rate is 145-175 years with a 5.7-6.9% canopy turnover rate per decade (Frelich and Lorimer 1991*a*). Other studies have resulted in similar conclusions (Frelich and Lorimer 1991*a*, Frelich and Graumlich 1994). Gaps are repopulated by opportunistic woody and herbaceous species. Lateral growth of the adjacent canopy can fill in small gaps or partially fill in larger gaps. As gap sizes increase, the woody species diversity, total basal area, stem count, and stem growth rate increases (Runkle 1981). As in blow down areas, tree fall pits, mounds, and logs facilitate seedling establishment (Barnes and Wagner 1981). However, in one study, hemlock replaced itself significantly less frequently than the current canopy composition would suggest (Barden 1979). Sugar maple dominance in the sapling layer, combined with browse damage, may have significant effects on the species type that recolonize a gap (Felich and Lorimer 1985, Anderson and Loucks 1979, Alverson et. al. 1988, Mlaidenoff and Stearns 1993).

Contemporary old-growth forests are regularly disturbed by natural and anthropogenic factors. The size of a stand correlates with it's capacity to absorb disturbance levels

(Shugart and West 1981). Nonetheless, selective logging, pollution, and disease can alter the natural composition of a hemlock-hardwood stand (Ebbers 1983, Davis 1993). There is controversy over exactly how much a stand can be disturbed before it is no longer pristine enough to be considered old-growth (Davis 1993). Usage history must be taken into account when determining the condition of a mature stand. The following section will evaluate the condition of the Britt woods by providing a site description and historical land use information.

Site Description

Location

Britt Woods is located in R5E, T21N, NE1/4 S36. The woods is bounded on the north by an agricultural field that rotates between crop and grazing usage, the Detroit and Mackinac Railroad right-of-way tracks on the east, and second growth forest on the west and the south (Figure-1.1). The old-growth section of the woods was estimated at approximately 8 ha by Snell Environmental Group. Further surveying, in August 1996, showed the old-growth section to be approximately 5.8 ha. An old horse and buggy road, known as Gravel Pit Road, intersects the north side of the woodlot (H. and W. Britt, pers.com 1995).

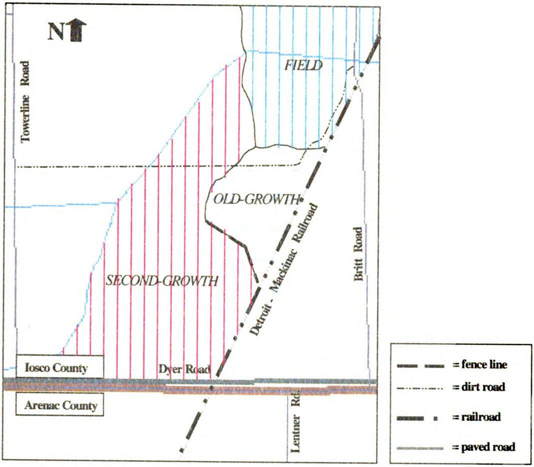


Figure 1.1 Map of Britt Woods

Source: U.S. Census Bureau, 1997

Vegetation

The dominant canopy trees are hemlock, sugar maple, basswood (*Tilia americana* L.), beech, and white ash (*Fraxinus americana* L.). Sugar maple is dominant in all size classes throughout the woods. Hemlock is most important on the north and east sides of the woods. Scattered throughout are stumps of white pine, hemlock, unidentified hardwood and possibly red pine. The occurrence of the stumps is the result of limited cutting, natural mortality, and wind storm damage. Successional woody species such as paper birch, bigtooth aspen, and trembling aspen are present on the western edge. The shrub layer is poorly developed in the old-growth section. Sugar maple saplings and the occasional hop-hornbeam, ironwood, service berry (*Amelanchia arborea* Michaux) and slippery elms occur in the understory. Sugar maple saplings, hophorn-beam, and ironwood increase in importance on the western edge.

The understory stratum is represented by a well developed vernal flora in which Carolina spring beauty (*Claytonia caroliniana* Michaux), Canadian violet (*Viola canadensis* L.) and other *Viola* spp. dominate with a patchy summer green component mixed in. Ferns, nettles (*Boehmeria cylindrica* Swartz, *Laportea canadensis* Weed, and *Pilea pumila* (L.) A. Gray), and other summer green species mature later in the season in more moist areas. Ash seedlings dominate gap areas resulting from recent canopy disturbance. Bracken fern, *Aster* spp., grasses and sedges tend to replace the old-growth understory stratum on the western edge of the woods.

Geology, Physiography, and Pedology

The land surface in the eastern portion of the woods is more noticeably rolling than the western side. The Britt woods is located on till or lacustrian sand and gravel which was originally a beach on the coastline of Lake Huron (USDA, Soil Conservation Service, Iosco County Soil Survey). The lacustrian beach dunes may account for the more rolling eastern section. The highest points in the woods are 660 feet above sea level (United States Department of Interior Geological Survey 1968). The slightly more depressed and flatter ground, of the south-western side, contains a spring pond. Continuous random tree falls have left the woods with the characteristic "pit and mound" microtopography. The major soil type, according to the Iosco county survey, is Algonquin silt loam.

Outcrops of gypsum have been discovered very close to the Britt Woods in the southwest corner of Section 36 (Cole 1903). Michigan Gypsum has been quarrying and selling this gypsum to cement companies for 33 years. Although Britt Woods has never been inspected for a stratum of shallow lying gypsum, a 1920 survey for minerals left a large unnatural pit in the southeast corner of the woods (H. and W. Britt, pers.com. 1995).

Climate

The Britt Woods is approximately 25 km from the Standish weather station. Wind currents, the proximity to Lake Huron, and the northern latitude affect the weather conditions of southern Iosco County. Westerly winds, which are most prevalent, increase cloudiness in late fall and early winter. Cool summers and early snow falls can prevail during more rare periods when the northeasterly or southeasterly winds from Lake Huron or Saginaw Bay, respectively, occur. There are seldom prolonged periods of hot and humid or extremely cold weather. This region has an average of 126 frost free days from approximately May 20th until September 23rd. Average precipitation from April to September is 43.5 cm. June tends to be the wettest month. During the winter months, an average of 115.3 cm of snow falls (National Oceanic and Atmospheric Administration 1995).

Michigan is located on the northeast edge of the Midwestern tornado belt. About 15 tornadoes hit Michigan each year, two within Iosco county (National Oceanic and Atmospheric Administration 1995). On July 15th, 1995 a heavy rain and wind storm passed through the Britt woods. Eight trees (6 > 30 cm diameter at breast height), 4 large snags, and many large branches were blown down by the high winds.

The 1995 winter and summer recorded above average temperatures, spring was noticeably cooler than usual and fall was only slightly cooler than normal (Table 1.2a). The winter, spring, and fall months of 1995 were slightly drier than usual, while the growing season, from June to August was wetter than average (Table 1.2a). Winter, spring, and summer were colder than normal in 1996. Early fall was close to normal while late fall was colder than usual. (Table 1.2b) The 1995 winter and fall months were dry while spring and summer were wetter than normal. The month of June was particularly wet receiving over 30% more precipitation than normal. (Table 1.2b) (National Oceanic and Atmospheric Administration 1995).

Table 1.2a Average temperature, precipitation, and departures from the normal for 1995.

	Temperature (C°)	Departure	Precipitation (cm)	Departure
January	-4.55	-1.09	3.45	-0.15
February	-7.6	-0.58	0.36	-2.64
March	1.05	0.13	3.56	-1.75
April	3.94	-0.35	8.15	1.85
May	12.27	0.05	3.3	-4.01
June	19.31	1.01	8.17	0.33
July	20.37	0.09	9.25	3
August	20.87	1.26	10.95	1.83
September	12.38	-0.91	4.47	-4.8
October	8.71	0.5	5.84	-0.76
November	-1.44	-0.34	8.71	2.9
December				

Table 1.2b Average temperature, precipitation, and departures from the normal for 1996.

	Temperature (C°)	Departure	Precipitation (cm)	Departure
January	-8.88	-1.17	3.89	0.28
February	-7.1	-0.19	2.74	-0.25
March	-3.61	-0.61	1.17	-4.14
April	3.77	-0.37	9.64	3.35
May	10.16	-0.73	10.92	3.61
June	17.76	0.19	15.6	7.75
July	18.26	-0.98	8.97	2.72
August	19.09	0.29	9.98	0.71
September	15.26	0.31	9.58	0.3
October	8.55	0.07	6.43	-0.18
November	-3.83	-1.71	2.69	-3.12
December	-2.66	0.71	5.99	0.33

Land use history of Britt Woods and surrounding area

Historical information about the Britt Woods was obtained from an interview with Warren and Howard Britt and original Michigan survey notes. The white pine logging era of Michigan brought pioneers to the land, built the economy, and left permanent ecological changes to the landscape (History of Iosco County Michigan 1981). The first load of white pine was exported in 1832, five years before Michigan officially became the twenty-sixth state of the Union. Michigan land surveyors discovered a pine belt in the center of the lower peninsula that went from Lake Michigan to Lake Huron. This pine belt included parts of Iosco county where the Britt Woods is located (Maybee 1960). In 1834, the lumber industry began in Saginaw Valley and within fifty years there were over eighty working mills (History of Iosco County Michigan, 1981). According to the original land surveyors notes, white pine did exist in the Britt Woods, however, exact coverage could not be determined from this source (Michigan Natural Features Inventory, 1994). Ruben Cox, a former neighbor of the Britts, once recalled that "a horse could be ridden all the way to Whittemore without his hoofs directly touching the ground because there were so many pine needles" (H. and W. Britt, pers.com. 1995).

Historian, George Hotchkiss, estimated that 160 billion board feet of pine had been logged from the state of Michigan by the year 1897. Some stands of mixed-hardwood hemlock were left standing after the pine era was over in

Iosco County (Maybee 1960). The Britts remember two stands of old-growth forest, which were similar to their own, that have been "cut over" during their life-time. One to the east of them on the Cox property, and another south of Maple Ridge (Figure 1.2). A large portion of the cleared land has left behind from the white pine era has grown back into forest or been converted to agricultural fields. By 1960, one half of the cut over land was classified as forest (Maybee 1960). The 1890's marked the beginning of the hardwood logging era in Michigan. Harvesting hardwoods presented difficulties previously not encountered during the Pine Era. Hardwoods are more susceptable to decay and could not be stacked for as long a period as pines. The extensive branches and limbs on hardwoods required extra time to process. In the past, pure or mixed stands of pine, were cut and sent to one mill for processing. Hardwoods, growing in mixed stands, had to be sent to different of mills because each species of hardwood had a specific use. Basswoods were used for house siding, cheap furniture, and food containers. Elm was used for cooperage and birch for flooring and spools of thread. Low quality hemlock wood was originally just used for rail ties, mine timber, and pulp until the leather industry became established in the late 1890's. Tannic acid, used for tanning leather, was found in hemlock bark (Karamanski 1989). The hardwoods and hemlocks that were not burned or otherwise removed for agriculture were probably processed at a sawmill near Prescott and Maple Ridge.

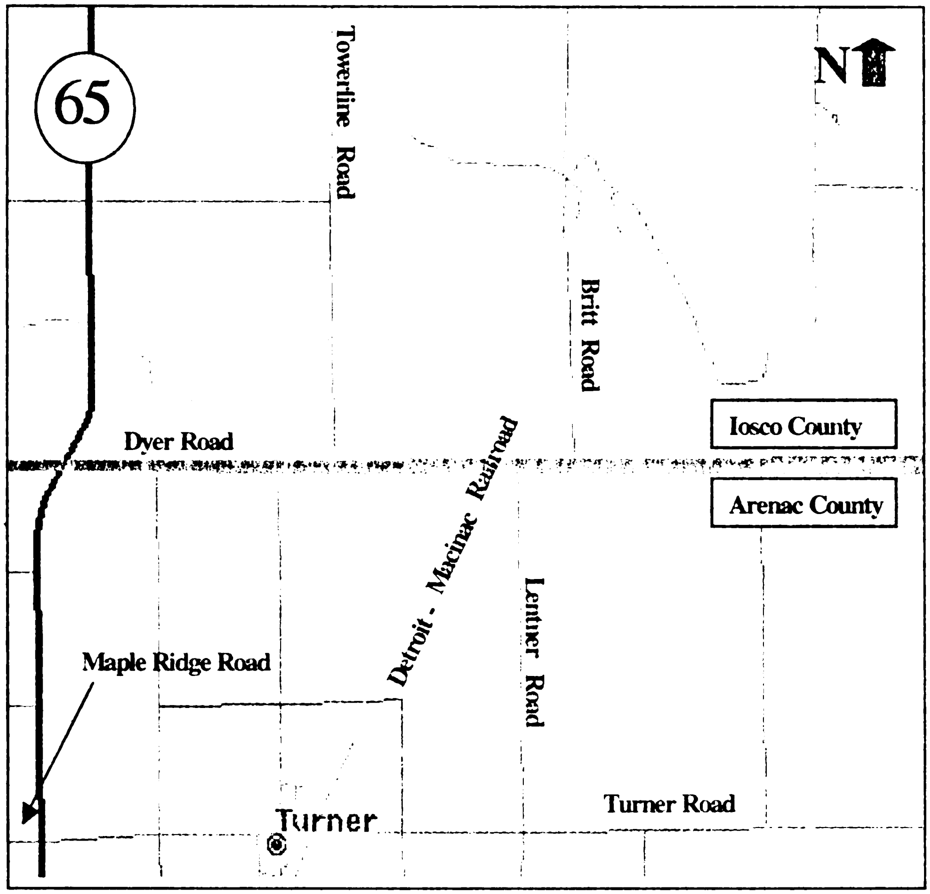


Figure 1.2 Map of the Britt Woods and surrounding area. The map shows Maple Ridge Road and Highway 65 where the 1915 wild fire originated.

Source: U.S. Census Bureau, 1997

That particular sawmill was built during the earlier part of this century and was not used to process the pines (H. and W. Britt, pers.comm. 1995).

Native Americans used the land for centuries before the arrival of Europeans in Michigan. The lower peninsula was originally inhabited by the Potawatomi, Chippewa, and Ottawa tribes. The Potawatomi spent spring and summer at their agricultural villages near Detroit and then headed north to their wintering grounds (Berthrong 1974). Warren Britt found what he interpreted as a native American artifact just east of the train tracks in a field. The artifact is a sculpted rock utensil that could have been used for grinding (H. and W. Britt, pers.com. 1995).

During the early summer of 1915, a wild fire burned from west of M-65 to the middle the Britt property (Figure 1.2). The fire burned through the second growth section up to the old-growth. The entire secondary growth section was burned. The fire was hot enough to burn the tops of green ash. Water was brought by hand from a water hole on the west side to keep the fire under control and out of the old-growth area (H. and W. Britt, pers.com. 1995).

A limited amount of anthropogenic disturbance has taken place in the Britt Woods. The Britts have done some selective logging and removal of snags for fire wood. In 1922, enough sugar maple was removed to make a barn frame. Then in 1946, one "300- ring" sugar maple and some hemlock trees were removed to be used as joints and rafters in a house. The Britts indicated that up to 120 trees were tapped for maple sugar during the late winter.

Wildlife species that use the woods include: coyotes, fox, white-tailed deer, skunk, porcupine, red and grey squirrel, chipmunk, mink, turkey, and "partridge" (ruffed grouse). The Britts have noted the following changes in the fauna and flora populations. The number of fox has decreased, transient quail and badgers are no longer seen. Large slippery elm trees existed on the west side of Britt Woods until they were killed by Dutch elm disease. There is still one large slippery elm (65.8 cm dbh) on the north-central side of the woodlot. The Britts noted that the population of *Trillium* spp. has decreased. In similar mesic habitats, decreasing *Trillium* spp. populations is an early indicator of browse effects of white-tailed deer (Alverson et. al. 1988).

Conclusion

The land-use history, structure, species composition, and microtopography indicates that the Britt woods is an old-growth hemlock hardwood remnant stand. Limited anthropogenic derived disturbance has taken place in the form of selective logging, tapping trees for maple sugar, and surveying for minerals. Herbivory may be altering the species composition. As with many old-growth fragments, the Britt Woods is not complete pristine condition. However, it is my hypothesis that this remnant stand is in sufficiently undisturbed to be considered old-growth. In order to support this conclusion, the following chapter documents and analyzes the species composition, distribution, age, and structure in the canopy stratum.

Literature Cited

Alverson, W. S., D. M. Waller, and S. L. Solheim, 1988. Forests Too Deer: Edge Effects in Northern Wisconsin. Conservation Biology. 4:349-358.

Anderson, R. C., and O. L. Loucks. 1979. White-tail deer (*Odocoileus virginianus*) influence on structure and composition of *Tsuga canadensis* forests. Journal of Ecology. 16:855-861.

Aber, J. D. and J. M. Melillo. 1991. Terrestrial Ecosystems, Saunder College Publishing, Philadelphia, Pennsylvania, USA.

Barbour, M. G., J. H. Burk, and W. D. Pitts. 1987. Terrestrial Plant Ecology. The Benjamin/Cummings Publishing Company, Inc., Menlo Park, California, USA.

Barden, L. S. 1979. Tree Replacement in Small Canopy Gaps of *Tsuga canadensis* Forest in the Southern Appalacians, Tennessee. Oecologia. 44:141-142.

Barnes, B. V., and W. A. Wagner. 1981. Michigan Trees. The University of Michigan Press, Ann Arbor, Michigan, USA.

Berthrong, D. J. 1974. A Historical Report on Indian use and occupancy of Northern Indiana and Southwestern Michigan. Garland Publishing Inc. New York, New York USA.

Bormann, F. H., and G. E. Likens. 1981. Pattern and Process in a Forested Ecosystem. Springer-Verlag, New York, New York, USA.

Braun, E. L. 1950. Deciduous Forests of Eastern North America. The Blakinson Company, Philadelphia, Pennsylvania, USA.

Britt, H. and W. Britt. Interview with author, Turner, Michigan, 22 July 1995.

Brubaker, L. B. 1975. Postglacial forest Patterns associated with till and outwash in North Central Upper Michigan. Quaternary Research. 5:499-527.

Burgis, W. A. 1977. Late-Wisconsinan History of North Eastern Lower Michigan. PhD dissertation, University of Michigan, Ann Arbor, Michigan, USA.

Burgis, W. A. and D. F. Eschman. 1981. Late-Wisconsinan History of northeastern lower Michigan. Midwest friends of the Pleistocene. Page 110 *In* proceedings of the 30th annual Field Conference. Ann Arbor, Michigan, USA.

Clements, F. E. 1916. Plant Succession. An analysis of the development of vegetation. Carnegie Institute, Washington, Publication, Washingtion D. C., USA.

-----. 1928. Plant Succesion and Indicators, H. W. Wilson, New York, New York, USA.

-----. 1936. Nature and Structure of the Climax. Journal of Ecology. 24:253-284.

Cole, L. J. 1903. The Delta of the St. Clair River, Robert Smith Printing Co., Lansing, Michigan, USA.

Crawley, M. J. 1986. The Structure of Plant Communities. Pages 2-5 *In* M. J. Crawly, editor. Plant Ecology. Blackwell Scientific Publications, London, England.

Davis, M. B. 1993. Old Growth in the East, a Survey. A Wild Earth Publication, Richmond, Vermont.

Dorr, J. A. and D. F. Eschman. 1971. Geology of Michigan. The University of Michigan Press, Ann Arbor, Michigan, USA.

Dunn, C. P. 1982. Catastrophic wind disturbance in an old-growth hemlock-hardwood forest, Wisconsin. Canadian Journal of Botany. 61:211-217.

Ebbers, B. C. 1983. Changes in Tree Composition in a Northern Michigan Hardwood Forest since 1934. The Michigan Botanist. 22:103-109.

Frelich, L. E., and C. G. Lorimer. 1985. Current and Predicted Long-term Effects of Deer Browsing in Hemlock Forests in Michigan, USA. Biological Conservation. 34:99-120.

-----. 1991*a*. A Simulation of Landscape-level Stand Dynamics in the Northern Hardwood Region. Journal of Ecology. 79:223-233.

-----. 1991*b*. Natural Disturbance Regimes in Hemlock-Hardwood Forests of the Upper Great Lakes Region. Ecological Monographs. 61(2):145-164.

Frelich, L. E., and L. J. Graumlich. 1994. Age-class distribution and spatial patterns in an old-growth hemlock-hardwood forest. Canadian Journal of Forest Research. 24:1939-1947.

Gates, F. C. 1926. Plant succession about Douglas Lake, Cheboygan County, Michigan. Botanical Gazette. 82:170-182.

-----. 1930. Aspen association in Northern Lower Michigan. Botanical Gazette. 90:233-259.

Gilliam, J. A., R. O. Kapp, R. O. Bogue. 1967. A Post-Wisconsin Pollen Sequence from Vestaburg Bog, Moncalm County, Michigan. Paper presented at the 52nd Michigan Academy of Science, Arts, and Letters. Michigan, USA.

Gorham, E., P. M. Vitousek, and W. A. Reiners. 1979. The regulation of chemical budgets over the course of terrestrial ecosystem succession. Ann. Rev. Ecol. and Syst. 10:53-84.

Graham, S. A. 1941. Climax forests of the Upper Peninsula of Michigan. Ecology. 22:355-362.

Heinselman, M. S. 1981. Fire intensity and frequency as factors in the distribution and structure of northern ecosysterms. Pages 7-57 *In* Fire regimes and ecosystems properties, proceedings of the conference. United States Department of Agriculture. General Technical Report WO-26.

Henry, J. D. and J. M. A. Swan. 1974. Reconstructing forest history from live and dead plant material- an approach to the study of forest succession in southwest New Hampshire. Ecology. 55:772-783.

Hett, J. M. and O. L. Loucks. 1971. Sugar maple (*Acer saccharum*) seeding mortality. Journal of Ecology. 59:507-520.

History of Iosco County Michigan. 1981. The Iosco County Historical Society, East Tawas, Michigan, USA.

Hix, D. M., and B. V. Barnes. 1984. Effects of Clearcutting on the Vegetation and Soil of an Eastern Hemlock dominated ecosystem, western Upper Michigan. Canadian Journal of Forest Research. 14:914-923.

Host, G. E., K. S. Pregitzer, L. W. Ramm, J. B. Hart, and D. T. Cleland. 1987. Landform-mediated differences in successional pathways amon upland forest ecosystems in Northwestern Lower Michigan. Forest Science. 33:445-457.

Hough, J. L., 1958. Geology of the Great Lakes. University of Illinois Press, Urbana, Illinois, USA.

Hunter, M. L. 1989. What Constitutes and Old-Growth Stand? Journal of Forestry. 87:33-35.

Hushen, T. W., R. O. Kapp, R. D. Bogue, and J.T. Worthington. 1966. Presettlement Forest Patterns in Montcalm County, Michigan. Michigan Botanist. 5:192-211.

Karamanski, T. J. 1989. Deep Woods Frontier. Wayne State University Press, Detroit, Michigan, USA.

Kelty, M. J. 1986 Development patterns in two hemlock-hardwood stands in southern New England. Canadian Journal of Forest Research. 16:885-891.

Kotar, J. and M. Coffman. 1984. Habitat type Classification System in Michigan and Wisconsin. Page 276 *In* J. G. Bockheim, editor. Forest and Land Classification: Experiences, Problems, Perspectives. Proceedings of the Symposium, Madison, Wisconsin, USA.

Leverett, F. 1917. Surface Geology and Agriculture Conditions of Michigan. Wynkoop Hallenbeck Crawford Co., Lansing, Michigan, USA.

Maissurow, D. K. 1941. The role of fire in the perpetuation of virgin forests of northern Wisconsin. Journal of Forestry. 39:201-207.

Maybee, R. H. 1960. Michigan's White Pine Era 1840-1900. A John M. Munson Michigan History Fund Publication, Lansing, Michigan, USA.

Michigan Natural Features Inventory. 1994. Department of Natural Resources Wildlife Division. Pre-European Settlement Landscape of Michigan. Lansing, Michigan, USA.

Mlaidenoff, D. J., and F. Stearns. 1993. Eastern Hemlock Regeneration and Deer Browsing in the Northern Great Lakes Region: A Re-examination and Model Simulation. Conservation Biology. 4:889-900.

Mlaidenoff, D. J., 1993. Comparing Spatial Pattern in Unaltered Old-Growth and Disturbed Forest Landscapes. Ecological Applications. 3:294-306.

National Oceanic and Atmospheric Administration. 1995 Climatological Data Annual Summary. Michigan. v 110.

Nowacki, G. J., and M. D. Abrams. 1994. Forest composition, structure, and disturbance history of the Alan Seeger Natural Area, Huntington County, Pennsylvania. Bulletin of the Torrey Botanical Club. 121:277-291,

Odum, E. P. 1969. The Strategy of Ecosystem Development. Science. 164:262-270.

Padley, E. A. 1989. Association among Glacial Land Forms, Soils, and Vegetation in Northeastern Lower Michigan. PhD dissertation, Michigan State University, East Lansing, Michigan, USA.

Raup, H. M. 1957. Vegetational adjustment to the instability of the site. Pages 36-48 *In* Proceedings and Papers of the 6th Technicaal Meeting of the International Union for the Protection of Nature. Edinburgh, Scotland.

Runkle, J. R. 1981. Patterns of Disturbance in some Old-Growth Mesic Forests of Eastern North America. Ecology. 63(5):1533-1546.

Schaetzl, R. J. 1990. Effects of Treethrow microtopography on the characteristics and genesis of spodosols. Soil Science- Hydrology- Geomorphology. 17:11-126.

Schaetzl, R. J. and L. R. Follmer. 1990. Longevity of Treethrow Microtopography: Implication for Mass Wasting. Geomorphology 3:113-123.

Scheiner, S. M., and J. A. Teeri. 1981. A 53-year record of forest succession following fire in northern lower Michigan. The Michigan Botanist. 20:3-14.

Shugart, Jr. H. H. and D. C. West. 1981. Long-Term Dynamics of Forest Ecosystems. American Scientist. 69:647-652.

Tyrrell, L. E., and T. R. Crow. 1994. Structural Characteristics Old-Growth Hemlock-hardwood Forests in Relation to Age. Ecology. 75:370-386.

Watkinson, A. R. 1986. Plant Population Dynamics. Page 182 *In* M. J. Crawley, editor. Plant Ecology. Blackwell Scientic Publications, Oxford, England.

Whitney, G. G. 1986. Relations of Michigan's Presettlement Pine Forest to Substrate and Disturbance History. Ecology. 67:1548-1559.

Whitney, G. G. 1987. An Ecological History of the Great Lakes Forest of Michigan. Journal of Ecology. 75:667-684. United States Department of Agriculture, Soil Conservation

Service, Iosco County, Michigan, 1995.
United States Department of Agriculture, Soil Conservation Service, Iosco County Survey, East Tawas, MI.

United States Census Bureau, Gazetteer Place and Zipcode files, accessed 13 December 1997; available from http://www.census.gov/cgi-bin/gazetteer.

United States Department of Interior, Geological Survey. 1968. Whittmore Quadrangle, Michigan. 7.5 Michigan Series (Topographic).

CHAPTER 2

Introduction

The purpose of this thesis is to provide a quantitative and qualitative survey of the Britt Woods and to compare the results to other stands identified as "old-growth" stands. The following objectives will be addressed:

Objectives

Canopy Stratum

1. To determine the relative density, relative frequency, relative dominance, and relative importance values for trees measured in 2 size classes: 1-9.9 cm diameter at breast height (dbh) and ≥ 10 cm dbh.
2. To determine the spatial distribution of the canopy dominants (trees with ≥ 5% importance).
3. To determine patterns of positive or negative association among the canopy dominants.
4. To determine and compare the average dbh and size class distributions of the canopy dominants, and to use these data sets to predict potential future changes in the canopy composition.

5. To determine the stand's age and chronological environmental history by cross-dating and analyzing core samples.

Understory Stratum

1. To determine the relative abundance, frequency, and importance values of each species.
2. To determine the relative importance values of the following ecological guilds: seedlings, woody species, ferns and fern allies, grasses and sedges, spring flora, summer greens, and fall flowering herbs.
3. To compare the species richness, diversity, maximum diversity, evenness, and coverage of the old-growth section of the Britt Woods with the second growth section on the west side of the Woods. This will be accomplished by comparing blocked areas of the old-growth section with the second-growth section.
4. To determine how hemlock trees affect understory coverage.
5. To analyze patterns of heterogeneity by looking at the compositional changes among 16 important understory species in the old-growth and second-growth section of Britt Woods.
6. To determine patterns of positive or negative association among important understory stratum species.

Woody Debris

1. To determine the volume and condition of woody debris (stumps, snags, and logs) found in a sample of the woods in the old-growth section.

Soil characteristics

1. To determine general soil characteristics (horizon, texture, and color) of 10 soil pedons excavated from a pit, a mound, and the dried up spring pond on the western side of the Britt Woods.

Materials and Methods

Canopy Stratum Sample Methods

The canopy stratum was sampled in August 1995 using the point quarter method (Brower & Zar 1984). Points were established at 20 m intervals along transects oriented north-south and parallel to the eastern margin of the woods. Fourteen transect lines at 20 m intervals were employed in the sample field, each beginning and ending 5-15 m from the north and south boundaries of the woods (Figure 2.1). Diameter at breast height (dbh=4'6" or 1.4 m) and species were recorded for two trees in each quarter within 10 m of each point, one representing the dominant size class ($\geq$ 10 cm), and the other representing the sapling and understory size class (1-<10.0 cm). The distance from the point to the center of the nearest living tree, in both size classes, for each quadrant, was measured in meters and recorded. The dbh of all coppice trunks was taken and recorded. Coppice individuals were most common among basswoods.

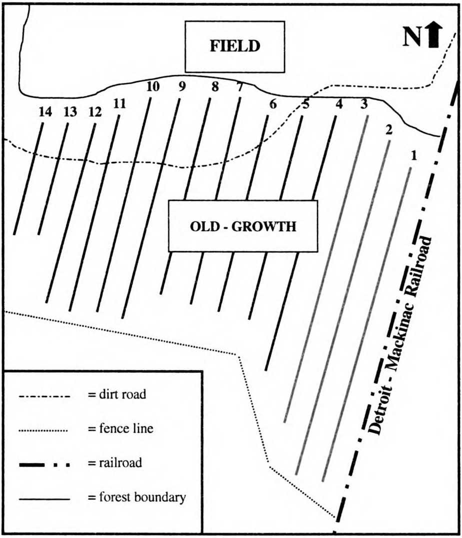


Figure 2.1 Map of Britt Woods with transect lines 1-14.

Canopy Stratum Data Analysis

Relative dominance, relative density, relative frequency, and importance values were determined for each species, in both size classes (Brower and Zar, 1977). Basal area (BA) was use to calculate dominance. Individual BA were calculated and summed for coppice trees, the total BA was used to calculate dominance. Average dbh and size class distributions were determined for sugar maple, red maple, ash, basswood, beech, and hemlock. The largest bole of individuals with coppice stems was used determine average dbh and size class distribution. Some coppice individuals had highly varied dbh values. Calculations were performed on Excel version 7.0 (1995).

The Kruskall-Wallis non-parametric 1-way ANOVA was used to make pairwise comparisons of the size class distributions for the canopy dominants on NCSS version 5.0 (1996).

Pairwise comparisons of association were made for the dominant canopy and sapling size class tree species. Positive or negative associations were determined by analyzing the occurance or absence of each pair of tree species at points located in transects 1-10. Pairwise comparisons were made with a 2x2 chi-square contingency analysis on NCSS.

The local distribution of sugar maple, red maple, ash, basswood, beech, and hemlock within the woods was plotted on separate 3-dimensional mesh graphs on Sigma Plot 2.0 (1994). The x-axis was represented by transects, the y axis was represented by points along transects, and the z axis was derived by totaling the individual species BA for each point.

Tree Core Methods

In August 1996, increment core samples were obtained from 11 canopy-dominant trees (2 beech, 2 sugar maple, 2 hemlock, 2 basswood, and 3 ash) growing in the interior of the old-growth section (transects 1-10). The dbh and one core sample were obtained for each tree. In August 1997, 2 core samples and the dbh were obtained from 5 hemlocks. In October 1997, the dbh and 2-4 core samples were obtained from 9 >55 cm dbh hemlocks. One core sample and the dbh were also obtained from a sugar maple tree in October, 1997. The 2 core samples were taken from opposite sides of each tree at <0.5 m above the ground. The cores were mounted and then sanded with a fine grade sand paper to create a smooth surface. Cores were removed from the trees, mounted, and sanded using methods described by M. A. Stokes and T. L. Smiley, 1967.

The "skeleton plot method" as described by Stokes and Smiley, 1967, was used to cross-date the cores and develop a hemlock chronology. A skeleton plot or chronology was first constructed on strips of graph paper for each core. Cores were examined with a 10x power microscope. Each vertical line on the graph paper corresponded to one ring. The center ring on each core was plotted at year one and each consecutive ring was than plotted until the bark was reached. Rings were plotted according to their relative degree of narrowness as compared to the immediate surrounding rings. Narrow rings were plotted with long lines which meant there was high response that year while wide rings were not plotted which meant there was no response evident that year. Response refers to environmental factors that may have limited tree growth during the year, such as nutrient availibility, water, or light levels. Cross-dating, by comparing 2 chronologies and matching up similar patterns, was used to construct a series of composite chronologies. Composites are made by plotting an average length line for corresponding response years of individual chronologies that cross-date. The chronology of hemlock cores from the same tree in 1997 and the two hemlock cores taken in 1996 were used to make the composites. Composite chronology's that cross-dated were used to construct a final composite. Matching similar patterns of each cores chronology made it possible to identify missing rings and false rings.

Understory Stratum Field Methods

In 1995, the forest floor cover was sampled in 0.5 x 0.5 m quadrats. Three quadrats were randomly located along each 20 m transect interval and permanently marked for subsequent reference. Sampling was conducted from June to late August, 1995. Each herbaceous and woody species was recorded and mapped onto a quadrat grid, (Figure 2.2) resulting in abundance estimates at a 1% resolution. Only 1% was recorded for abundance, if more than one individual of the same species occupied the same location in 1% of the grid. Total abundance (i.e. total number of individual species) was recorded if more than 1 individual of different species occupied the same location in 1% of the grid.

In 1996, the understory stratum was sampled for spring flora in May and early June. The quadrats were resampled in August to obtain later emerging species. The 1995 transect lines and points remained in place. Random quadrats were re-established and sampled along transect lines 2, 4, 5, 6, 7, 8, 10, and 13 with the methods described for the 1995 sampling. Any infrequent and rare species that did not occur within the sampled area, in 1995 or 1996, was identified and recorded. The microtopograpy within and surrounding each quadrat was noted in 1995.

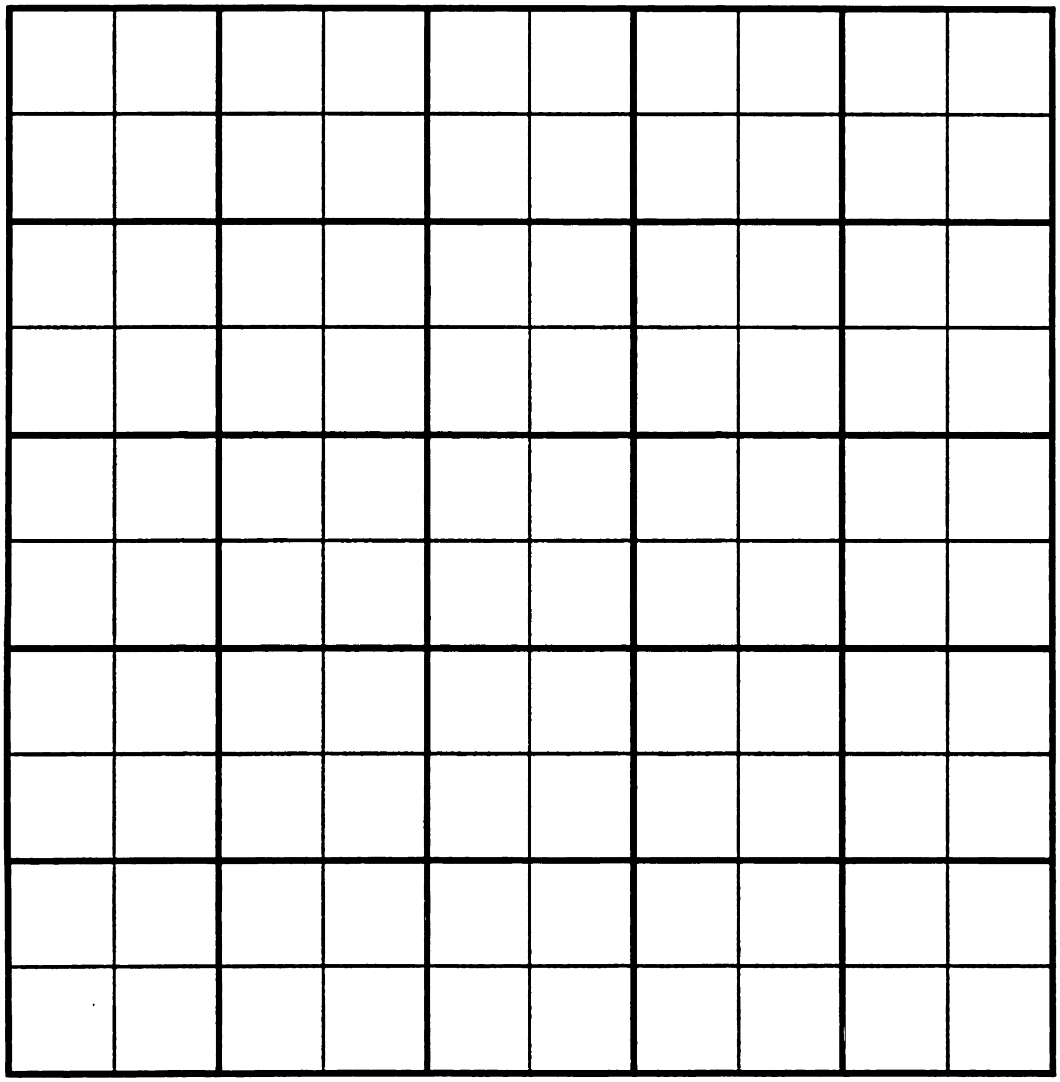


Figure 2.2 0.5 x 0.5 m grid for understory sampling. Plants were identified and mapped on grid.

Understory Stratum Data Analysis

The forest floor was analyzed separately for 1995 and 1996. Relative abundance, relative frequency, and importance values were determined for each species that was sampled. Sampled species were categorized into the following guilds: ferns and fern allies, grasses and sedges, woody species, seedlings, spring flora (spring flowering species and spring ephemerals), summer greens (summer flowering species), and fall flowering species. Importance values were determined for each guild (Brower and Zar, 1977). Calculations were performed on Excel.

The understory stratum was divided into 43 blocks that contained 12 quadrats (3 m^2) each. Each block was assigned a row and column letter for computer program analysis (Figure 2.3). The abundance and species richness were determined for each block. The following values were calculated for each column and all columns combined: plots sampled (k), area sampled in m^2, species richness (s), total number of individual plants sampled (N), maximum diversity (H_{max}'), evenness (J'), Shannon-Weiner diversity index (H'), Simpson's Diversity Index (D_s), Simpson's Dominance, and the inverted Simpson's Dominance (d_s).

The following procedure was used to determine the effect hemlock had on abundance. Hemlock coverage (the total BA in m^2) and understory abundance was calculated for each block. A linear regression was performed on Sigma Plot version 2.0 (1994) to determine whether understory species abundance responded significantly to hemlock coverage values in each block.

Abundance of the 16 most important/frequent species or species groups was determined for each block (see Figure 2.3). A non-parametric simple correspondence analysis of the blocked areas was performed on Minitab version 8.0 (1996) to assess similarities and differences among blocks. A second correspondence analysis of each of the 16 most frequent species was performed to assess patterns of positive, neutral, and negative association among species and species groups.

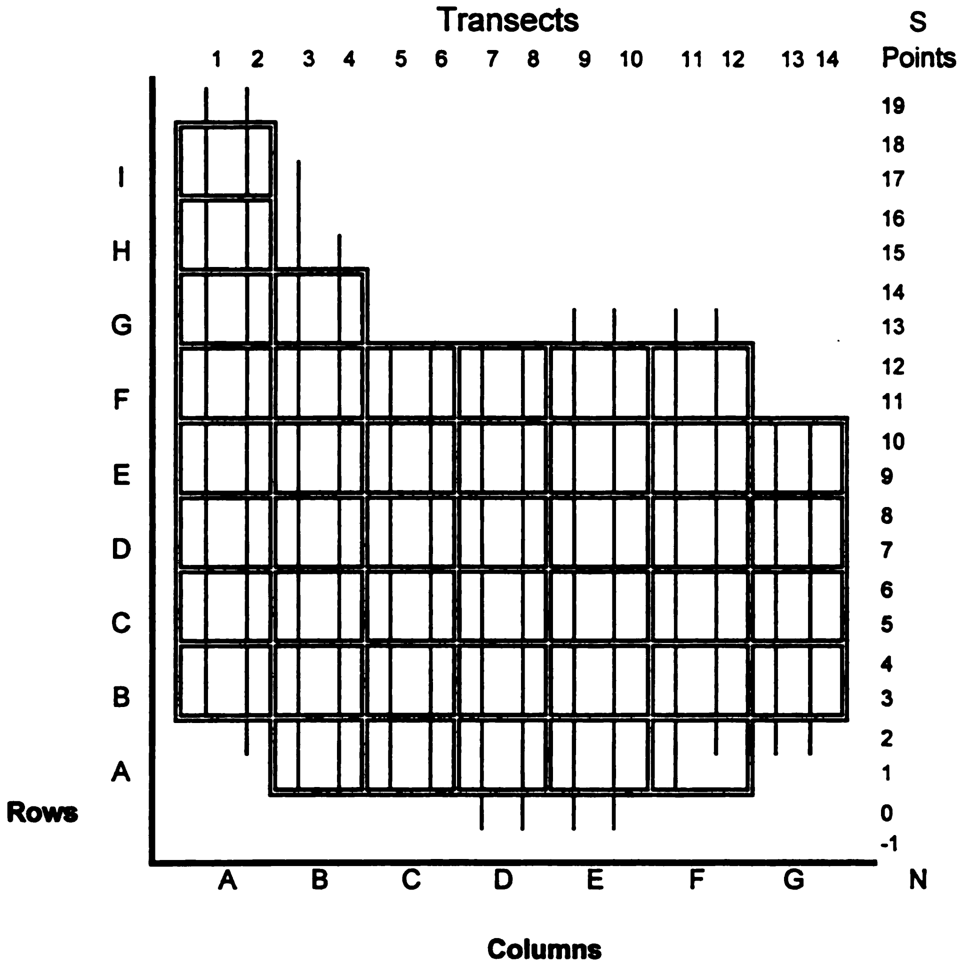


Figure 2.3 Blocked areas of Britt Woods. Each block is designated with a column (a-f) and row (a-h) label. Columns are formed by 2 transects (north to south) and rows are formed by 2 points (east to west). Blocks contain 12 quadrats = $3m^2$.

Coarse Woody Debris Sampling Methods

Methods for sampling the coarse woody debris (cwd) were modeled after Tyrell and Crow, 1994. Approximately 5% of the woods located between transect lines 1-10 (the old-growth section of the woods) was surveyed. The 3,000 m^2 area was divided into 6 randomly located 50 x 10 m plots. The length and diameter at both ends were measured for logs or sections of logs that were > 20 cm dbh. The volume was determined as a cylinder by averaging the radii of both ends. Fallen logs were identified, if possible, and categorized into one of 5 decay classes (Table 2.1a). Snag basal diameter was measured and height was recorded in the following size classes: <5m, 6-10 m, 11-25 m, and >25 m. Each snag was identified, if possible, and the condition of the crown was noted and applied to the formula used for calculating volume (Table 2.1b). Calculations were performed on Excel.

Table 2.1a Decay classes for stumps, snags, and logs (after Tyrell and Crow 1994).

Wood Decay Class/Description			
Class/Description	Leaves	Wood	Shape and Form
I. Recent	present	solid	round
II. Solid	absent	solid	round
III. Solid-decayed	absent	solid/punky	round/oval
IV. Decayed	absent	punky	oval, w/ form
V. Very decayed	absent	punky	<oval, w/o form

Table 2.1b Formulas for determining snag volume; BA- basal area (after Tyrell and Crow 1994).

Snag Volume Formulas	
Crown type	Volume
Intact	(BA.ht) x 0.50
Crown absent, large branches present	(BA.ht) x 0.75
Bole only	(BA.ht) x 1.00

Soil Pedon Sampling Methods

Ten pedons were taken from three soil pits in October, 1995. Each soil pit was 50-70 cm deep, oblong in shape, and approximately 60 x 120 cm. The first soil pit (A) was excavated on top of a larger mound on the central east side of the woods. The second soil pit (B) was excavated in a pit on the central south side of the woods. The last soil pit (C) was excavated from the dried up spring pond on the west side. A total of 10 soil pedons were analyzed. One pedon was taken from each of the north, south, east, and west sides of the first and second soil pits. Two pedons were taken from the north and south sides of the third soil pit. Pedon horizons were identified, textured, measured for depth, and the color was determined with a Munsell color chart. Texture refers to the relative proportion of sand, silt, and clay in the soil. Soils were textured by feel using methods from Mokma, 1993. Colors were determined by comparing a moist sample from each horizon to a standard found in the Munsell color chart. Hue identifies the quality of color as seen by the eye in relation to wavelength of light, value indicates the degree of light or darkness of the color, and chroma indicates the degree of dilution of a color by a neutral gray of the same value (Mokma 1993).

Results

Canopy Stratum

Transect lines 1-10 crossed through the oldest portion of the woods, 11-12 crossed through a transition area that contained successional and climax species, and transects 13-14 crossed through second-growth (see Figure 2.1).

Importance:

Relative importance values for trees in the $\geq$ 10 cm dbh size class ranged from 0 to 0.31 (Figure 2.4a). The importance value for sugar maple was nearly twice that of beech the next most important species. Other species with importance values > 0.05 include basswood, hemlock, white ash, and red maple. Red maple had similar values for relative density, dominance, and frequency. Beech and hemlock had similar values for relative density and dominance, while the relative frequency value was slightly higher. Ash and sugar maple had similar values for relative dominance and frequency, while relative density was slightly lower with ash and notably higher for sugar maple. Basswood had higher relative dominance and lower relative density in comparison with relative frequency. The relative dominance value for basswood may have been inflated due to coppice boles. Some of the basswoods had large basal areas due to those coppice boles. See Appendix A for further details.

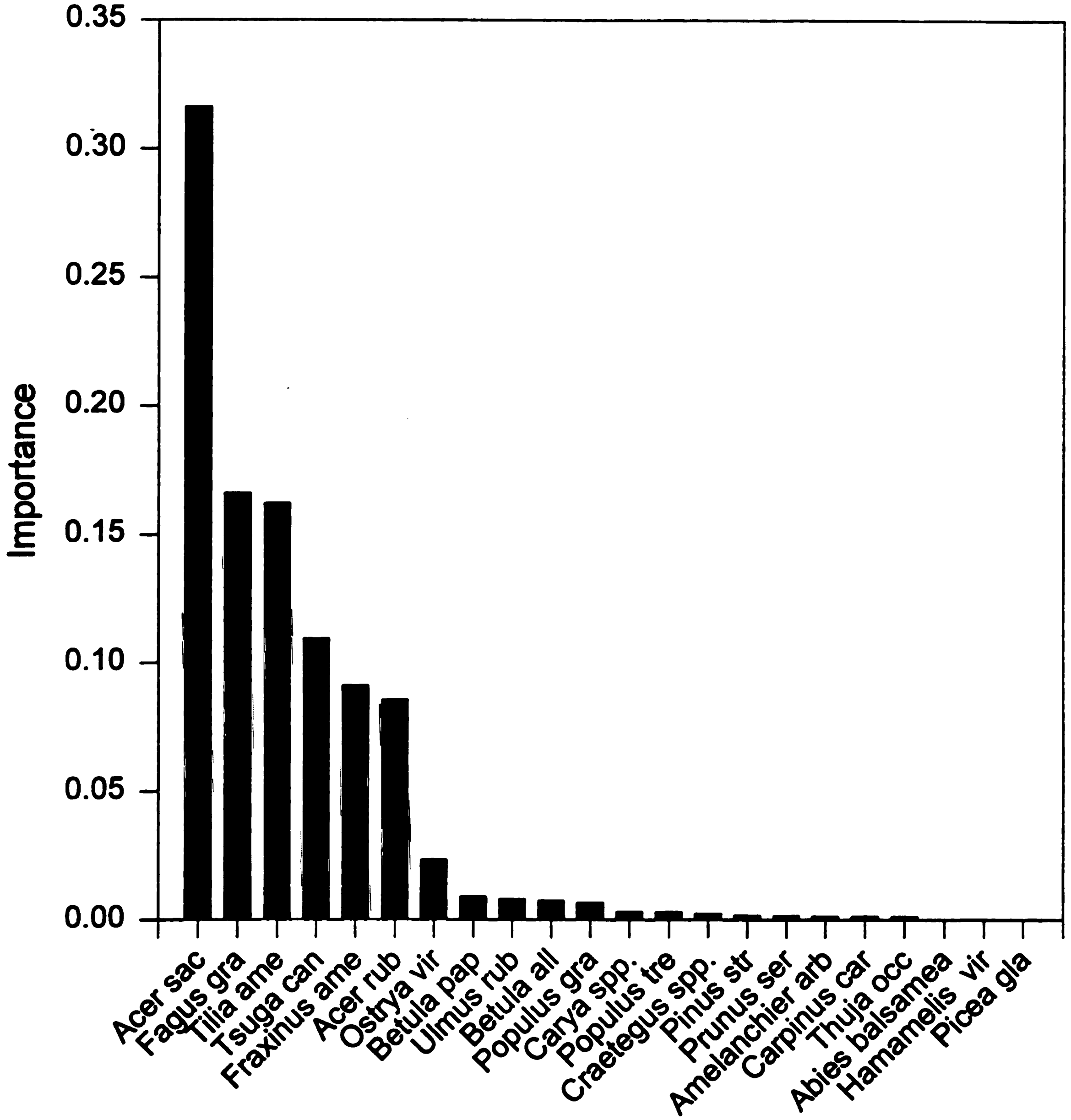


Figure 2.4a Importance values for trees with > 10 cm dbh.

Relative importance values in the < 10.0 cm dbh size class ranged from 0 to 0.62 (Figure 2.4b). Sugar maple is even more important in the smaller size class with a value four times as great as the second most important canopy understory species, hop-hornbeam. Beech and a canopy understory species, ironwood also have importance values > 0.05. Beech decreases slightly in importance from the larger to smaller size class. Red maple is approximately a third as important in the smaller size class as compared to the larger. Basswood, hemlock, and ash decrease significantly in importance in the smaller size class. See Appendix A for further details.

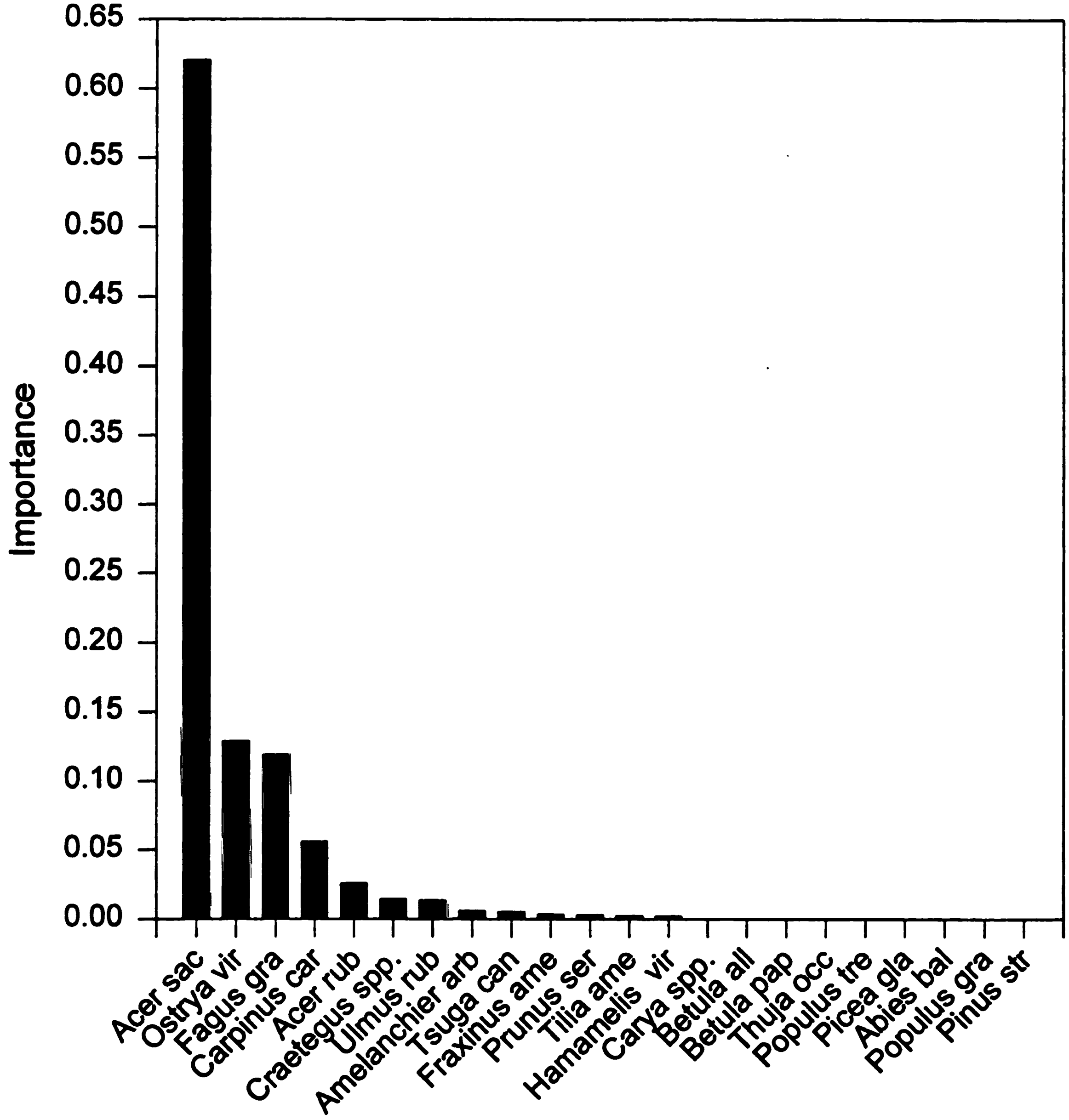


Figure 2.4b Importance values for trees with < 10 cm dbh.

Size Class Distribution:

The Kruskall-Wallis test showed that the size class distribution for sugar maple was significantly different from red maple, basswood, hemlock, and ash ($P < 0.05$) and beech at ($X^2=15.10$, $P < 0.01$). The Chi-Square value corrected for ties was 15.10 with a P-value < 0.01. Sugar maple had a descending monotonic size class distribution with a notably high number of individuals found in the 5-9.99 cm dbh sapling size class (Figure 2.5a). Red maple had a right-skewed unimodal size class distribution with few individuals in size classes > 40-44.99 cm dbh and none above the 60-64.99 cm dbh size class (Figure 2.5b). Basswood had a left-skewed unimodal size class distribution with no individuals found in the smallest size class and only 1 individual found in the next three successive size classes (Figure 2.5c). Ash had a varied distribution that was superficially unimodal in pattern (Figure 2.5d). The majority of ash individuals had a dbh in the 20 to 50.99 cm dbh range. Hemlock had a slightly left-skewed size class distribution with no individuals found in the smallest size class (Figure 2.5e). Beech had a cyclic distribution with the highest number of individuals found in the smaller size classes and few individuals found in the 25-29.99 and 65-69.99 size classes (Figure 2.5f).

Figure 2.5a-2.5f

The size class distributions of the canopy dominants are represented in individual histograms: *Acer saccharum* - Figure 2.5a, *Acer rubrum* - Figure 2.5b, *Tilia americana* - Figure 2.5c, *Fraxinus americana* - Figure 2.5d, *Tsuga canadensis* - Figure 2.5e, *Fagus grandifolia* - Figure 2.5f. Frequency, the number of individuals per size class, is shown on the x-axis. Size classes are listed in increments of 5 cm dbh on the y-axis. Frequency and size class ranges vary for each species.

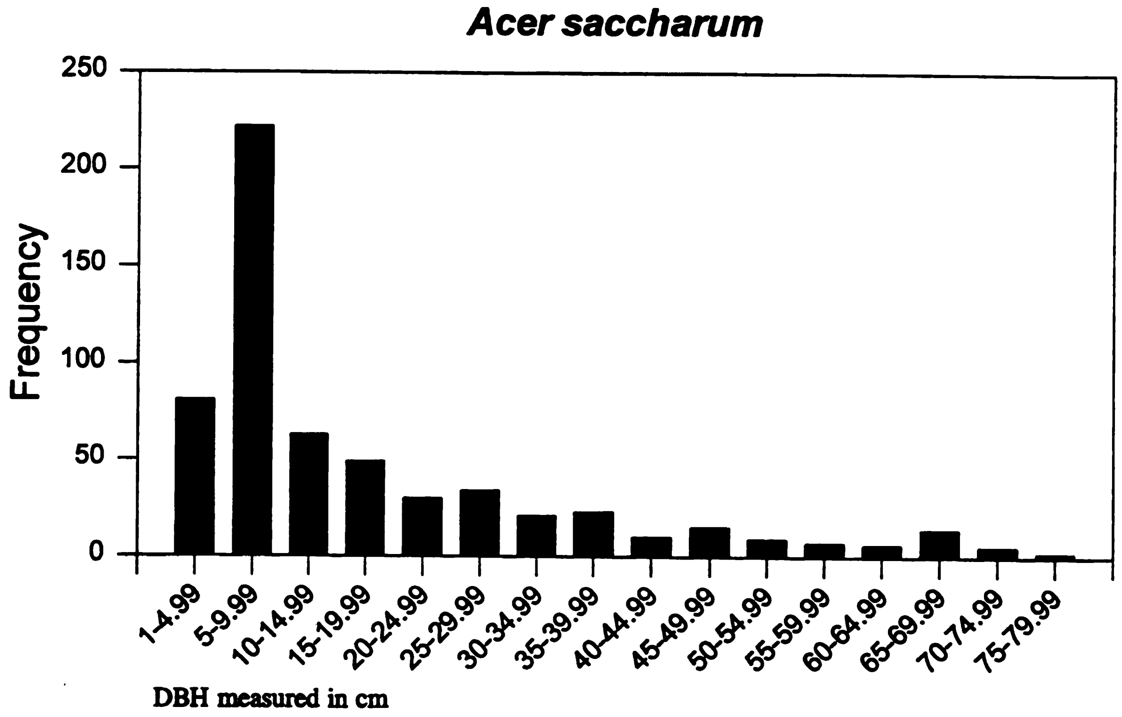


Figure 2.5a

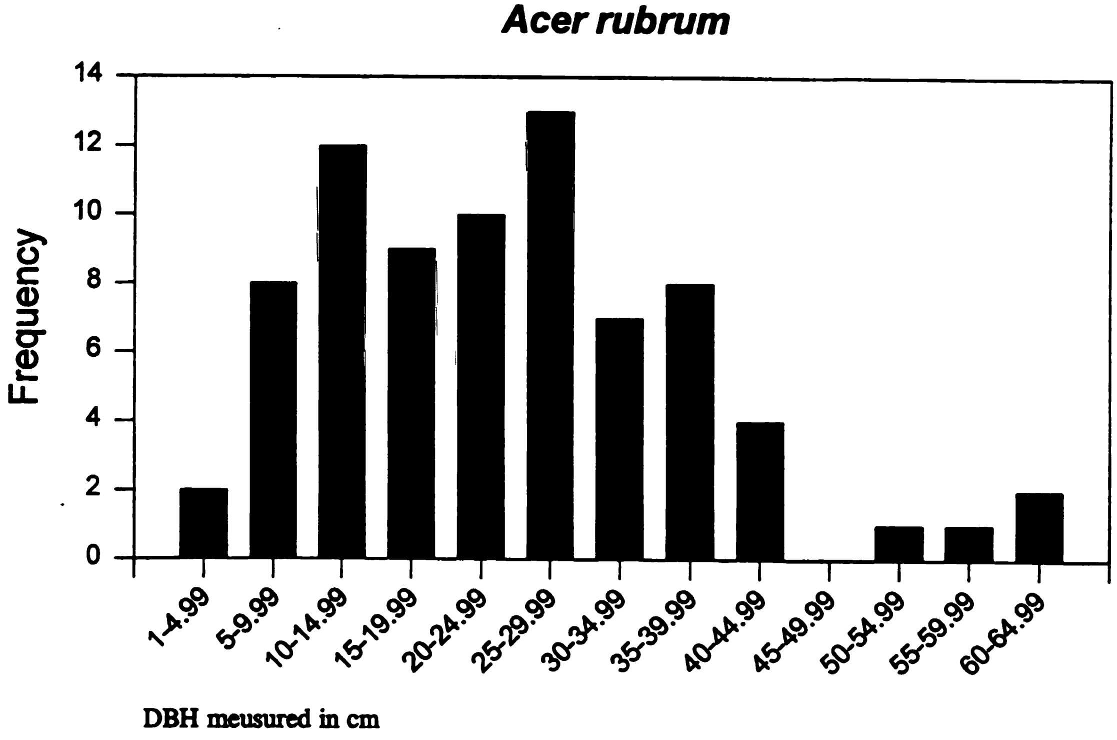


Figure 2.5b

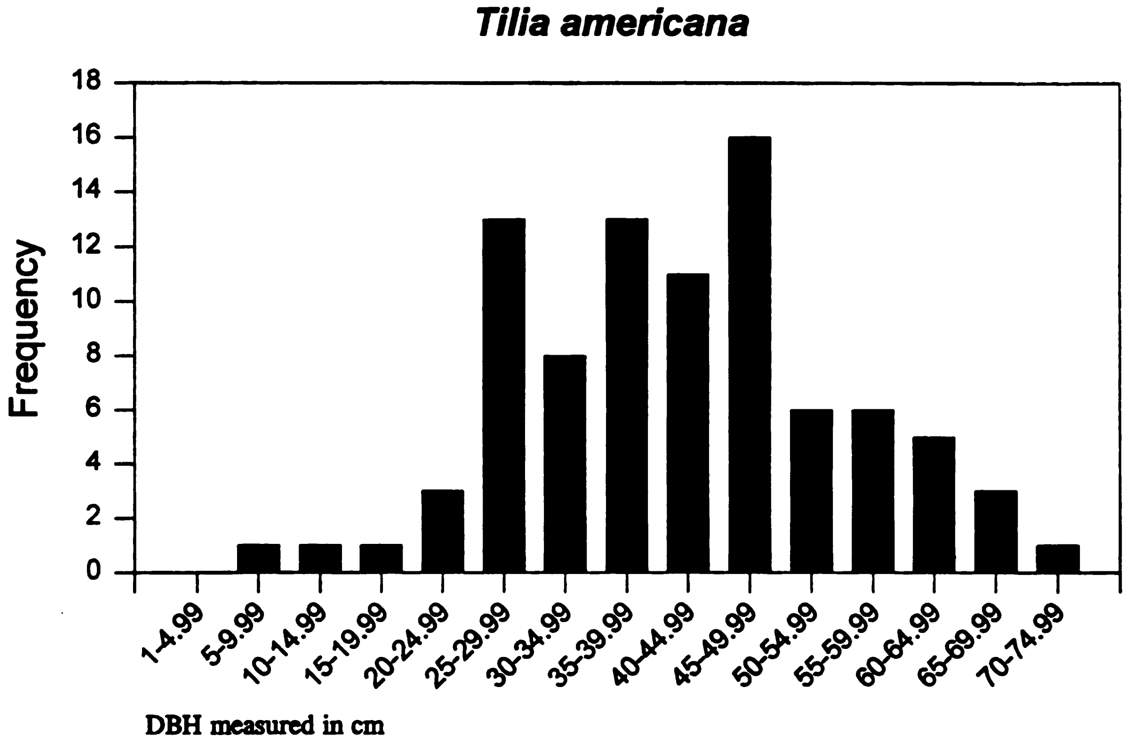


Figure 2.5c

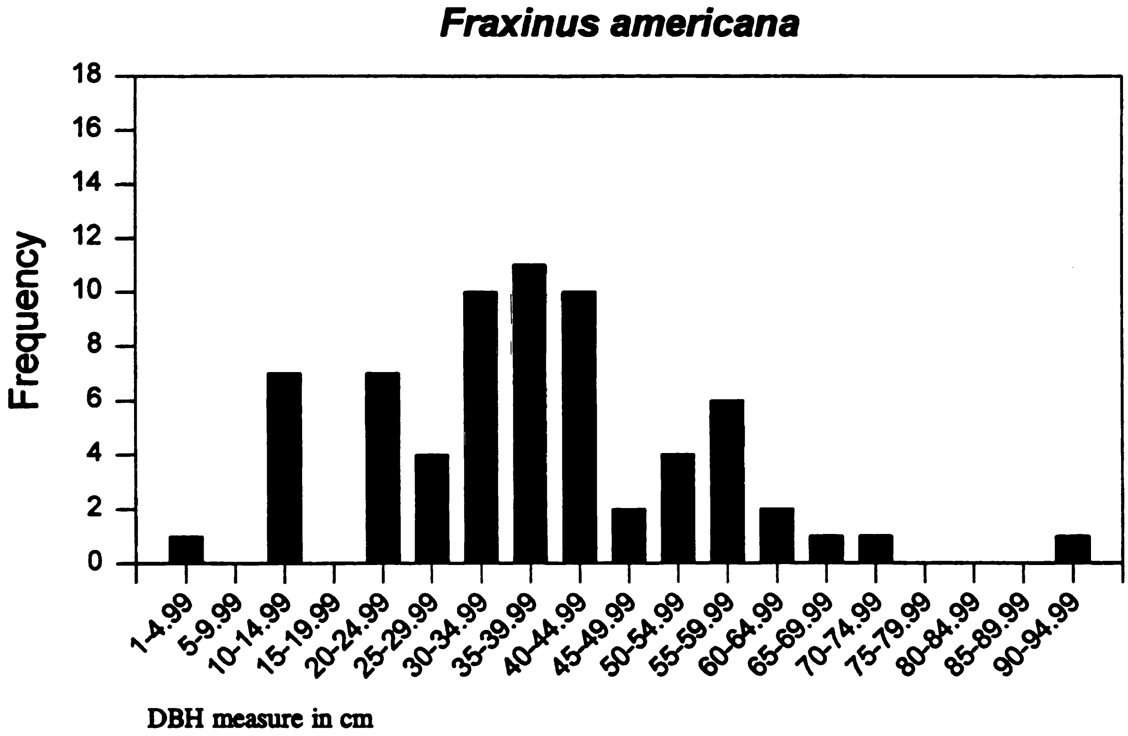


Figure 2.5d

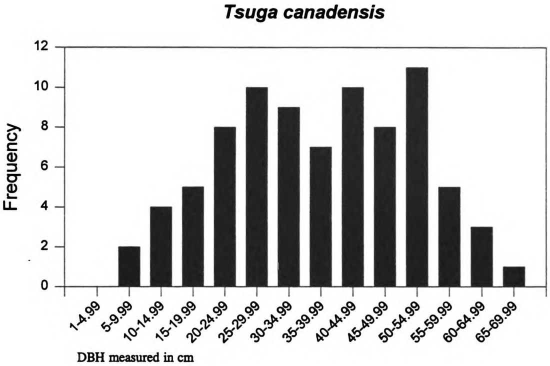


Figure 2.5e

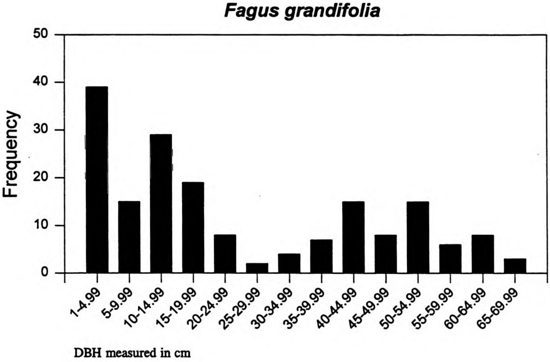


Figure 2.5f

The average dbh for each of the 6 dominant tree species for all size classes in Britt Woods was as follows: sugar maple- 28.6 cm dbh, red maple- 32.2 cm dbh, beech- 33.1 cm dbh, hemlock- 37.5 cm dbh, ash 38.1 cm dbh, and basswood- 42.5 cm dbh.

Spatial Distribution:

Sugar maple had a fairly uniform spatial distribution throughout most of the woods (Figure 2.6a). There were 2 or 3 notable peaks > 0.75 m^2/point total BA in the center of the woods. Few sugar maples occurred in on the central to northern part of the most eastern transect. The second-growth area on the west side had lower total BA values, and the northwest corner was completely devoid of sugar maple. Red maple distribution was patchy and occurred predominantly on the northern and western boundary (Figure 2.6b). Few red maple trees occurred in the majority of the old-growth area. Basswood occurred throughout most of the old-growth section (Figure 2.6c). Coppice trunks caused a few notable peaks in the total BA values. Only one coppice individual basswood occurred in the two western-most transects (13 and 14). Ash was patchy, and occurred predominantly in the northeast and south-central sections of the woods (Figure 2.6d). Ash trees were scattered in the old-growth and second-growth sections. Hemlock was also patchy and occurred mostly in the north-central to northeast sections and along the eastern boundary (Figure 2.6e). Few other hemlock trees were scattered in the old-growth section. Hemlock trees were not sampled in the west-central to southwest section of the woods, and few existed in the rest of the second-growth section. Beech trees occurred throughout most of the old-growth section, and some of the second-growth section, with a few notable peaks in occurrence (Figure 2.4f). Few beech trees were sampled in the northeast corner, north-central to northwest area, and southwest corner.

Figure 2.6a-2.6f

Canopy dominants distribution in the Britt Woods in 3-dimensional graphs, viewed from a northeast and southwest perspective: *Acer saccharum* - Figure 2.6a, *Acer rubrum* - Figure 2.6b, *Tilia americana* - Figure 2.6c, *Fraxinus americana* - Figure 2.6d, *Tsuga canadensis* - Figure 2.6e, *Fagus grandifolia* - Figure 2.6f. The transects (x-axis) run north to south and points (y-axis) run east to west. The total BA (z-axis) is the sum of the BA for individual trees of the same species found at each point.

Acer saccharum

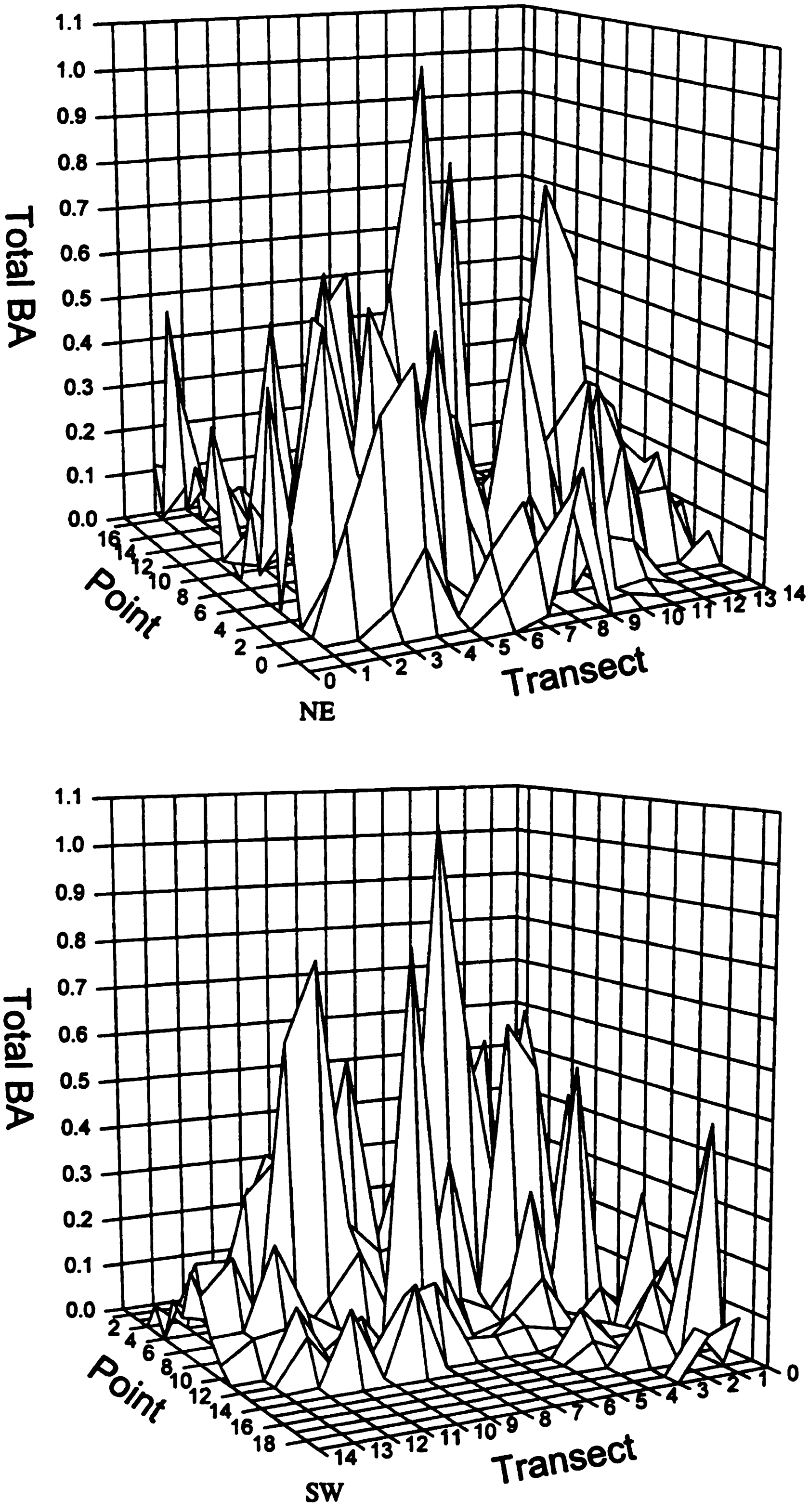


Figure 2.6a *Acer saccharum* distribution

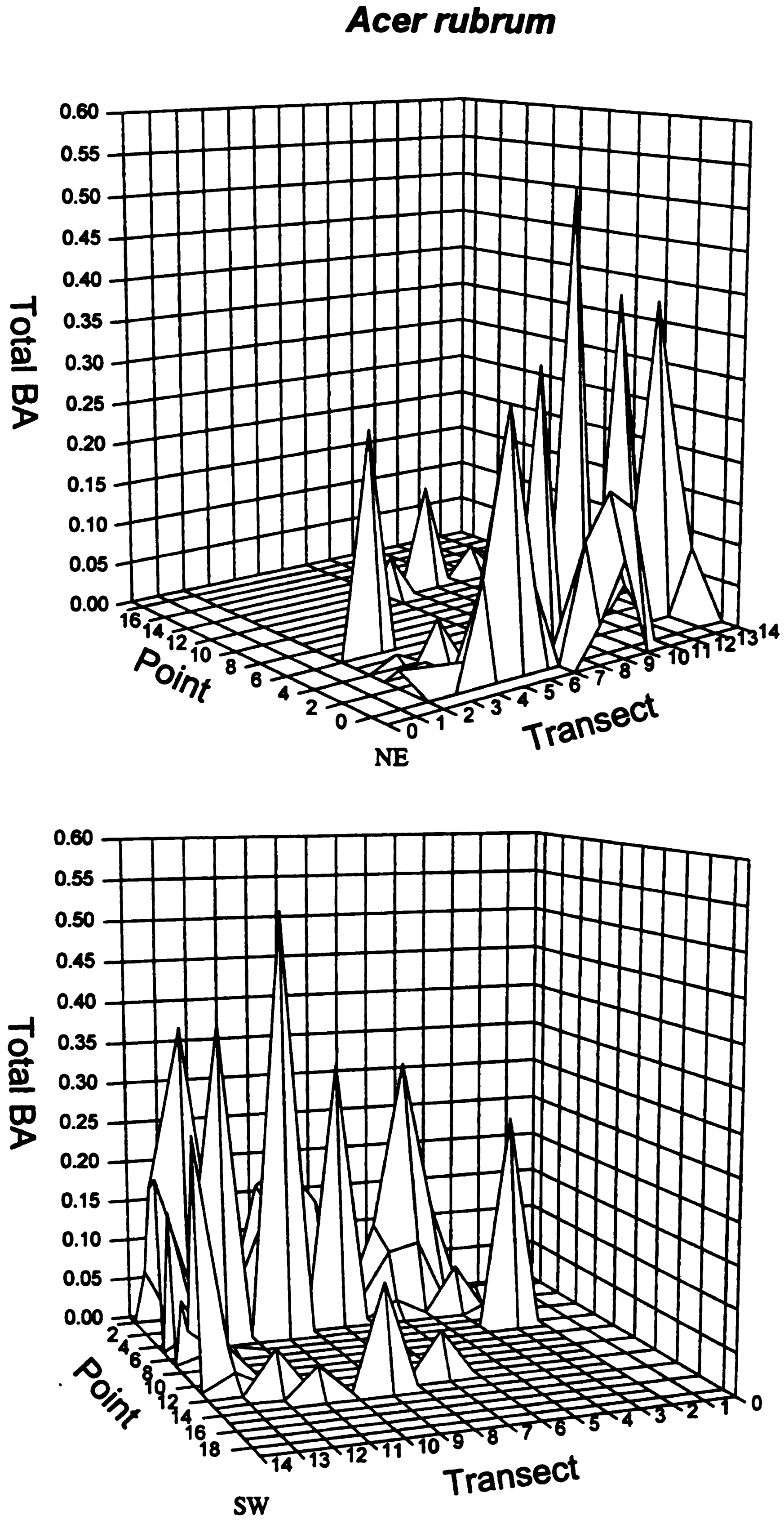


Figure 2.6b *Acer rubrum* distribution

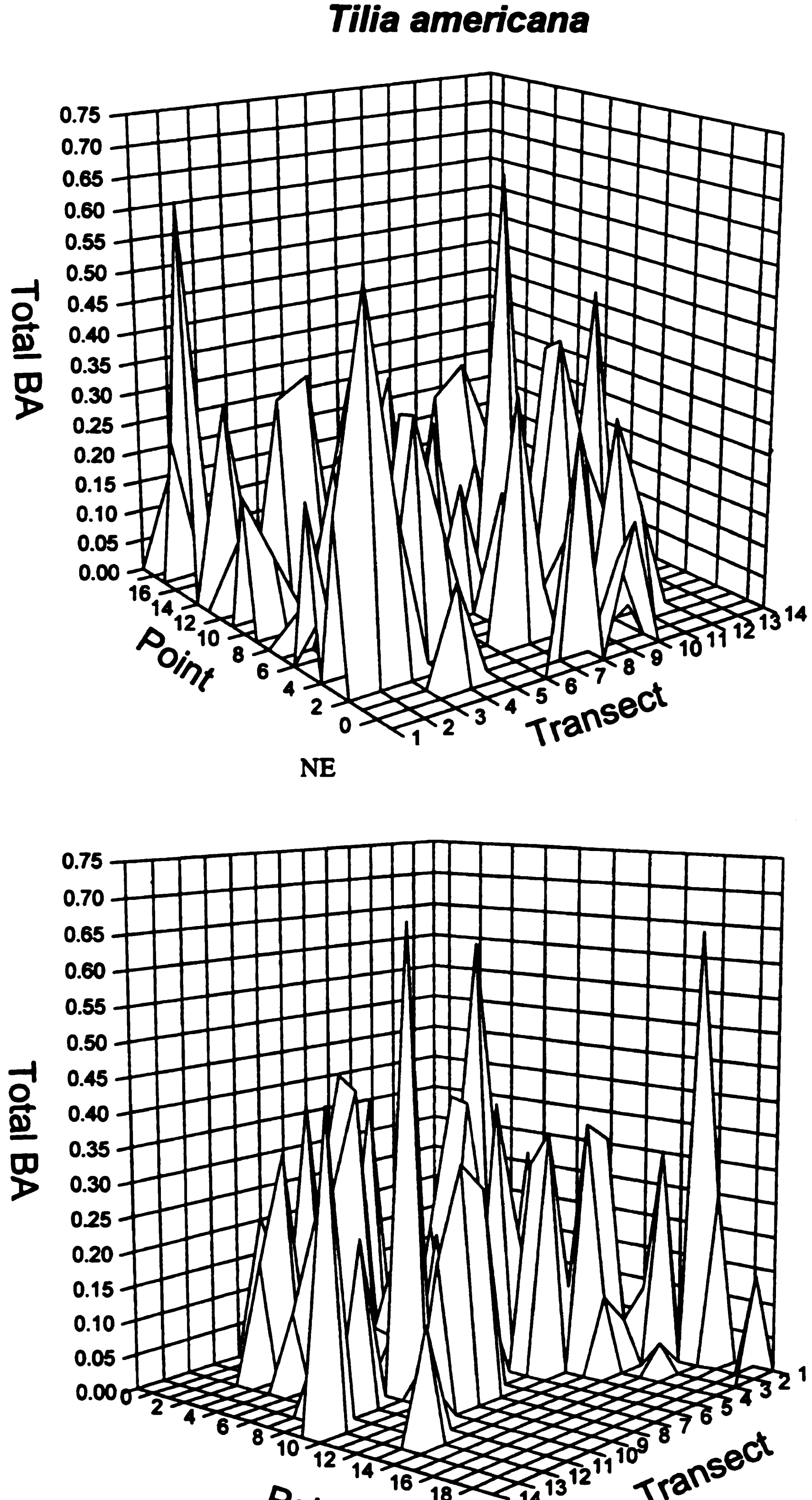


Figure 2.6c *Tilia americana* distribution

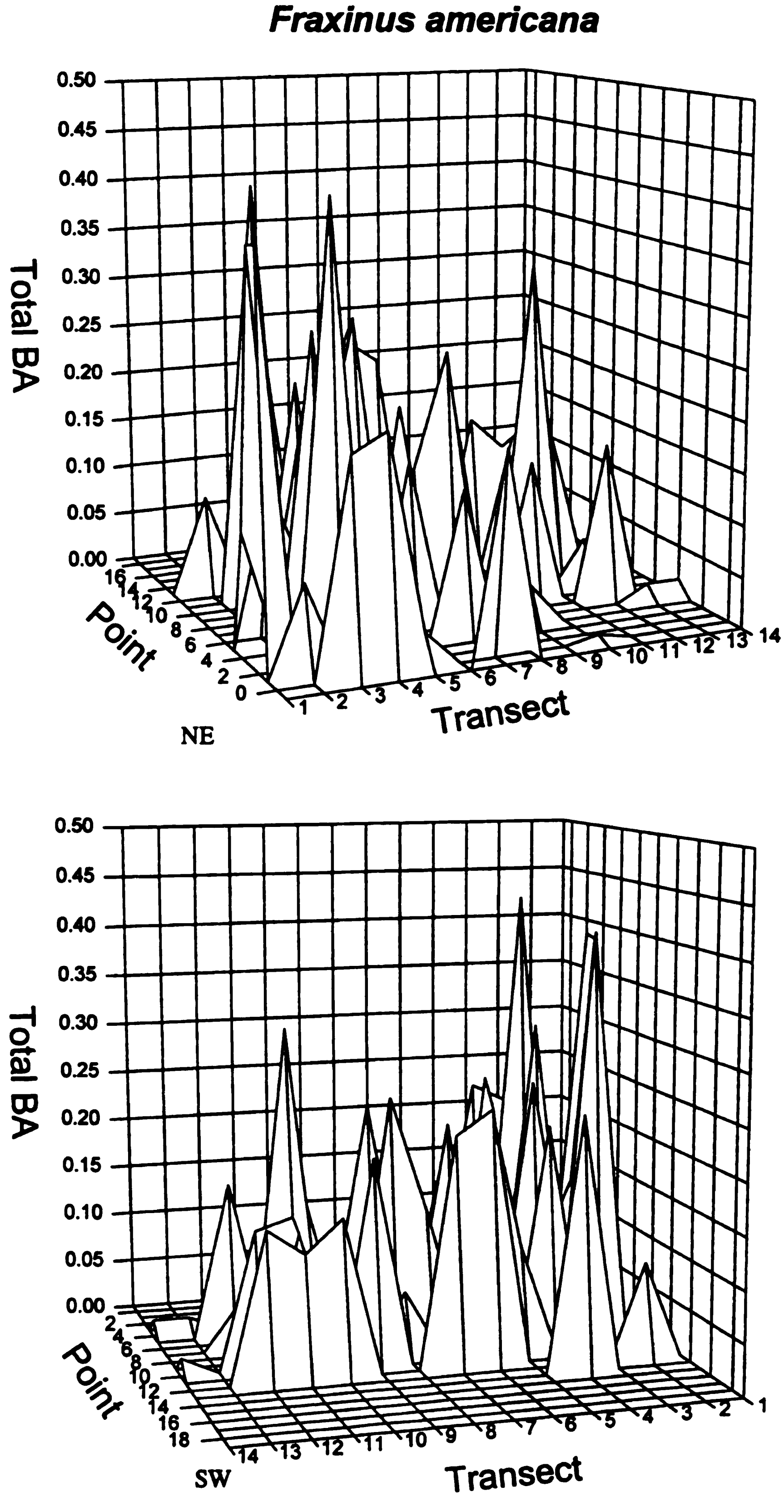
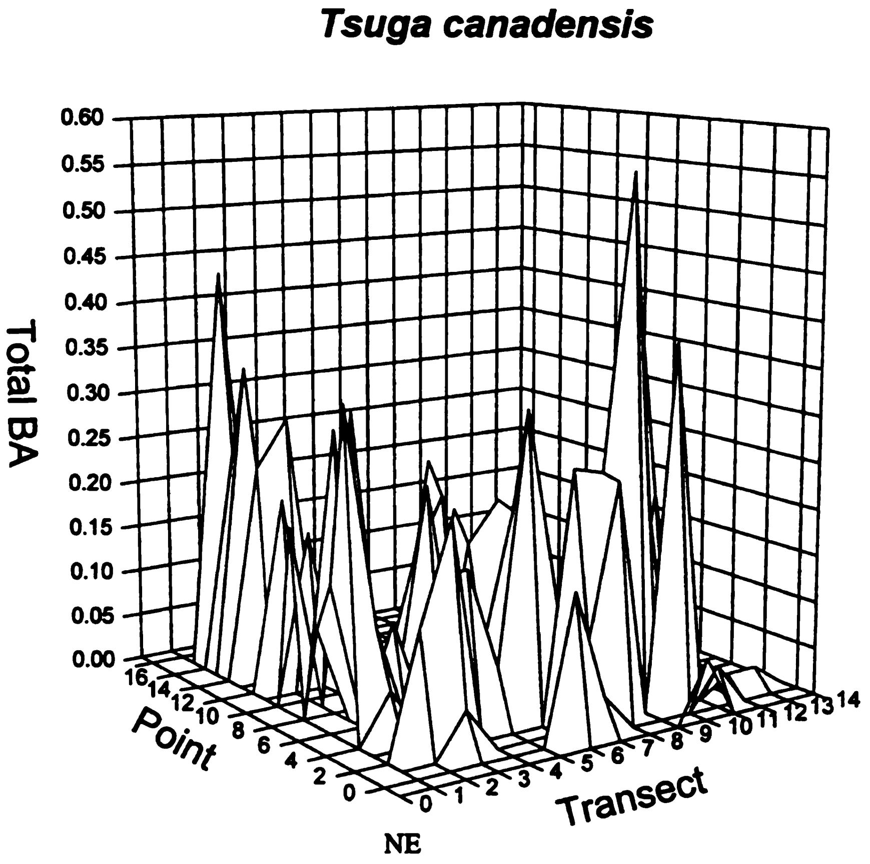


Figure 2.6d *Fraxinus americana* distribution



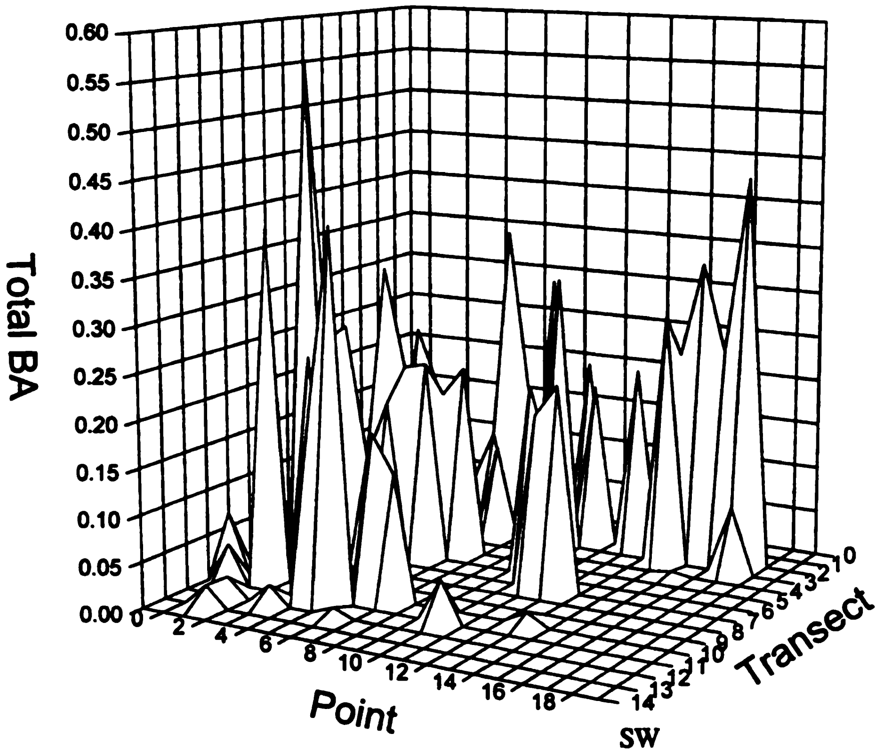


Figure 2.6e *Tsuga canadensis* distribution

Fagus grandifolia

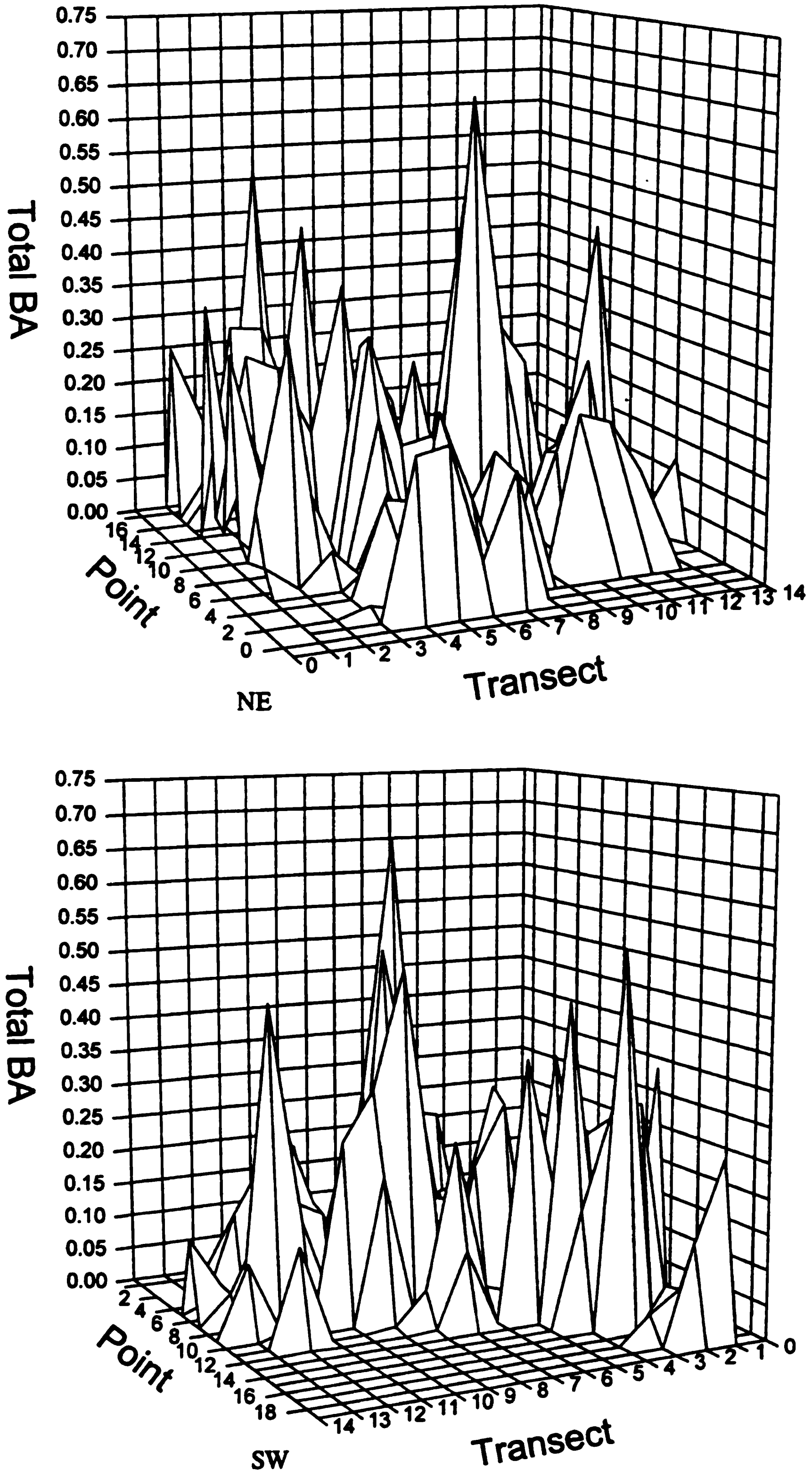


Figure 2.6f *Fagus grandifolia* distribution

Species Associations:

Species associations using pairwise comparisons are summarized in Table 2.2. Sugar maple saplings were positively associated with $\geq$ 10.0 cm dbh sugar maples, basswood, and beech, and negatively associated with $\geq$ 10.0 cm dbh ash and hemlock. Beech were positively associated with $\geq$ 10.0 cm dbh beech and red maple. No association was found between sapling sized beech and sugar maple or sapling sized beech and < 10.0 cm dbh hop hornbean.

Table 2.2 Pairwise comparisons of association were made using a 2x2 X^2 contingency analysis.

Pairwise Comparisons			P-value	Assoc.
≤ 9.9 cm dbh *Acer sac*	x	≥ 10.0 cm dbh *Acer sac*	< 0.01	+
≤ 9.9 cm dbh *Acer sac*	x	≥ 10.0 cm dbh *Fraxinus ame*	< 0.05	-
≤ 9.9 cm dbh *Acer sac*	x	≥ 10.0 cm dbh *Tilia ame*	< 0.01	+
≤ 9.9 cm dbh *Acer sac*	x	≥ 10.0 cm dbh *Tsuga can*	< 0.10	-
≤ 9.9 cm dbh *Acer sac*	x	≥ 10.0 cm dbh *Fagus gra*	< 0.01	+
≤ 9.9 cm dbh *Fagus gra*	x	≥ 10.0 cm dbh *Fagus gra*	< 0.01	+
≤ 9.9 cm dbh *Fagus gra*	x	≥ 10.0 cm dbh *Acer rub* *	< 0.05	0
≤ 9.9 cm dbh *Fagus gra*	x	≤ 9.9 cm dbh *Ostrya vir*	> 0.10	
≤ 9.9 cm dbh *Fagus gra*	x	≤ 9.9 cm dbh *Acer sac*	> 0.10	

* Invalid cross - 1 cell of contingency table was < 5

Tree Core Results

Hemlock and ash trees showed the most response, while sugar maple, beech, and basswood had less obvious response. The sample number (one sample = one individual), year cored, species, number of cores taken per sample, dbh, age of oldest core taken per sample, +/- intersection of the center, and number of missing rings in samples that were cross-datable are shown in Table 2.3. Cores varied in age by nearly 150 years from 45 to 191 years. The cores extracted from the beech and sugar maples were not close to the center, especially on the trees with a very large dbh.

Sixteen of the hemlock cores taken in 1996 and 1997 were used for the final composite (Figure 2.7a). The other hemlock cores were damaged and not useable for cross-dating due to missing core segments, inverted segments, or segments that were mounted out of order; 4 of the 10 cores obtained in August 1997 were too damaged to age. A number of high response years (1960, 1950, 1948, 1944, 1936, 1934, 1926, 1918, 1914, 1901, 1887, 1885, 1883, and 1881) showed up repeatedly in the core samples. The later years in the final composite provided a more robust representation of the hemlock chronology (see Figure 2.7b). The oldest core was used solely to develop the chronology for the first 65 years. Nine cores cross-dated (from samples 1, 2, 3, 4, and 5) back to 1881 and 13 cores (from samples 1, 2, 3, 4, 5, 7, and 15) cross-dated back to 1901. Missing rings were found in cores from samples 2, 4, and 5.

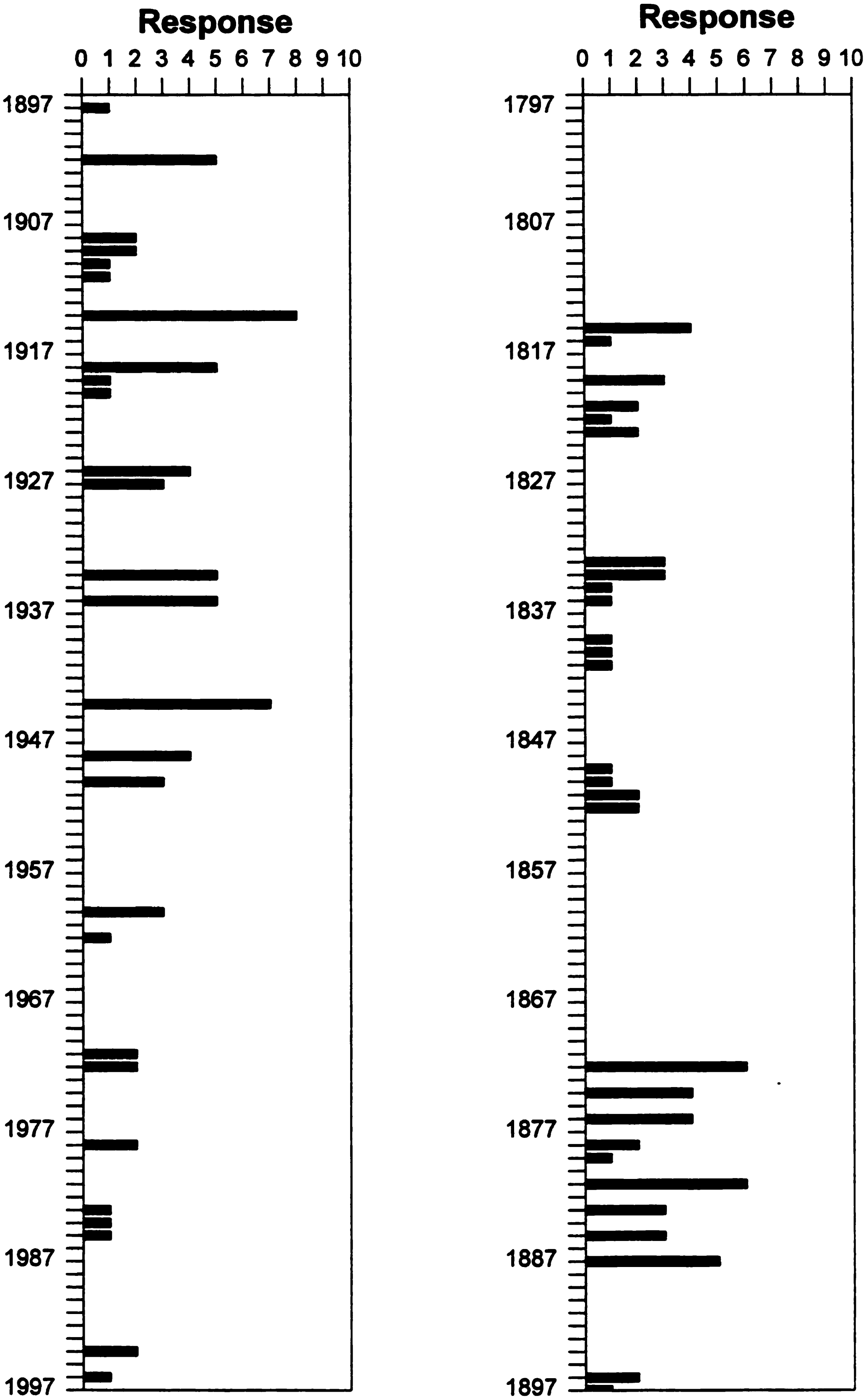
Table 2.3 Britt Woods tree cores 1996-1997.

Core	Year	Species	Cores taken	DBH	Age	Pith	Missing Rings
1	1997	*Tsuga canadensis*	2*	79	142	Y	0
2	1997	*T. canadensis*	4*	58	177	N	4
3	1997	*T. canadensis*	2*	66.2	140	N	0
4	1997	*T. canadensis*	2*	70	191	Y	1
5	1997	*T. canadensis*	2*	61.7	166	N	1
6	1997	*T. canadensis*	2*	53.2	93	N	-
7	1997	*T. canadensis*	3*	62.3	140	N	-
8	1997	*T. canadensis*	2	58.5	102	N	-
9	1997	*T. canadensis*	2*	58.1	135	N	-
10	1997	*T. canadensis*	2	74.6	142	N	-
11	1997	*T. canadensis*	1	77.3	119	N	-
12	1997	*T. canadensis*	2	60.5	146	N	-
13	1997	*T. canadensis*	1	71.5	108	N	-
14	1996	*T. canadensis*	1*	37.5	87	N	-
15	1996	*T. canadensis*	1*	56.3	105	N	-
16	1996	*Fraxinus americana*	1	34.3	67	Y	-
17	1996	*F. americana*	1	34	75	Y	-
18	1996	*F. americana*	1	24	45	Y	-
19	1996	*Tilia americana*	1	48.5	103	Y	-
20	1996	*T. americana*	1	25.5	77	Y	-
21	1997	*A. saccharum*	1	84	114	N	-
22	1996	*A. saccharum*	1	56.2	68	N	-
23	1996	*A. saccharum*	1	67	95	N	-
24	1996	*A. saccharum*	1	46.3	111	N	-
25	1996	*Fagus grandifolia*	1	65.7	105	N	-

(*) ≥1 core in sample was cross-datable

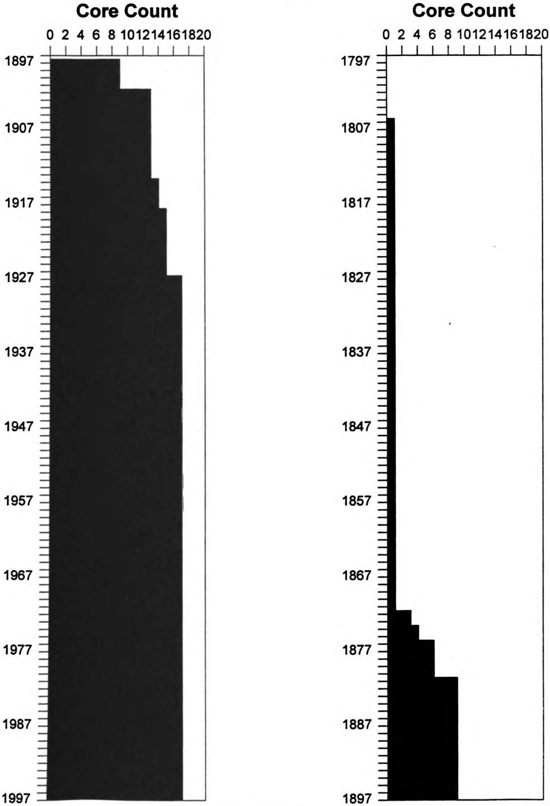
Cores obtained in 1996 have one year added to the actual ring count.

DBH taken in cm



*** Response refers to the amount of environmental stress which was measure by how narrow the ring was.**

Figure 2.7a Hemlock Chronology 1806-1997



*Core count shows the number of cores used to determine the hemlock chronology for each year.

Figure 2.7b Cores used in Hemlock Chronology

Understory Stratum

Importance:

Understory species are listed in descending order of importance for 1995 (Table 2.4a) and 1996 (Table 2.4b). Ash seedlings were the most important in 1995 and 1996. Ash seedlings were more than twice as important as the second most important species, *Viola canadensis*, in 1995. Ash seedlings were not as important in 1996 during the earlier season sampling. *Viola canadensis* and *Viola* spp. were second and third most important during both seasons. Sugar maple seedlings were fourth most important in 1995 and sixth in 1996. *Claytonia caroliniana* was not surveyed in 1995. However, in 1996 it was the fourth most important understory species. Figure 2.8 shows species that had $\geq$ 10% frequency in either 1995 or 1996. The fifteen species that had $\geq$ 10% frequency in 1995 or 1996, with a few exceptions, had similar rankings for importance. Sweet cicely (*Osmorhiza claytonii* (Michaux) C.B. Clarke) was ranked in the top ten for importance but had < 10% frequency. *Aster* spp. had a lower importance ranking compared to the $\geq$ 10% frequency value in 1996.

Table 2.4a Importance values for understory species, 1995. All 14 transects were sampled in June and July.

Species	**Importance**
Fraxinus americana	0.2377
Viola canadensis	0.0994
Viola spp.	0.0856
Acer saccharum	0.0578
Cyperaceae spp.	0.0550
Maianthemum canadense	0.0394
Tilia americana	0.0356
Acer rubrum	0.0299
Osmorhiza claytonii	0.0267
Hepatica acutiloba	0.0263
Galium spp.	0.0224
Viola rostrata	0.0197
Trillium spp.	0.0159
Actaea pachypoda	0.0147
Mitella diphylla	0.0145
Poaceae spp.	0.0137
Aster species A	0.0133
Aster spp. b (daast)	0.0132
Circaea alpina	0.0120
Aster spp. c (sol)	0.0112
Streptopus roseus	0.0111
Sanicularia gregaria	0.0101
Circaea lutetiana	0.0090
Viola pubescens	0.0084
Ostrya virginiana	0.0083
Rubus spp.	0.0078
Carpinus caroliniana	0.0076
Parthenocissus quinquefolia	0.0072
Prenanthes alba	0.0067
Prunella vulgaris	0.0052
Cystopteris bulbifera	0.0041
Fagus grandifolia	0.0035
Toxicodendron radicans	0.0032
Carya spp.	0.0032
Sapling b	0.0032
Hepatica americana	0.0025
Caulophyllum thalitroides	0.0025
Sapling a	0.0025
Laportea canadensis	0.0024

Table 2.4a cont.

Species	**Importance**
Amelanchia aborea	0.0023
Trientalis boriealis	0.0023
Athyrium filix-femina	0.0023
Crataegus spp.	0.0022
Vitis spp.	0.0020
Unknownc	0.0020
Popular spp.	0.0020
Botrichium virginianum	0.0019
Unknowna	0.0018
Viburnum acerfolium	0.0014
Arisaema triphyllum	0.0013
Pteridium aquilium	0.0013
Mitchella repens	0.0012
Anemone quinquefolia	0.0012
Medeola virginiana	0.0011
Tsuga canadensis	0.0011
Osmunda longistylis	0.0011
Equisetum arvense	0.0010
Geum aleppicum	0.0009
Unknown	0.0009
Geum canadensis	0.0008
Adiatum pedatum	0.0008
Matteuccia struthiopteris	0.0007
Boehmeria cylindrica	0.0007
Pyrola rotundifolia	0.0007
Ranunculus hispidus	0.0007
Sapling c	0.0007
Epipactis helleborine	0.0006
Sambucus racemosa	0.0006
Achillea millefolium	0.0006
Onoclea sensibillis	0.0006
Viola sororia	0.0005
Ulmus rubra	0.0004
Fragaria virginiana	0.0004
Ranunculus abortivus	0.0004
Monotropa uniflora	0.0004
Unknowne	0.0004
Unknowno	0.0004
Pyrola elliptica	0.0004
aththe	0.0004

Table 2.4a cont.

Species	**Importance**
Anemone canadensis	0.0003
Unknownb	0.0003
Equisetum sylvaticum	0.0003
Gymnocarpium dryopteris	0.0003
Osmunda claytoni	0.0003
Unknownm	0.0003
Agrimonia gryposepala	0.0002
Aquilegia candensis	0.0002
Arctium minus	0.0002
Boraginaceae spp.	0.0002
Dryopteris boottii	0.0002
Laminaceae spp.	0.0002
Pilea pumila	0.0002
Plantago rugelli	0.0002
Prunus serotina	0.0002
Thelypteris palustrus	0.0002
Unknownd	0.0002
Unknownf	0.0002
Unknownn	0.0002
Unknownp	0.0002
Asclepia ssp.	-
Cirsium vulgare	-
Claytonia caroliniana	-
Cornus alternifolia	-
Cornus canadensis	-
Cornus stonifera	-
Cryptotaenia canadensis	-
Epifagus virginiana	-
Galium circaexans	-
Galium triflorum	-
Goodyera pubescens	-
Impatiens capensis	-
Lonicera spp.	-
Lycopus uniflorus	-
Meminspermum canadense	-
Panax quinquefolium	-
Physocarpus opulifolius	-
Populus grandidentata	-
Populus tremuloides	-
Quercus spp.	-

Table 2.4a cont.

Species	**Importance**
Rubus hisbidus	-
Trillium gradiflorum	-
Uvularia perfoliata	-
Viola blanda	-
Viola conspersa	-

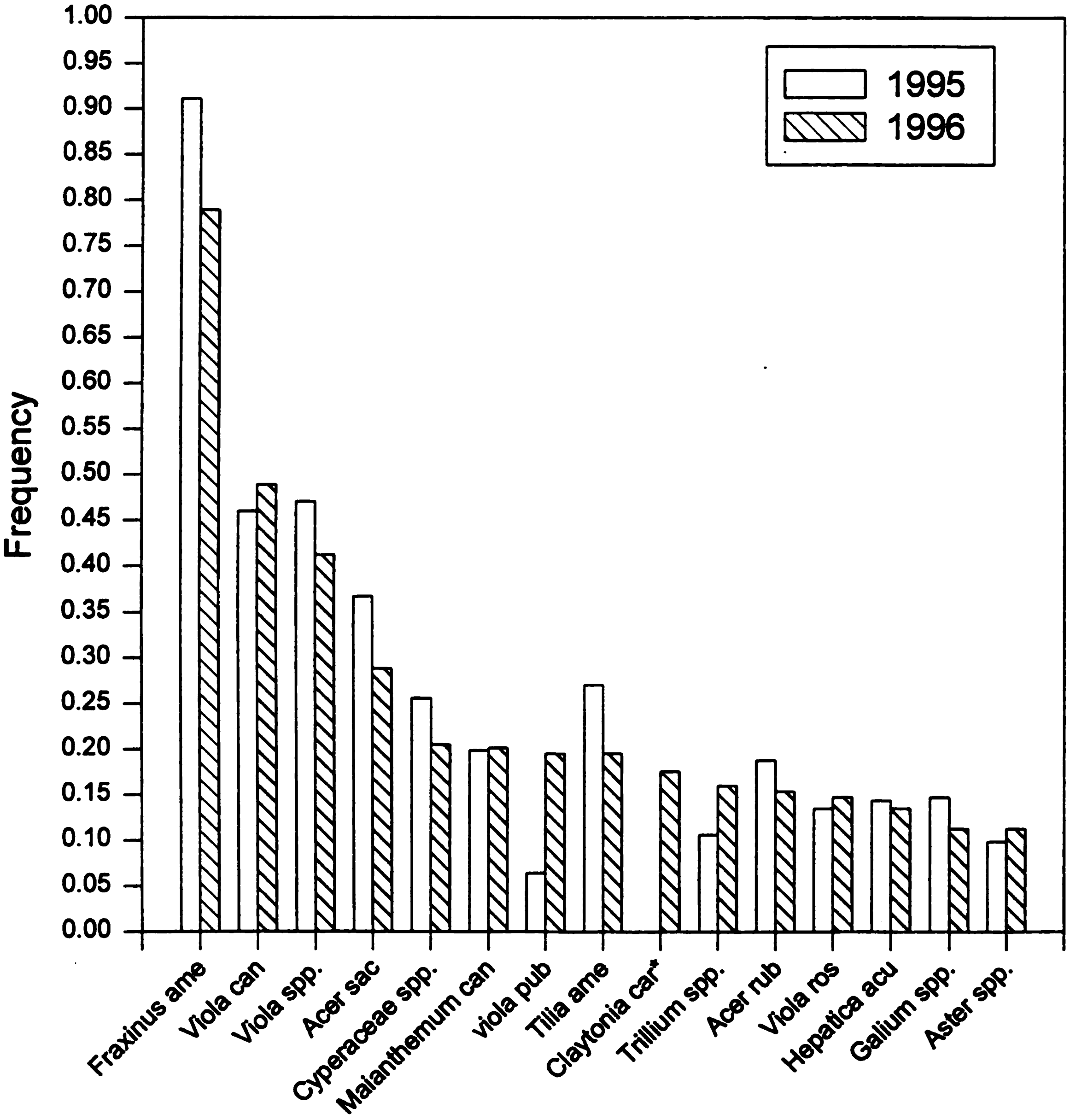
(-) Rare, infrequent, or early season species that occurred in Britt Woods are listed after the species that were sampled.

Table 2.4b Importance values for understory species, 1996. Transects 2, 4, 5, 6, 7, 8, 10, and 13 were sampled.

Species	**Importance**
Fraxinus americana	0.1650
Viola canadensis	0.1405
Viola spp.	0.0745
Claytonia caroliniana	0.0624
Cyperaceae spp.	0.0504
Acer saccharum	0.0434
Viola pubescens	0.0427
Maianthemum canadense	0.0407
Osmorhiza claytonii	0.0317
Tilia americana	0.0269
Trillium spp.	0.0258
Hepatica acutiloba	0.0257
Acer rubrum	0.0240
Viola rostrata	0.0221
Galium spp.	0.0190
Circaea lutetiana	0.0162
Aster spp. b (daast)	0.0160
Mitella diphylla	0.0132
Actaea pachypoda	0.0123
Aster spp. c (sol)	0.0096
Circaea alpina	0.0087
Athyrium filix-femina	0.0085
unknownh	0.0079
Prenanthes alba	0.0075
Cystopteris bulbifera	0.0071
Aster species A (astwi)	0.0067
Uvularia perfoliata	0.0066
Ostrya virginiana	0.0060
Fagus grandifolia	0.0054
Parthenocissus quinquefolia	0.0052
Carpinus caroliniana	0.0045
Laportea canadensis	0.0042
unknownl	0.0041
Carya spp.	0.0032
Trientalis boriealis	0.0032
Rubus spp.	0.0030
Viola sororia	0.0030

Table 2.4b cont.

Species	**Importance**
Sanicularia gregaria	0.0028
Rubus hisbidus	0.0026
Crataegus spp.	0.0025
Viola conspersa	0.0023
Prunella vulgaris L.	0.0022
Botrichium virginianum	0.0020
Ulmus rubra	0.0020
Anemone quinquefolia	0.0018
Amelanchia aborea	0.0017
Caulophyllum thalitroides	0.0017
unknown	0.0016
Vitis spp.	0.0016
Arisaema triphyllum	0.0016
Pilea pumila	0.0012
unknownq	0.0012
Toxicodendron radicans	0.0012
Claytonia virginica	0.0011
Poaceae spp.	0.0010
Pteridium aquilium	0.0010
Viburnum acerfolium	0.0010
Viola blanda	0.0009
Prunus serotina	0.0008
Ranunculus hispidus	0.0008
unknowna	0.0008
unknowni	0.0008
Adiatum pedatum	0.0007
Mitchella repens	0.0005
Osmunda claytoniana	0.0005
Aster spp.2	0.0004
Epipactis helleborine	0.0004
Onoclea sensibillis	0.0004
Physocarpus opulifolius	0.0004
Physocarpus opulifolius	0.0004
Tsuga canadensis	0.0004
unknownj	0.0004
unknownk	0.0004

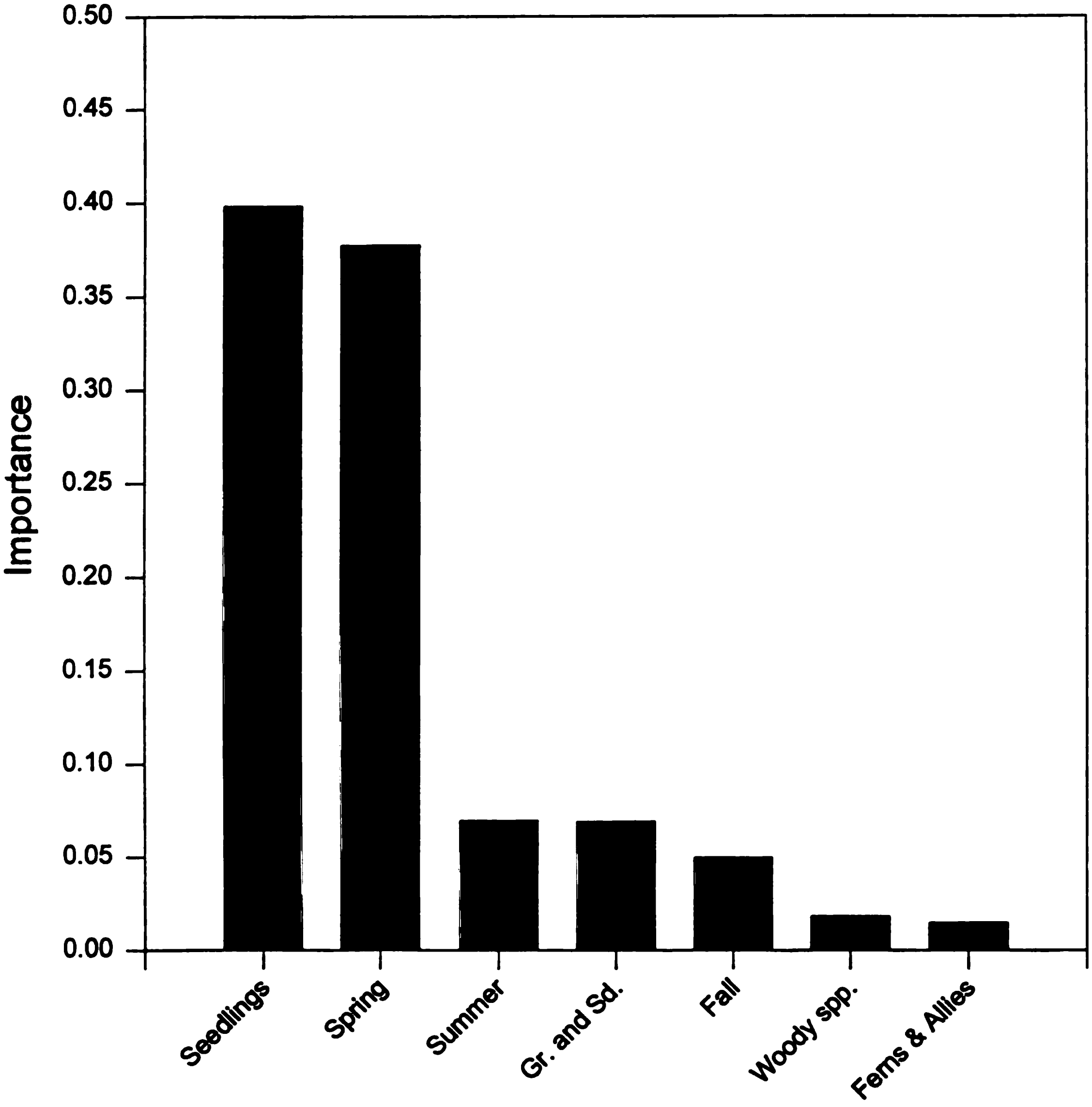


*** Claytonia caroliniana, an ephemeral, was not recorded in 1995 because sampling took place during June and July.**

Figure 2.8 Understory stratum species with > 10% frequency.

Ecological Guilds

The woody seedlings guild was the most important, followed closely by the spring flowering guild (Figure 2.9). The summer greens, grasses and sedges, fall flowering, woody species, and ferns and fern allies had importance values that were less than a fifth of woody seedling and spring flowering values. Asters accounted for the majority of the fall flowering and were found primarily in the second-growth section.



Seedlings (woody seedlings), Spring (spring flowering), summer (summer greens), Gr. and Se. (grasses and sedges), Fall (fall fowering), Woody spp. (woody species)

Figure 2.9 Importance values of ecological guilds for species within the understory stratum.

Blocked Areas

The abundance totals for blocked areas (see Figure 2.3) are shown on Figure 2.10a. Columns a through e (transects 1-10) are the old-growth section. Column f (transects 11 and 12) is the transition area from old to second-growth and column g (transects 13 and 14) is the second-growth area. Columns a through e tend to have lower coverage values than columns f and g. In columns f and g, 9 of the 10 blocks surveyed have abundance values > 1.5 m^2 (> 50% abundance) while only 8 of the 33 surveyed in columns a through e have abundance values that high. The species richness values for blocked areas in columns f and g also tend to be higher on average than blocked areas in columns a-e (Figure 2.10b). Species richness ranges from 22 to 38 in columns f and g with a mean of 29.1. In columns a through e species richness ranges from 17 to 27 with a mean of 19.5.

Diversity and evenness values of blocked columns (see Figure 2.3) reveal that there are changes from the old-growth section to the second-growth section (Table 2.5). Simpson's diversity index and the Inverted Simpson's Dominance are higher in the second-growth area (column g) than in the rest of woods. The Shannon-Weiner diversity index and evenness are slightly higher in column f (transects 10-11, the transition area from old to second growth) and column g. The number of species and total number of individuals sampled in column g was similar to the other columns, however only 12 m^2 were surveyed as compared to 18 to 21 m^2 in the other columns. Column f had the highest species richness.

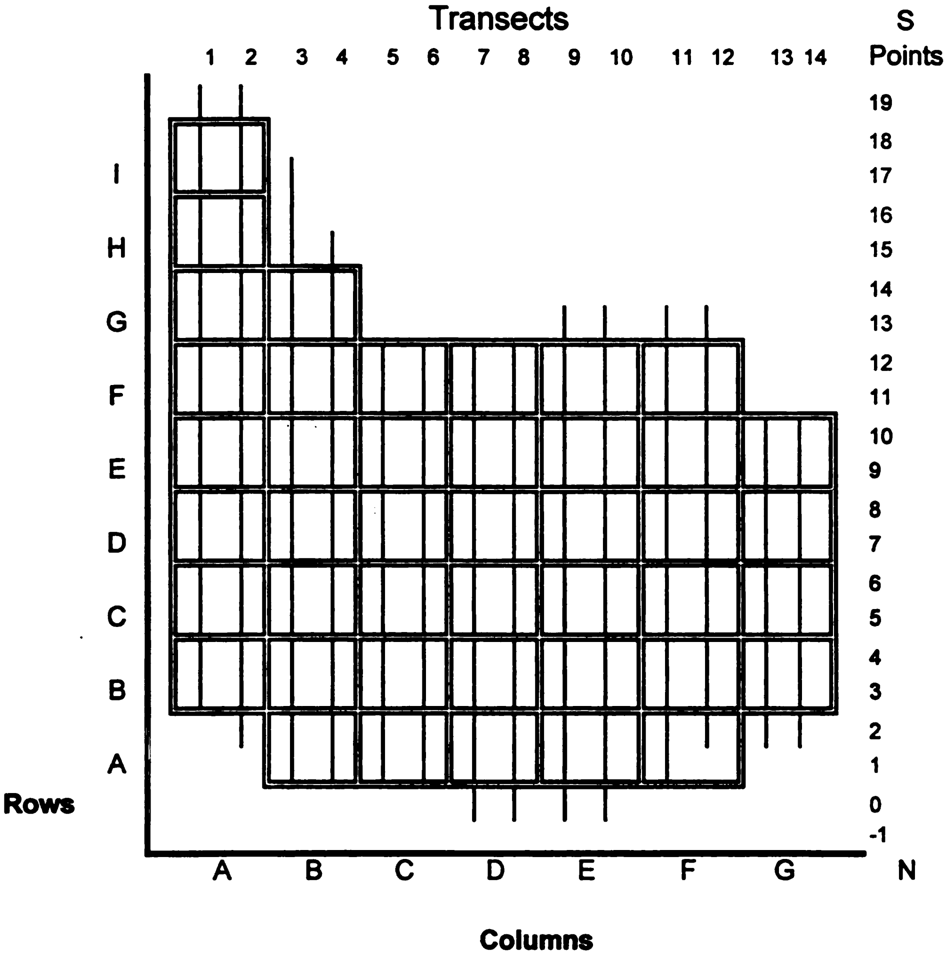
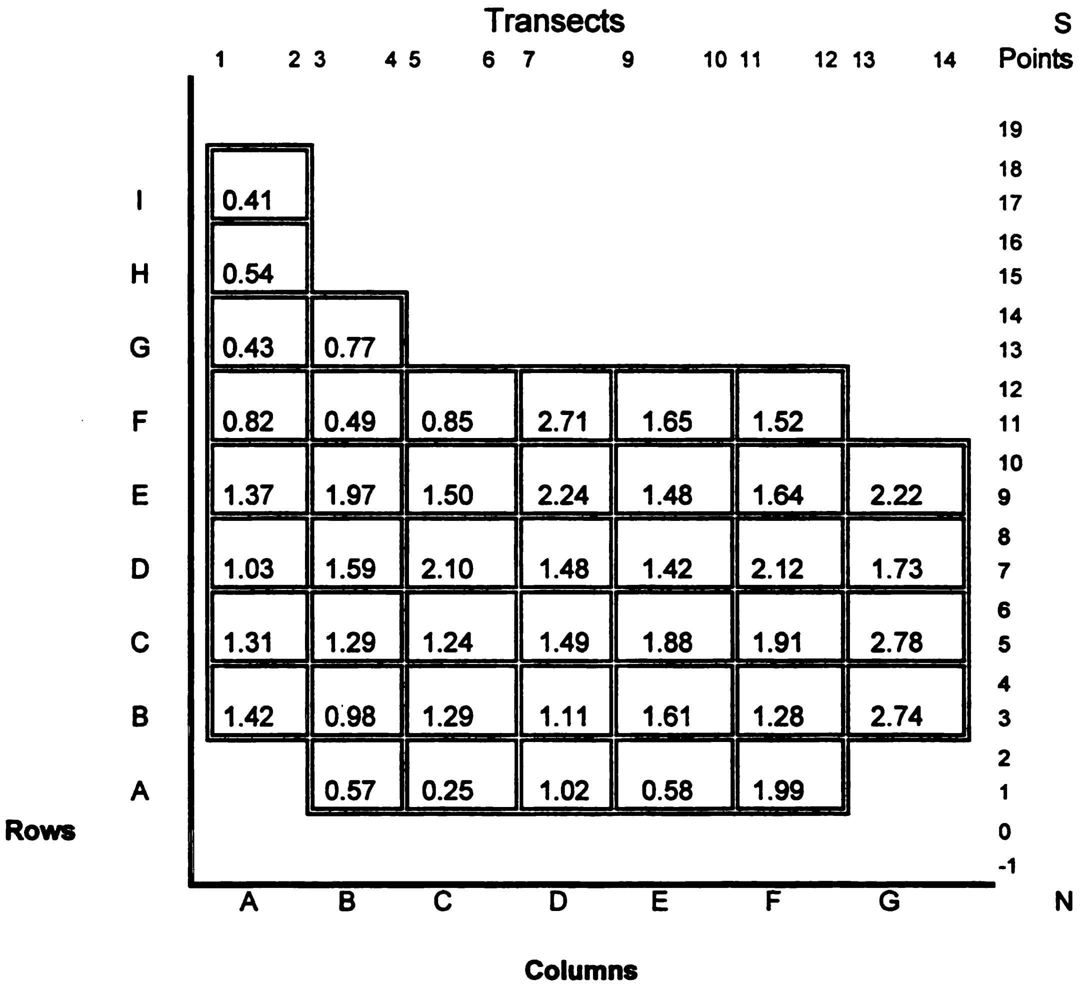
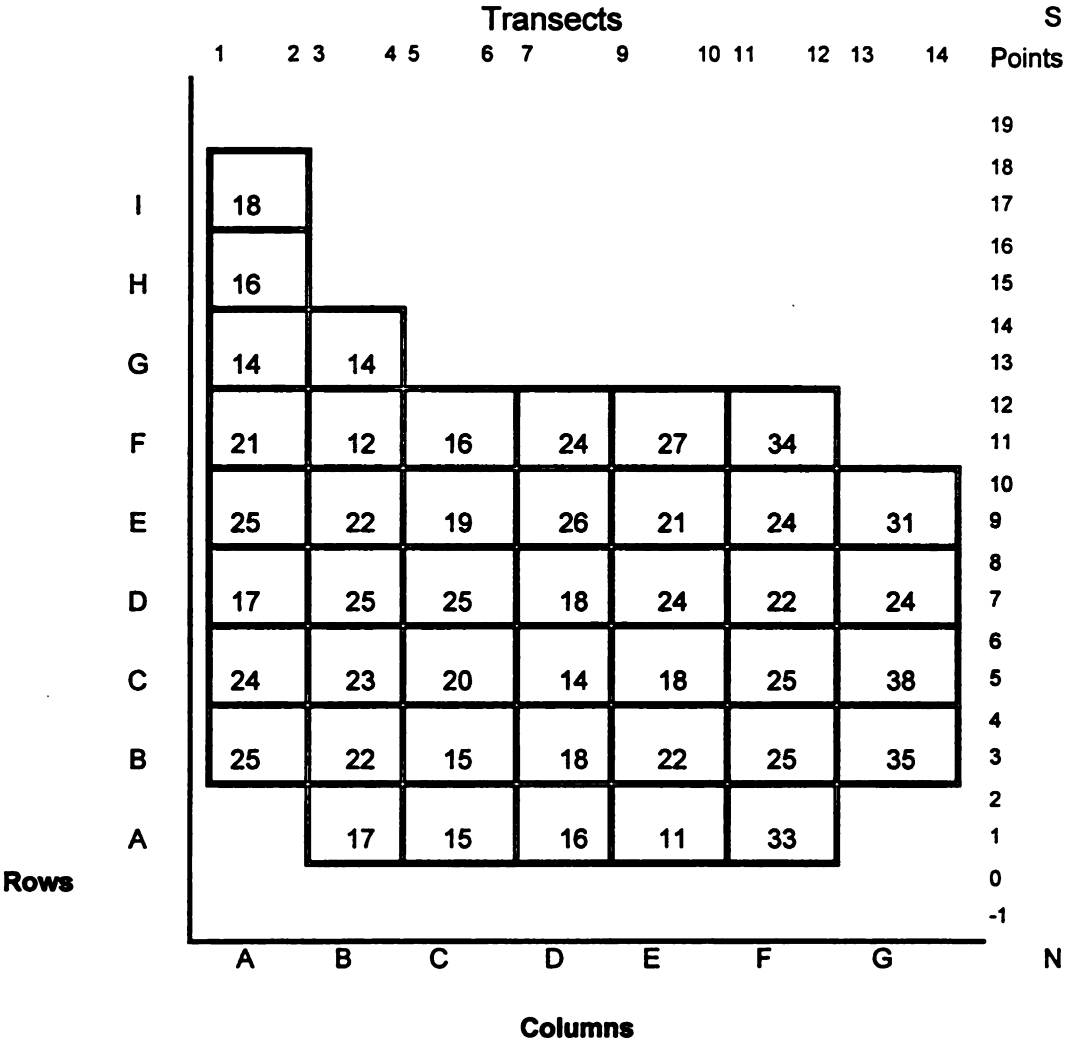


Figure 2.3 Blocked areas of Britt Woods. Each block is designated with a column (a-f) and row (a-h) label. Columns are formed by 2 transects (north to south) and rows are formed by 2 points (east to west). Blocks contain 12 quadrats = $3m^2$.



Rows	A	B	C	D	E	F	G
I	0.41						
H	0.54						
G	0.43	0.77					
F	0.82	0.49	0.85	2.71	1.65	1.52	
E	1.37	1.97	1.50	2.24	1.48	1.64	2.22
D	1.03	1.59	2.10	1.48	1.42	2.12	1.73
C	1.31	1.29	1.24	1.49	1.88	1.91	2.78
B	1.42	0.98	1.29	1.11	1.61	1.28	2.74
A		0.57	0.25	1.02	0.58	1.99	

Figure 2.10a Abundance values in m^2 for blocked areas in Britt Woods.



Rows	A	B	C	D	E	F	G
I	18						
H	16						
G	14	14					
F	21	12	16	24	27	34	
E	25	22	19	26	21	24	31
D	17	25	25	18	24	22	24
C	24	23	20	14	18	25	38
B	25	22	15	18	22	25	35
A		17	15	16	11	33	

Figure 2.10b species richness for blocked areas in Britt Woods.

Table 2.5 Diversity indices, species richness, number of individuals sampled, evenness, area in m^2 , and number of plots are listed for each column sampled in Britt Woods (see Figure 2.3).

	Columns							
	a	b	c	d	e	f	g	**Total**
Plots Sampled k	84	84	72	72	72	72	48	504
Area Sampled- m^2	21	21	18	18	18	18	12	126
Species Richness s	57	45	43	40	44	58	51	99
Total number of individuals N	1226	1267	1234	1697	1462	1769	1596	11160
Maximum Diversity H_{max}'	1.756	1.65	1.63	1.602	1.643	1.763	1.708	1.996
Evenness J'	0.673	0.68	0.58	0.632	0.615	0.696	0.73	0.621
S-W diversity index H'	1.182	1.13	0.95	1.013	1.011	1.227	1.246	1.24
Simp. Diversity index	0.851	0.86	0.78	0.81	0.786	0.862	0.911	0.866
Simp. Dominance	0.149	0.14	0.22	0.19	0.214	0.138	0.089	0.134
Inverted Simp. Dominance d_s	6.732	7.39	4.64	5.261	4.664	7.266	11.2	7.473

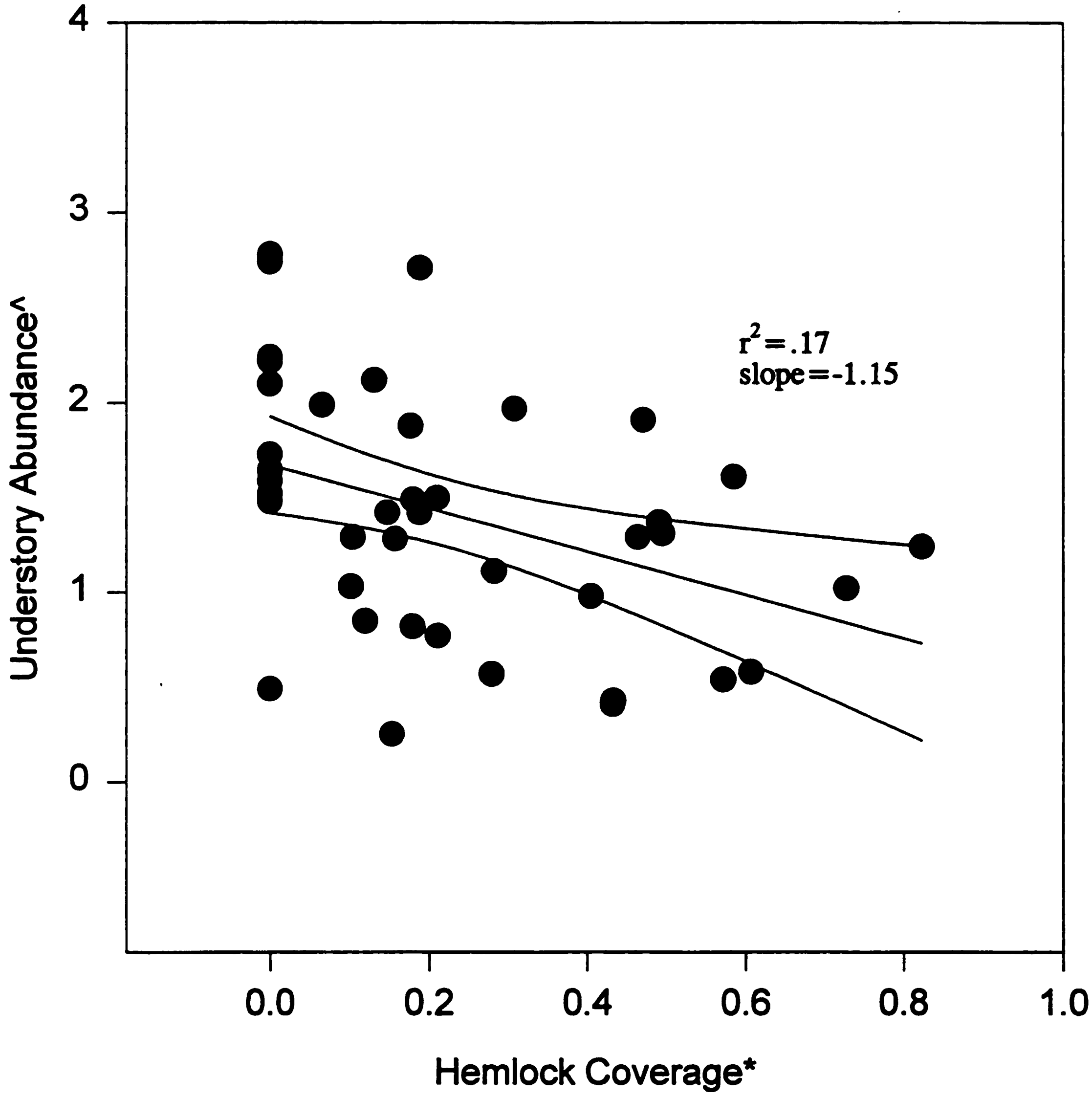
S-W = Shannon-Weiner
Simp.=Simpson's

A weak negative trend resulted from understory abundance regressed against hemlock coverage (total BA for each Block) with an r^2 value of .17 ($r=.4$, $p < .05$, $N=43$) (Figure 2.11). There was a decrease in understory abundance as hemlock coverage increased, the slope was - 1.15.

The correspondence analysis of blocks resulted in two distinct groupings (Figure 2.12). Group 1 is composed of second growth blocks- FA, FF, and GB-GE, and group 2 which was composed of the other 37 blocks. Group 2 had a linear distribution that correlates with column location. Blocks located in the eastern columns clustered closer to the upper right corner of quadrant 1, while blocks located in the western columns distibuted closer to the origin and upper right corner of quadrant 3.

The correspondence analysis of important understory species shows there are positive, negative, and neutral associations between understory stratum species (Figure 2.13). The fern group had the most obvious separation from the rest of the species. Red maple, *Galium* spp., and sedge spp. clustered off to the left, which showed a negative association with trillium, ash, sugar maple, and *Viola canadensis*. Table 2.6 contains a summary of associations between species.

Understory Abundance^



^Understory abundance is a measure in m^2 abundance per block
* Hemlock coverage is a measure of total BA in m^2 per block

Figure 2.11 Linear regression of hemlock coverage against understory abundance with 95% confidence.

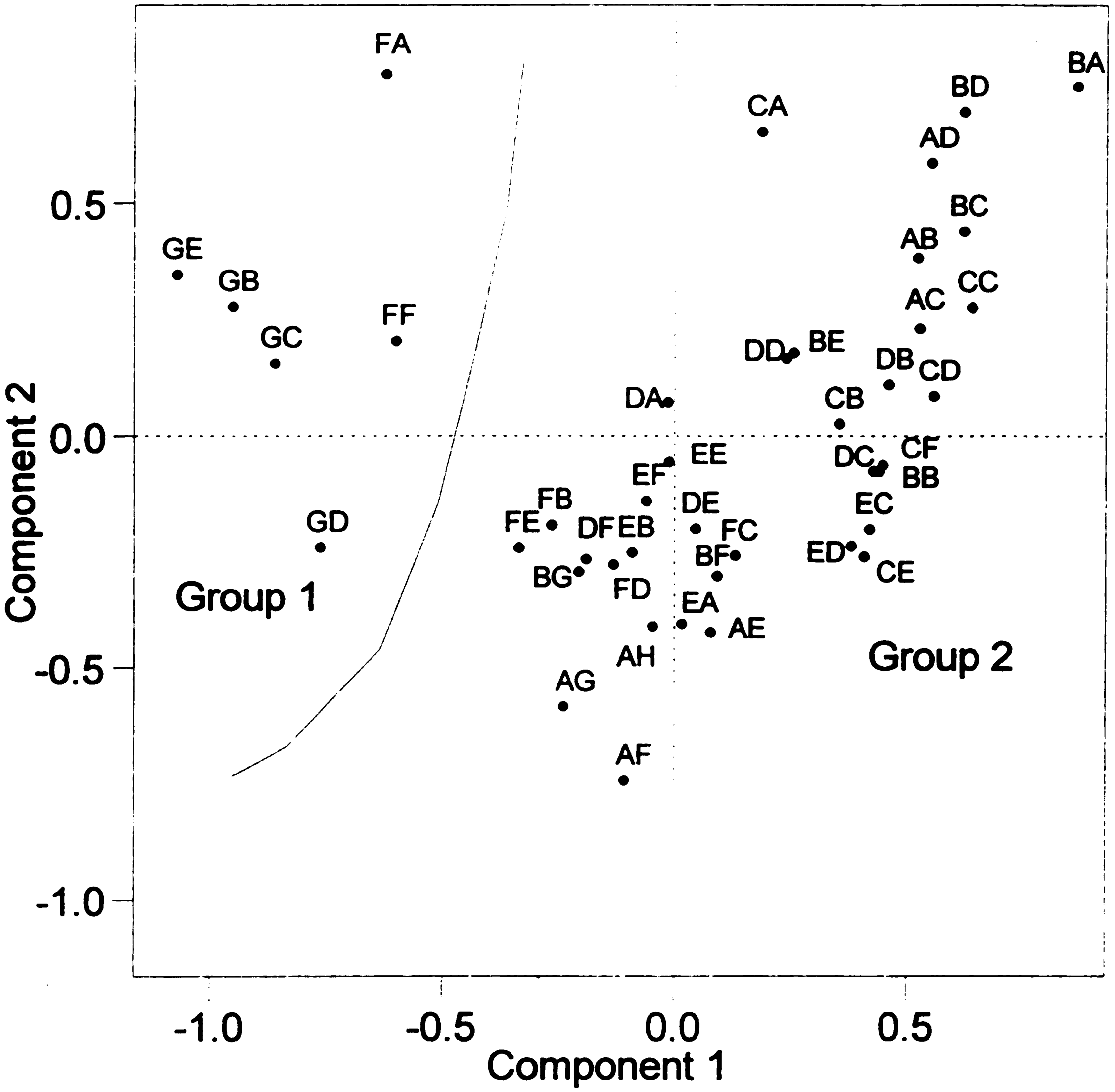


Figure 2.12 Correspondence analysis of blocks

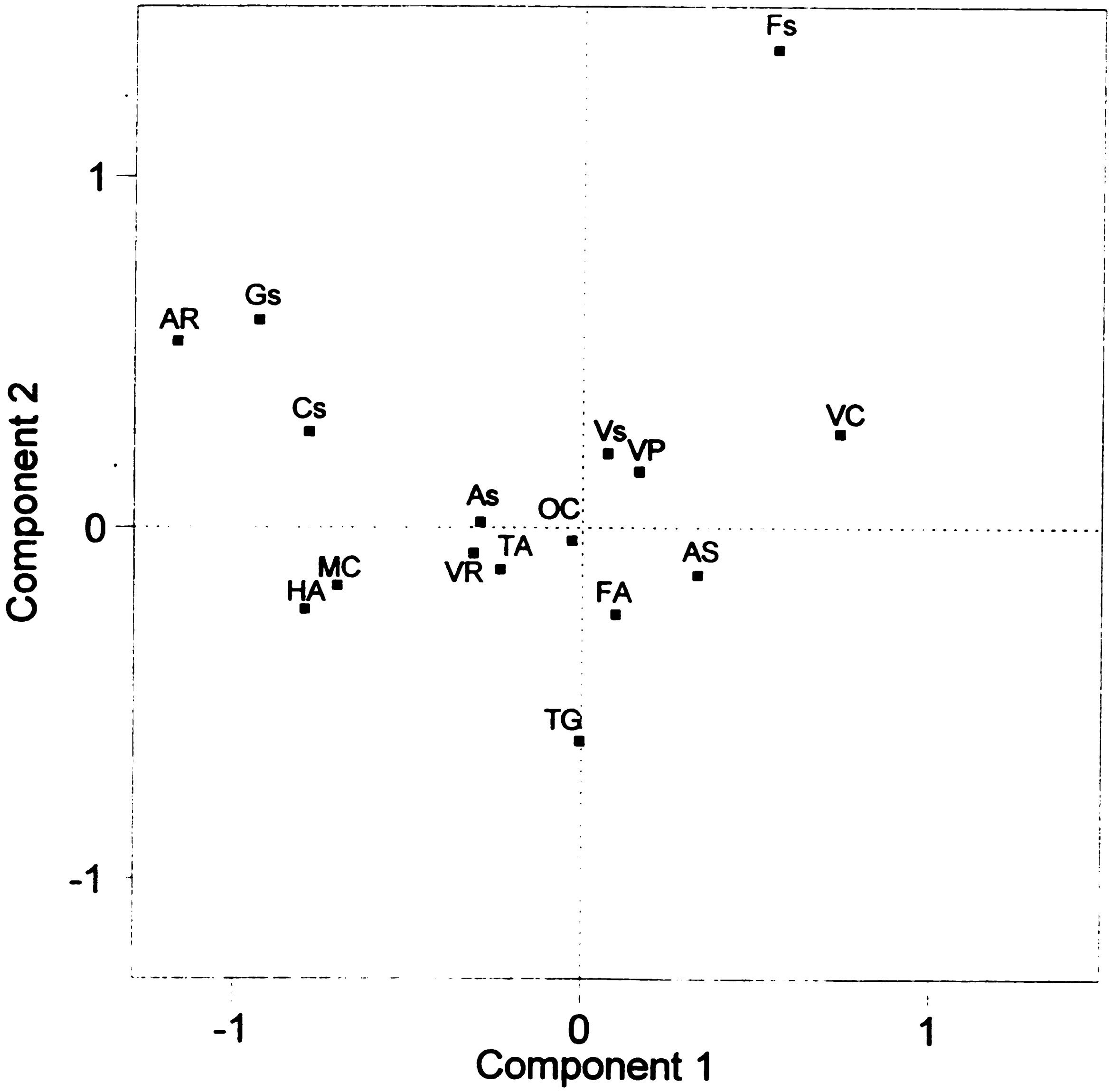


Figure 2.13 Correspondence analysis of species

Acer rubrum =AR, *Acer saccharum*=AS, *Aster* spp. =As, Cyperaceae spp.=Cs, Fern spp.=Fs, *Faxinus americana*=FA, *Galium* spp.=Gs, *Hepatica acutiloba*=H *Maianthemum canadense*=MC, *Osmorhiza claytonii*=OC, *Tilia americana*=TA, *Trillium grandiflorum*=TG, *Viola canadensis*=VC, *Viola pubescence*=VP. *Viola rostrata*=VR, *Viola* spp.=Vs.

Table 2.6 Species associations derived from the correspondence analysis of 16 dominant understory species (Figure 2.13).

	Acer rubrum	*Acer sacharum*	Aster spp.	Cyperaceae spp.	Fern spp.	*Fraximus americana*	*Gallium* spp.	*Hepatica acutiloba*	*Maianthmum canadense*	*Osmorhiza claytonni*	*Tilia americana*	*Trillium grandfolium*	*Viola canadensis*	*Viola pubescence*	*Viola rostrata*
Acer rubrum															
Acer sacharum	-														
Aster spp.	+	-													
Cyperaceae spp.	+	-	+												
Fern spp.			-												
Fraximus americana	-	+	-	-	-										
Gallium spp.	+	-	+	+		-									
Hepatica acutiloba	+	-	+	+	-		+								
Maianthmum canadense	+	-	+	+	-		+	+							
Osmorhiza claytonni	+		+	+	-	+	+	+	+						
Tilia americana	+	-	+	+	-		+	+	+	+					
Trillium grandfolium	-	+		-	-	+	-	+	+	+	+				
Viola canadensis	-	+	-	-	+		-	-	-	-	-	-			
Viola pubescence	-	+	-	-	+	-		-	-	-	-	-	+		
Viola rostrata	+	-	+	-	-		+	+	+	+	+	+	-	-	
Viola spp.			-		+	-	+	-	-	-	-	-	+	+	-

(-) = negative association
(+) = positive association
( ) = neutral association

Coarse Woody Debris Results

The coarse woody debris (cwd) sampling showed that there were 79.5 m^3/ha in the Britt Woods (Table 2.7). The majority of the CWD sampled was unidentifiable (15.24 m^3). Basswood was the highest identifiable species sampled (11.4 m^3/ha). About 1/3 of the woody debris sampled was in decay class V. Some of the woody debris samples were clean cut by a saw.

Table 2.7 Species, volume, and decay class for approximately 5% (3000m^2) of the woods.

	Decay Class*				
Species	II	III	IV	V	Total m^3/ha
Acer rubrum	1.58	0.00	0.00	0.00	5.26
Acer saccharum	1.61	0.00	0.00	0.00	5.35
Fagus grandifolia	0.55	0.00	0.00	0.00	1.83
Tilia americana	0.00	0.00	3.80	0.00	12.56
Tsuga/Pinus	0.00	0.85	0.00	0.00	2.82
Tsuga canadensis	0.17	0.00	0.10	0.00	0.90
Unknown	0.04	5.62	1.90	7.67	50.77
Total m^3/ha	13.2	21.5	19	25.6	79.49

* See Table 2.1a for a description of decay classes.

Soil Pedon Analysis Results

Soil Pit A had loamy A horizons with 15 cm depth; wetter loam, clay loam, or clay B horizons with 35-45 cm depth; drier more sandy, C horizons with 55-65 cm depth (Table 2.8a). The south and east soil pedons were C_r (soft rock that can be shoveled) horizons made up of a whitish, gypsum like material. Soil Pit B had drier loamy A horizons with 15 cm depth, drier loamy B horizons with 30-45 cm depth, and gravelly sandy loam C horizons with 60-70 cm depth (Table 2.8b). Soil Pit C, which was excavated from the spring pond on the western side of the woods, had organic O horizons with 10-13 cm depth and clay loam B horizons with 25-50 cm depth. Gleying and bright mottles were prominent in soil pit C (Table 2.8c).

Table 2.8a Soil pit A was located on a mound near transect 3 and point 9 on the northeastern side of Britt Woods.

Soil Pit A				
Ord.*	Depth	Horizon	Color	Texture
North	15 cm	A	10 YR 3/1	loam
	45 cm	B	7.5 YR 5/2	clay loam
	60 cm	C	10 YR 4/3	sandy clay loam
South	15 cm	A	10 YR 3/1	loam
	35 cm	B	10 YR 5/3	loam
	55 cm	C_r	10 YR 5/4	gravelly loamy sand
East	15 cm	A	10 YR 3/1	loam
	35 cm	B	10 YR 5/3	loam
	65 cm	C_r	10 YR 5/4	gravelly loamy sand
West	15 cm	A	10 YR 3/1	loam
	45 cm	B	7.5 YR 4/4	clay
	60 cm	C	10 YR 4/3	sandy clay loam

* Ord.- the direction in the pit from which the soil pedon was excavated.

Table 2.8b Soil pit B was located in a pit near transect 6 and point 11 on the south-central side of Britt Woods.

Soil Pit B				
Ord.	Depth	Horizon	Color	Texture
North	15 cm	A	10 YR 3/3	loam
	45 cm	B	7.5 YR 2/2	loam
	70 cm	C	10 YR 5/4	gravelly sandy loam
South	15 cm	A	10 YR 3/2	loam
	45 cm	B	7.5 YR 4/4	loam
	70 cm	C	10 YR 5/4	gravelly sandy loam
East	15 cm	A	10 YR 3/2	loam
	40 cm	B	7.5 YR 2/2	loam
	65 cm	C	10 YR 5/4	gravelly sandy loam
West	15 cm	A	10 YR 3/2	loam
	30 cm	B	7.5 YR 4/4	loam
	60 cm	C	10 YR 5/4	gravelly sandy loam

* Ord.- the direction in the pit from which the soil pedon was excavated.

Table 2.8c Soil pit C was located in the spring pond on the west side of Britt Woods near Transect 10 and between points 12 and 13.

Soil Pit C				
Ord.	Depth	Horizon	Color	Texture
North	10 cm	O	10 YR 2/0	organic
	50 cm	B	10 YR 5/3^	clay loam
South	13 cm	O	10 YR 2/0	organic
	25 cm	B_g	10 YR 6/0^	clay loam

^ bright mottles

* Ord. - the direction in the pit from which the soil pedon was excavated.

Discussion

The oldest core, of 191 years and forest structure suggests the Britt Woods is old-growth, however, only 2 other cores were 150+ years. Some of the other hemlock trees may have been older, but it was impossible to determine since the pith was not extracted. It is probable that the beech and sugar maple populations contain more individuals in older age classes than the hemlock. The thick branches on some of the larger sugar maple and beech indicate there may be some very aged individuals in Britt Woods.

The age of the cores did not appear to correlate with dbh. Tyrell and Crow's 1995 study of 25 old-growth hemlock-hardwood stands showed similar results. Tree diameter was not a good predictor for stand age; some trees with a small dbh were quite old, while other trees with a large dbh were not very old. Interestingly, 4 out of the 6 stands that were > 275-300 years showed there was a significant correlation between age and dbh.

The importance values, average dbh, and size class distributions suggests that the Britt Woods is succeeding from a mixed hemlock-hardwood stand to a beech-maple stand. This trend most likely will continue, unless some sort of catastrophic or anthropogenic disturbance occurs. Similar trends have been observed in other northern forest stands located in Michigan and Wisconsin (Anderson and Loucks 1979, Frelich and Lorimer 1985, Alverson et al. 1988, and Parshal

1995).

Sugar maple is the dominant tree species in every size class measured in the canopy stratum. The notably high value for relative density and lower relative dominance and frequency values indicates there is some clumping and the majority of individuals are in smaller size classes. The high importance value of trees in the sapling size class, low average dbh, and steeply descending monotonic size class distribution suggests the population is growing. The peak in the 5-9.9 cm dbh size class could be due to canopy suppression. Younger trees growing in gaps would have a comparable dbh to older trees suppressed by the canopy. Sugar maples are shade tolerant, but eventually need a canopy release in order to produce enough photosynthate to survive (Barnes and Wagner 1981). Most young trees are continuously suppressed by the dense canopy which can cause mortality. This constant suppression accounts for the dramatic decrease in the 10-14.99 cm dbh size class.

Sugar maple seems to be slowly moving into the second-growth area. The northwest corner appears to be at an earlier stage of succession, which explains the complete absence of sugar maple. The average dbh of trees $\geq$ 10 cm, in the northwest corner, was 23.2 cm (point quarters that contained no sugar maple include 12.1-3, 13.1-3, and 14.1-2). Sugar maple seedlings were an important part of the understory stratum though out the old-growth section. However, competition with red maple could be slowing the second-growth colonization process since fewer sugar maple seedlings were found in this area. This explains why the red maple and sugar maple seedlings were negatively associated in the correspondence analysis of species. The lower abundance of sugar maple in the northeast corner may have been caused by the edge effect, moister soil conditions, and or competition with ash. However, the correspondence analysis showed ash and sugar maple seedlings were positively associated. Ash, which can germinate in variable conditions, and sugar maple seedlings were prolific throughout the old-growth section.

The negative association between sapling-sized sugar maples and mature hemlock is probably caused by hemlock induced localized site conditions. Hemlock needles cause heavy shading and acidify the soil. High acidity leaches soil of important nutrients and minerals necessary for many species to survive (Barnes and Wagner 1981). Sugar maple has been shown to have a strong negative association with hemlock trees in mixed forests, but a neutral association in largely hardwood communities (Frelich et. al. 1993). The weak negative association between canopy size-class hemlocks and sapling size-class sugar maples might have had a more significant P-value if hemlocks and hardwoods were more evenly distributed.

The population of beech in the Britt Woods, although not demographically balanced, is apparently increasing at a slower rate than the sugar maple. The beech sapling size class importance value, 33.1 cm average dbh, and size class distribution support this conclusion. The cyclic distribution of beech trees could have been caused by various factors such as storm damage and varying seed years. After a storm, a cohort of root sprouting beech would mature quickly if parent trees were destroyed. Root sprouting is apparently responsible for the exceptionally high level of association ($P < 0.01$) between mature and sapling sized trees. It is also possible that one or two good seed years could have occurred with an interval of many poor seed years in between. However, variable seed years are less likely to cause a cyclic effect than storm damage. Beech trees are known to have a good seed crop only intermittently and will more often reproduce by root sprouting (Voss 1985). The few seedling sized beech trees observed in 1995 and 1996 were sprouts.

As with sugar maple, beech was abundant throughout most of the old-growth but apparently have not had time to colonize the second-growth area. Beech would probably not have survived the fire 80 years ago since they are highly susceptible to fire damage because of their thin bark and shallow root systems. Beech are slow growing shade tolerant trees that need drier upland soils (Barnes and Wagner 1981).

Currently, red maple seems to have a demographically balanced population. The importance of red maple saplings and right skewed size class distribution suggests the population is maintaining itself at present. However, few trees in the 1-4.9 cm size class suggests the future of red maples may be problematic.

Red maples are fast growing, moderately long lived, moderately shade tolerant, and aggressive colonizer in upland, disturbed, and swampy areas (Barnes and Wagner 1981). The average dbh is small since red maples are medium sized trees that grow to 50-80 cm dbh. Populations of red maple in North America have naturally increased with levels of disturbance (Barnes and Wagner, 1981). The red maple's ability to colonize disturbed areas explains the high abundance of this species in the second-growth section. As was mentioned earlier, the red maple seedlings were an important part of the second-growth understory stratum.

Interestingly, the red maple population of canopy, sapling, and seedling size individuals was higher among the hemlocks on the northern section than in most other areas. The moister soil in the north-central area would have provided safe-sites for red maples, a facultative wetland species. In addition, there is less competition from sugar maples. Unlike sugar maple, a hemlock overstory does not have a negative effect on red maple seedlings (Frelich et. al. 1993).

The few red maples measured in the 1-4.99 cm size class may be due to increased deer browsing. Browsing on woody species is a common occurrence during the winter, but less frequent in the growing season (Canham et al., 1994). The availability of resources like light and nutrients can directly influence seedling survival. Shade tolerant seedlings that store a high percent of their photosynthate in their root system rather than the shoot have a better chance of regenerating after browse damage (Canham et al., 1994). One study showed shade grown red maples have a small reduction in growth due to summer browsing, while winter browsing actually enhances summer shoot growth (Canham et al., 1993). In contrast, sun grown red maples did not respond as well as the shade grown seedlings to browse damage. Sporadic late spring and early summer browsing had more severe effects on red maple than the constant dormant season browse.

The red maple population will most likely sustain itself on the Britt property although continued presence in the old-growth section may be questionable.

The basswood population may decrease in the future even though the current importance value is only slightly less than that of beech. The highly left skewed size class distribution, very high average dbh, and extremely low importance in the sapling size class indicate that the basswood population is demographically unbalanced and definitely diminishing. Interestingly, basswood seedlings were an important part of the understory statum throughout the old-growth. It is possible browse damage may be hindering the basswood population. The high dominance could be due to the presence of coppice individuals. The higher relative frequency, as compared to red maple, ash, and hemlock, indicate that basswood has a more even distribution. However, basswood do not appear to be as well dispersed in the areas where hemlock dominate (the north and eastern side) or the second-growth section on the western side.

The ash population also appears to be decreasing. The unimodal size class distribution, average dbh, and low importance value in the sapling size class indicate that the ash trees are demographically unbalanced. Like the basswood, the ash are an important understory species. Ash seedlings and small saplings were the most important and widely dispersed understory species during both sampling years, yet very few 1 to < 10 cm dbh ash saplings were observed. Ash is moderately shade tolerant and needs gaps to grow. There were numerous gaps covered with small ash saplings and seedlings that most likely need a further canopy release. Some of the gaps have been covered with small repressed ash saplings for many years (H. and W. Britt pers.com. 1995). Ash trees are primarily browsed during the summer unlike many other woody species. Summer browsing may further obstruct seedlings and saplings from growing. Carbohydrate reserves are necessary to survive low light levels and mend any browse damage. Less common fall browsing has been shown to have a more negative effect than summer browsing (Canham et al. 1994). Similarly to beech, the varied size class distribution may have been due to the release of different cohorts after a storm.

Ash has a patchy distribution that appears to be related to moisture availability. Ash has been declining in the north eastern United States since 1925 due to drought, air pollution, and infection by mycoplasma-like organisms associated with the disease "ash yellows" (Miller et al. 1989, Sinclair et al. 1990, and Woodcock et al. 1993). Climate, in addition to light and browse damage, may be preventing ash saplings from maturing. Ash can establish in drier sites but may not survive through prolonged drought years (Woodcock et al. 1993). Woodcock et al., 1993, found that ash trees had a better chance of surviving in lowland, moist, nutrient rich sites than in more upland areas.

The population demographics of the hemlock suggests that continued survival in the Britt Woods is problematic. Unlike ash and basswood, hemlock seedling recruitment is very poor. Hemlocks were more important in the Great Lakes region during the last century (Eckstein 1980). The disappearance of hemlocks from stands in the Great Lakes region is a common occurrence that concerns ecologists. In contrast to beech and maples, hemlocks have not been able to recolonize or maintain their population. Exclosure studies in Michigan and Wisconsin suggest that browse damage on young hemlocks is the limiting factor (Anderson and Loucks 1979, and Alverson et. al 1988). Hemlocks do not have the adaptive advantage of being able to resprout when damaged, like hardwoods (Braun 1950). Other ecologists have hypothesized that there are numerous limiting factors working at the regional level. Hemlock reproduction is asyncronous between stands. The internal dynamics of each stand determine when the hemlocks will reproduce and there is evidence that it can occur as rarely as every 10-20 years (Graham 1941, Hough and Forbes 1943, Hett and Loucks 1976). Logging and the tanning industry have limited the seed source. In addition, hemlock seedlings are highly susceptible to desiccation (Gadman and Lancaster 1990). Seedlings germinate on rotting wood which holds moisture, or on mineral soil. Localized microtopography can also determine potential safe sites for hemlocks. Hardwood leaves that have accumulated in pits can smother germinating hemlock seedlings (Hilaire and Leopold, 1995). Moss covered mounds and rotting logs and stumps provide better safe sites for colonization (St. Hilaire and Leopold, 1995). Hardwood dominated stands maintain positive feedbacks; hardwood seed banks continue to be sustained while soil properties and nutrient cycles are further altered with deciduous leaf litter (Mlaindenoff and Stearns 1993).

In the Britt woods, seedling recruitment was very poor and few seedlings were observed in 1995 and 1996. Exclosures would need to be set up to determine if deer are the limiting factor. Reproduction first needs to take place to conclude whether herbivory is having a serious impact on the hemlock population.

Lack of suitable safe sites, in the Britt Woods, may also be a limiting factor for hemlock seedling germination since only 79.5 m^3/ha of CWD was sampled. This is slightly lower in comparison with Tyrell and Crow's, 1994, results. Tyrrell and Crow studied 25 hemlock-hardwood stands that were dominated (>50% basal area) by hemlocks in northern Wisconsin. The results showed that the average volume of CWD < 200 years was 84.5 m^3/ha and 150-200 m^3/ha for older stands. Hemlock trees accounted 22.9 m^3/ha of CWD in the younger stands and 50-75 m^3/ha in the older stands. Only 3.72 m^3/ha of CWD sampled was hemlock in the Britt Woods. A lower value for hemlock CWD would be expected because hemlocks did not dominate in the Britt Woods. However, 3.72 m^3/ha probably is not an accurate representation since the six randomly located CWD sampling plots did not fall close to the northern or eastern boundary of the Britt Woods where hemlock dominated. In addition, other factors may have altered the CWD results; selective logging was done for firewood and the CWD sampling area was only 0.3 ha in the Britt Woods while Tyrrell and Crow's 25 stands were 0.5-100.8 ha.

Natural soil heterogeneity may have facilitated the heavy colonization of hemlocks in the northern and eastern sections of the Britt Woods. As was pointed out earlier, hemlock dominated soils are moist, acidic, and low in nutrients which often deters hardwood seedlings from establishing.

The hemlock's response to stress made it possible to cross-date this species. Ring widths were variable on all of the cores due to internal stand dynamics; suppression and release, aging of the tree, and climatic conditions. Cross-dating filtered out rings that were suppressed due to stand dynamics and age. Hemlocks require moister conditions and were most likely stressed during drier years (Barnes and Wagner 1981). Signature years (high response years) 1934 and 1936, which occurred during the drought dust bowl, were seen on all 16 cores. Signature years were also used to determine missing rings in some of the core samples. Missing or locally abscent rings occur during extremely dry years (Smiley and Stokes 1967).

The forest floor stratum was spatially heterogenous in the Britt Woods. Species populations and guilds varied in frequency and abundance throughout the woods. Certain blocks showed patterns of similarity in species composition, richness, diversity, and abundance while other blocks were notably different. Positive, negative, and neutral association occurred between important species or family groups.

The ability of a species to germinate, mature, reproduce, and distribute seed in a forest habitat, like the Britt Woods, is influenced by the following environmental and physiological factors: light availability, litter type and quantity, microtopography, moisture levels, climate, stem flow, pH, soil type, nutrient status, competition, pathogens, mycorrhizal fungi and other soil microflora, herbivory, catastrophic disturbances, and individual reproductive rates and dispersal mechanisms (Curtis 1959, Hicks 1980, Thompson 1980, Sydes and Grime 1981, Hemstrom and Franklin 1982, Romme 1982, Maguire and Forman 1983, Beatty 1984, Crozier and Boerner 1984, Collins 1990). Many plants find ways of compensating for their individual limitations. As was pointed out earlier, ash compensated for shade intolerance by mass seed dispersal and the ability to germinate in variable conditions. Many forest floor species take advantage of the early spring light availability even though flowering in early spring can be problematic for insect pollinated flowers during cold years. Violets, which were highly important in the Britt Woods, remedy poor insect pollination years with cleistogamous reproduction (Zomlefer 1994).

The woody seedling guild easily dominated since the category was composed of various important canopy sized species like ash, basswood, red maple, and sugar maple. All of these species have high reproductive rates and efficient wind dispersal mechanisms. The spring flowering ecological group was represented by various important vernal species like violets, trillium, spring beauty, and wild lilly of the valley (*Maianthemum canadense* Desf.). Nutrient poor soil, slow litter decomposition rates, short growing seasons, and evergreen shading can limit spring ephemeroids and spring flowers in northern forests (Rogers 1982). The region around the Britt Woods is far enough south to maintain rich soil and a dominant deciduous canopy. These conditions enabled the spring flora to prosper, although spring beauty was the only ephemeroid species.

The divergent range of importance values represented for guilds might have differed if the understory species canopy coverage was measured. The actual importance value for summer greens, grasses and sedges, and particularly ferns and fern alies may have been altered due to sampling methods. Abundance rather than coverage was determined by abundance of stems. One stem covering 6.25 cm^2 (1% coverage of the plot) was equal to numerous stems covering the same 6.25 cm^2. Species that had bunched stems at the base and a large canopy, like ferns, were poorly represented. Similarly, those species with single stems and small canopies, like some seedlings, were over represented. The stem abundance method was chosen because forest floor stratum canopy coverage is difficult to measure accurately. Canopy coverage estimation values can vary greatly between field researchers. Mature forests naturally have a sparse shrub layer which explains the low importance value for the woody species guild.

The -0.60 slope value for understory abundance regressed against hemlock coverage suggests there is a negative relation between hemlock coverage and understory abundance. The r^2, of .17 ($r=.41$, $p < .05$, $N = 43$), indicates there is a weak relationship between hemlock and understory abundance. The coefficient of determination, r^2, measures the relative strength of the corresponding regression, or how much of y (the dependent variable) is explained by variation in x (the independent variable) (Freund and Wilson, 1993). None of the blocks had pure hemlock coverage, although the understory abundance directly under the dense evergreen branches was usually sparse. Other localized environmental factors, previously discussed, may have caused variation in understory abundance. Many plots fell under deciduous trees or gaps rather than hemlocks. Plots in the southeast and south central section of the woods had low abundance under hemlock and hardwood canopies. Varied topography, which was more evident in this section of the forest, may have altered understory abundance. Similar correlations between hemlock coverage and understory abundance have been documented in comparable forest systems

(Rogers 1982).

Hemlock covered forest floor stratum do not have a distinct species composition, but certain species tend not to do as well under hemlock as compared to deciduous canopy coverage. Often species that are common under hardwoods become rare under hemlocks, while few species prefer hemlock coverage to hardwood coverage (Rogers 1980). No obvious visual difference in species composition was noted in the Britt Woods between hemlock and deciduous coverage.

The open canopy of the second-growth section in columns f and g (see Table 2.5a), may have caused the dense understory abundance to develop. Columns f and parts of g contained both secondary and mature forest species. This ecotone effect, combined with the higher light levels, could have resulted in the higher species richness values, evenness values, and diversity indice values in columns f and especially g (See Table 2.5c). Relative species abundances were the most similar in column g since evenness was closest to 1. Species diversity indices are a measurement of richness and evenness. In the second-growth section, the Simpson's diversity index was relatively higher than the Shannon-Weiner index because it reflects dominance and therefore is less sensitive to rare species (Barbour et. al. 1987).

One rare species that occurred in Britt Woods was wild ginseng (*Panax quinquefolium* L.). Ginseng is a threatened species that was over collected for medicinal purposes during the 1800's (Gilmore 1977). Two species of orchids: *Goodyera pubescens* ((Willd.) R. Br.) and *Epipactis helleborine* ((L.) Crantz), an exotic, were also recorded.

In the correspondence analysis of the understory, 2 separate groups showed there was a distinct species compositional difference between the second-growth and old-growth portions of the Britt Woods. The environmental factor causing blocks to separate along component 1 is probably light (-1.0 - 1.0 = high to low light intensity). The canopy in the second-growth section was more open under aspen, red maples, white birch (*Betula papyifera*, Marshall), and other hardwoods than in the old-growth. Blocks AE-AH, BF, and BG, located near 0.0 on component 1, were close to the edge in a more open section of the woods. Another possible cause for the distribution could be age, since the second-growth section was burned 80 years ago. Blocks AC, AD, BA-BC, and DB, which clustered closer to 1.0, were found under higher hemlock coverage than most other blocks. As was noted earlier, species composition is not distinct under hemlock trees, but relative population sizes can differ which most likely affected the distribution pattern of hemlocks in the correspondence analysis (Rogers 1980).

There is an environmental gradient causing the linear pattern of group 2. Topography, which was more varied in the eastern section, may have caused the linear pattern in group 2. Soil type, drainage, or nutrient availability are other possible causes.

The correspondence analysis of forest floor species showed there were positive, negative, and neutral associations between species. Ferns, which were highly negatively associated with a number of other species, often grow in large homogenous patches. The fern canopy and subterrainium rhizomes compete efficiently for resources. Ferns may also be allelopathic. Red maples, *Galium* spp., and sedges were more important in the second-growth than old-growth section. Sugar maple, ash, and trillium were found predominantly in the old-growth section which accounts for their negative association with red maple. *Hepatica acutiloba* (DC.) and *Maianthemum canadense* (Desf.) appear to have similar habitat requirements; both species are found in rich soils. *Maianthemum canadense* can be found in aspen groves (Smith 1966). Both species were more dominant in the western portion of the woods where aspen is more important. *Viola rostrata* (Pursh.) was negatively associated with *V. pubescens* (Aiton) and *V. canadensis* which is reflective of their habitat requirements. *Viola rostrata* needs more calcareous conditions than *V. pubescens* or *V. canadensis* (Smith 1966). *Hepatica acutiloba* which associated near *V. rostrata*, is also found in calcareous rich woods (Smith 1966). Component 2 may be moisture related since red maples, ferns, and some sedges, located close to 1.0, are found in moister conditions, while sugar maple and basswood, located close to the origin, are not. Component 1 may be a light gradient (-1.0 - 1.0 = high to low light intensity) since species that dominated the second-growth open canopy section like red maple, *Galium* spp. and Cyperaceae spp. clustered close to -1.0 and shade tolerant species such as ferns and the Canadien violet distributed closer to 1.0. However other gradients, or a combination of other gradients could have caused the species distribution in the correspondence analysis.

The soil pedons, not surprisingly, had varied horizons with different textures, colors, and widths. This variability was most likely due to a number of factors including: continuous random tree falls, different rates of leaching due to topography, diverse plant material biodegrading into humus, and glacial history. The non-sorted and stratified material in soil pit A (Table 2.7a) was deposited by lacustrine beach or outwash. The proximity to Lake Huron's ancient shorelines and dune-like topography on the east sides make lacustrian beach a likely parent material. Gleying and bright mottles in the south pedon indicated there was standing water for part of the year.

Conclusion

The Britt Woods is an old-growth hemlock hardwood remnant that has had some moderate disturbance. The Britts have removed snags for fire wood and a few other trees through the years. Some white pine did exist in the stand prior to the logging era and was most likely removed before the Britts owned the property. It is probable that some of the largest pitchified stumps were white pine rather than hemlock. Most of the hemlocks cored were < 150 years, which indicates the individuals were present prior to the presumable date of logging. The stumps came from trees that were extremely large and conceivably older than the oldest hemlocks in the stand at present. The highly degraded condition of the stumps and hand saw marks indicates these trees were removed long ago. The removal of the white pine from the stand may have released the hemlock. As was stated earlier, the beech and sugar maple probably have older individuals in their population. The large dbh and very thick branches suggests some of the trees are 200+ years old.

My objective of providing a quantitative and qualitative survey of the Britt Woods was met in the second chapter. The canopy dominants differed in abundance, localized distribution, size class distribution, and pairwise associations throughout the old and second-growth sections of the woods. Current population demographics show the Britt Woods is succeeding from a mixed hardwood-hemlock stand to a beech-maple stand. Exact cause(s) of succession in the Britt Woods and many other stand remains questionable. The understory stratum species showed patterns of association and had a variable composition and abundance throughout the woods. Possible factors affecting understory stratum species distribution include light, moisture, topography, canopy coverage, and forest age.

This research project provided valuable information on the current condition of a very rare habitat in Michigan and the U.S. Current structure, composition, and potential future changes are comparable to other old-growth systems. The population of hemlocks, bass, and ash, in the Britt Woods, is diminishing. Stand dynamics in the Britt Woods and other similar stands may have been altered significantly since pre-settlement times. Further research is necessary to determine what factor(s) are causing these alterations at the localized and regional level.

Literature Cited

Alverson, W. S., D. M. Waller, and S. L. Solheim. 1988. Forests too deer: Edge effects in Northern Wisconsin. Conservation Biology. 2:348-359.

Anderson, R. C., and O. L. Loucks. 1979. White-tail deer (*Odocoileus virginianus*) influence on structure and composition of *Tsuga canadensis* forests. Journal of Applied Ecology. 16:855-861.

Barbour, M. G., J. H. Burk, and W. D. Pitts. 1987. Terrestrial Plant Ecology. The Benjamin/Cummings Publishing Company, Inc. Menlo Park, California, USA.

Barnes, B. V., and W. A. Wagner. 1981. Michigan Trees. The University of Michigan Press, Ann Arbor Michigan, USA.

Beatty, S. M. 1984. Influence of microtopography and canopy species on spatial patterns of forest understory plants. Ecology. 65:1406-1420.

Braun, E. L. 1950. Deciduous Forests of Eastern North America. The Blakinson Company, Philadelphia, Pennsylvania, USA.

Britt, H. and W. Britt. Interview with author, Turner, Michigan, 22 July 1995.

Brower, J. E. and J. H. Zar. 1977. Field and Laboratory methods for General Ecology. Wm C. Brown Company Publishers, Dubuque, Iowa, USA.

Canham, C. D., J. B. McAninch, and D. M. Wood. 1994. Effects of the frequency, timing, and intensity of simulated browsing on growth and mortality of tree seedlings. Canadian Journal of Forest Research. 24:817-825.

Collins, S. L. 1990. Habitat relationships and survivorship of tree seedlings in hemlock-hardwood forest. Canadian Journal of Botany. 68:790-797.

Curtis, J. T. 1959. The vegetation of Wisconsin. University of Wisconsin Press, Madison, Wisconsin, USA. Collins, S. L. 1990. Habitat relationships and survivorship of tree seedlings in hemlock-hardwood forest. Canadian Journal of Botany. 68:790-797.

Crozier, C. R. and Ralph E. J. Boerner. 1984. Correlations of understory herb distribution patterns with microhabitats under different tree species in a mixed mesophytic forest. Oecologia. 62:337-343.

Eckstein, R. G. 1980. Easten hemlock (*Tsuga canadensis*) in north central Wisconsin. Research Report 104. Wisconsin Department of Natural Resources, Madison Wisconsin.

Frelich, L. E., and L. G. Lorimer 1985. Current and predicted long-term effects of Deer browsing in hemlock forests in Michigan, USA. Biological Conservation. 34:99-120.

Frelich, L. E., R. R. Calcote, and M. B. Davis. 1993. Patch formation and maintenance in an old-growth hemlock-hardwood forest. 74:513-527.

Freund, R. J., and W. J. Wilson. 1993. Statistical Methods. Harcourt Brace Jovanovich, Publishers, Boston, Mass., USA.

Gilmore, M. R. 1977. Uses of Plants by Indians of the Missouri River Region. University of Nebraska Press, Lincoln, Nebraska, USA.

Godman, R. M., and K. Lancaster. 1990. *Tsuga canadensis* (L.) Carr. eastern hemlock. pages 604-612 in R. M. Burns and B. H. Honkala, coordinators. Silvics of North America. Agriculture Handbook 654. Forest Service, U.S. Department of Agriculture, Washington, D.C.

Graham, S. A. 1941. Climax forests of the Upper Peninsula of Michigan. Ecology. 22:355-362.

Henstrom, M. A., and J. F. Franklin. 1982. Fire and other distrubances of the forests in Mount Rainier National Park. Quaternary Research. 18:32-51.

Hett, J. M., and O. L. Loucks. 1976. Age structure models of balsam fir and eastern hemlock. Journal of Ecology. 64:1029-1044.

Hicks, D. J. 1980. Intrastand distribution patterns of southern Appalachian cove forest herbaceous species. American Midland Naturalist. 104:209-223

Hough, A. F., and R. D. Forbes. 1943. The ecology and silvics of forests in the high plateaus of Pennsylvania. Ecological Monographs. 13:299-320.

Maguire, D. A. and R. T. Forman1983. Herb cover effects on tree seedling patterns in a mature hemlock-hardwood forest. Ecology. 64: 1367-1380.

Microsoft Excel, version 7.0, Microsoft Corporation, 1995.

Miller, I., D. S. Shriner, and D. Rizzo. 1989. History of hardwood decline in the eastern United States> USDA For. Serv. Gen. Tech. Rep., NE-126:75.

Mlaidenoff, D. J. and F. Stearns. 1993. Eastern hemlock regeneration and deer browsing in northern Great Lakes Region: a re-examination and model simulation. Conservation Biology. 7:889-900.

Minitab statistical software, version 8.0, Minitab Incorporation, State College, PA, 1996.

Parshall, T. 1995. Canopy mortality and stand-scale change in a northern hemlock-hardwood forest. Canadian Journal of Forest Research. 25:1466-1478.

Rogers, S. R. 1980. Hemlock Stands from Wisconsin to Nova Scotia: Transitions in Understory Composition along a Floristic Gradient. Ecology. 61:178-193.

-----. 1982. Early spring herb communities in mesophytic forests of the Great Lates Region. Ecology. 63:1050-1063.

Romme, W. H. 1982. Fire and landscape diversity in sub-alpine forests of Yellowstone National Park. Ecological Monographs. 52:199-221.

Sigma Plot for Windows, version 2.0, Jandel Corporation, 1994.

Sinclair, W. A., R. J. Iuli, A. T. Dyer. 1990. Ash yellows: geographic range and association with decline of white ash. Plant Dis. 74:604-607.

Smith, H. V. 1966. Michigan Wildflowers. Cranbrook Institute of Science, Bloomfield Hills, Michigan, USA.

St. Hilaire, L. R. and D. J. Leopold. 1995. Conifer seedling disribution in relation to microsite conditions in a central New York forested minerotrophic peatland. Canadian Journal of Forest Research. 25:261-269.

Stokes, M. A. and T. L. Smiley. 1967. An introduction to tree-ring dating. The University of Chicago Press, Chicago, Illinois, USA.

Sydes, C. and J. P. Grime. 1981. Effects of Tree Leaf Litter on Herbaceous Vegetation in Deciduous Woodland. Journal of Ecology. 69:237-248.

Thompson, J. N. 1980. Treefalls and colonization patterns of temperate forest herbs. American Midland Naturalist. 104:1976-1984.

Tyrrell, L. E., and T. R. Crow. 1994. Structural characteristics of old-growth hemlock-hardwood forests in relation to age. Ecology. 75:370-386.

Voss, E. G. 1985. Michigan Flora, Part II Dicots. Regents of the University of Michigan, Ann Arbor, Michigan, USA.

Woodcock, H., W. A. Patterson, K. M. Davies. 1993. Forest Ecology and Management. 60:271-290.

Zomlefer, W. B. 1994. Guide to Flowering Plant Families. The University of North Carolina Press. Chapel Hill, USA, and London, England.

APPENDIX A

APPENDIX A

Table 3.1 Relative density, dominance, frequency, and importance values of trees > 10 cm dbh.

Species	Relative Density	Relative Dominance	Relative Frequency	Relative Importance
Acer saccharum	0.3731	0.2810	0.2942	0.3161
Fagus grandifolia	0.1606	0.1590	0.1789	0.1662
Tilia americana	0.1153	0.2280	0.1431	0.1621
Tsuga canadensis	0.1049	0.1081	0.1153	0.1094
Fraxinus americana	0.0842	0.0934	0.0954	0.0910
Acer rubrum	0.0868	0.0825	0.0875	0.0856
Ostrya virginiana	0.0298	0.0062	0.0338	0.0233
Betula papyrifera	0.0065	0.0166	0.0040	0.0090
Ulmus rubra	0.0091	0.0051	0.0099	0.0080
Betula alleghaniensis	0.0091	0.0051	0.0080	0.0074
Populus grandidentata	0.0052	0.0067	0.0080	0.0066
Carya spp.	0.0039	0.0014	0.0040	0.0031
Populus tremuloides	0.0026	0.0024	0.0040	0.0030
Crataegus	0.0026	0.0003	0.0040	0.0023
Pinus strobus	0.0013	0.0017	0.0020	0.0017
Prunus serotina	0.0013	0.0012	0.0020	0.0015
Amelanchia arborea	0.0013	0.0007	0.0020	0.0013
Carpinus caroliniana	0.0013	0.0004	0.0020	0.0012
Thuja occidentalis	0.0013	0.0003	0.0020	0.0012
Abies balsamea	0.0000	0.0000	0.0000	0.0000
Hamamelis virginiana	0.0000	0.0000	0.0000	0.0000
Picea glauca	0.0000	0.0000	0.0000	0.0000

Table 3.2 Relative density, dominance, frequency, and importance values of trees ≤ 10 cm dbh.

Species	Relative Density	Relative Dominance	Relative Frequency	Relative Importance
Acer saccharum	0.6143	0.7442	0.5036	0.6207
Ostrya virginiana	0.1510	0.0862	0.1500	0.1291
Fagus grandifolia	0.1102	0.0651	0.1821	0.1191
Carpinus caroliniana	0.0653	0.0316	0.0714	0.0561
Acer rubrum	0.0204	0.0284	0.0286	0.0258
Crataegus	0.0122	0.0124	0.0179	0.0142
Ulmus rubra	0.0102	0.0153	0.0143	0.0133
Amelanchia arborea	0.0041	0.0062	0.0071	0.0058
Tsuga canadensis	0.0041	0.0044	0.0071	0.0052
Fraxinus americana	0.0020	0.0007	0.0071	0.0033
Prunus serotina	0.0020	0.0034	0.0036	0.0030
Tilia americana	0.0020	0.0016	0.0036	0.0024
Hamamelis virginiana	0.0020	0.0006	0.0036	0.0021
Abies balsamea	0.0000	0.0000	0.0000	0.0000
Betula alleghaniensis	0.0000	0.0000	0.0000	0.0000
Betula papyrifera	0.0000	0.0000	0.0000	0.0000
Carya sp.	0.0000	0.0000	0.0000	0.0000
Picea glauca	0.0000	0.0000	0.0000	0.0000
Pinus strobus	0.0000	0.0000	0.0000	0.0000
Populus grandidentata	0.0000	0.0000	0.0000	0.0000
Populus tremuloides	0.0000	0.0000	0.0000	0.0000
Thuja occidentalis	0.0000	0.0000	0.0000	0.0000

APPENDIX B

APPENDIX B

Pteridophytes

Equisetaceae

Equisetum arvense L.

Equisetum hyemale L.

Ophioglossaceae

Botrychium virginianum (L.), Swartz

Osmundaceae

Osmunda claytoniana L.

O. regalis L.

Pteridaceae

Adiatum pedatum L.

Dryopteridaceae

Athyrium filix-femina (L.) Mertens

Cystopteris bulbifera (L.) Bernhardi

Dryopteris spp.

Gymnocarpium dryopteris (L.) Newman

Matteuccia struthiopteris (L.) Todaro

Onoclea sensibilis L.

Gymnosperms

Cupressaceae

Thuja occidentalis L.

Pinaceae

Abies balsamea (L.) Miller

Picea glauca (Moench) A. Voss

Pinus strobus L.

Tsuga canadensis (L.) Carriere

Angiosperms

Monocots

Araceae

Arisaema triphyllum (L.) Schott

Cyperaceae

Liliaceae

Maianthemum canadense Desf.

Medeola virginiana L.

Streptopus roseus Michx.

Trillium grandiflorum (Michx.) Salisb.

Uvalaria perfoliata

Orchidaceae

Epipactis hilleborine (L.) Crantz

Goodyera pubescens (Willd.) R. Br.

Poaceae

Dicots

Aceraceae

Acer rubrum L.

A. saccharum Marshall

Anacardiaceae

Toxicodendron radicans (L.) Kuntze

Apiaceae

Cryptotaenia canadensis (L.) DC.

Osmorhiza claytonii (Michx.) C. B. Clarke

Osmorhiza longistylis (Torr.) DC.

Sanicula gregaria E. Blickn.

Araliaceae

Panax quinquefolium L.

Asclepiadaceae

Asclepias syriaca L.

Asteraceae

Achillea millefollium L.

Arctium minus Schk.

Aster spp.

Cirsium vulgare (Savi) Tenore

Prenanthes alba L.

Solidago sp.

Balsaminaceae

Impatiens capensis (Meerb.)

Berberidaceae

Caulophyllum thalictroides L.

Betulaceae

Betula alleghaniensis Britton

B. papyrifera Marshall

Carpinus caroliniana Walter

Ostrya virginiana (Miller) K. Koch

Boraginaceae

Lithospermum spp.

Caprifoliaceae

Lonicera

Sambucus racemosa L.

Viburnum acerifolium L.

Cornaceae

Cornus alternifolia L.f.

Cornus canadensis L.

Fabaceae

Fagus grandfolia Ehrh.

Quercus spp.

Grossulariaceae

Ribes spp.

Hamamelidaceae

Hamamelis virginiana L.

Juglandaceae

Carya spp.

Lamiaceae

Lycopus uniflorus Michx.

Prunella vulgaris L.

Monotropaceae

Monotropa uniflora L.

Oleaceae

Faxinus americana L.

Onagraceae

- *Circaea alpina* L.
- *Circaea lutetiana* L.

Orobanchaceae

- *Epifagus virginiana* (L.) Barton

Plantaginaceae

- *Plantago* spp.

Portulacaceae

- *Claytonia caroliniana* Michx.

Primulaceae

- *Trientalis borealis* Raf.

Pyrolaceae

- *Pyrola elliptica* Nutt.
- *Pyrola rotundifolia* L.

Ranunculaceae

- *Actaea pachypoda* (L.) Miller
- *Actaea rubra* (Aiton) Willd.
- *Anemone canadensis* L.
- *Anemone quinquefolia* L.
- *Aquilegia canadensis* L.
- *Hepatica acutiloba* DC.
- *Hepatica americana* (DC.) Ker Gawler
- *Ranunculus hispidus* Michx.
- *Ranunculus* spp.

Rosaceae

Agrimonia grypsepala Wallr.

Amelanchier arborea (Michx. f.) Fernald

Crataegus spp.

Fragaria virginiana Duchesne

Geum aleppicum Jacq.

Geum canadense Jacq.

Prunus serotina Ehrh.

Rubus hispidus L.

Rubiaceae

Galium circaezans Michx.

Galium triflorum Michx.

Mitchella repens L.

Salicaceae

Populus deltoides Marshall

Populus grandidentata Michx.

Populus tremuloides Michx.

Saxifragaceae

Mitchella diphylla L.

Tiliaceae

Tilia americana L.

Ulmaceae

Ulmus rubra Muhl.

Urticaceae

Boehmeria cylindrica (L.) Swartz

Laportea canadensis (L.) Wedd.

Pilea pumila (L.) A. Gray

Violaceae

Viola blanda Willd.

Viola canadensis L.

Viola conspersa Reichb.

Viola pubescens Aiton

Viola rostrata Pursh.

Viola sororia Willd.

Vitaceae

Parthenocissus vitaceae (Knerr)i. A. Hitchc.

Vitis spp.