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Local Ecology Research Papers

A Study of Edge Effects on Exterior and Interior Forest Composition between Two Small Forests

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Edge Effects on Exterior and Interior Forest Composition

Abstract

Edge habitat and interior forest composition in southeastern Minnesota on the St. Olaf College campus were examined. Species diversity and density of seedlings, saplings, and mature trees between interior and exterior areas within and between each site were recorded. Diameters of mature trees were also noted. Norway Valley (site 1) and Manitou Woods (site 2) included local native hardwood species of maple, ash, and oak. Two 2x60m belt transects (five were bisected by dirt paths) subdivided into 5m intervals were used. Scotch pines and northern red oaks had the largest diameters for sites 1 and 2, respectively. Sapling diversity was significantly lower than seedling or mature trees in site 1, but was higher than seedling and mature trees in site 2. Sugar maples and white ashes were most common in both sites. Density of the three tree types showed significant patterns within and between each site. Site 1 had approximately the same amount of each of the tree types. However, a high number of seedlings were found in site 2. Site 1 was found to have moderately fast growing, shade tolerant species. This aging forest had many open, disturbed areas. In site 1, white ash, green ash, and sugar maples should comprise most of the future forest. Species in site 2 were more shade tolerant. Likely to see continued basswood, maples, and buckthorn in the future forest composition of site 2. The impact of edges on the interior was not significant. Microclimate conditions should be studied in order to understand the impact of edges on abundance and distribution of species.

Introduction

Studies on edge effect are important; our present land-use practices (e.g. urbanization and agriculture) will have a dramatic effect on future trends of our forests. An edge can be defined as the junction of two different landscape elements (e.g., plant community type, successional stage, or land use (Thomas, Maser & Rrodick 1979 in Yahner 1988). Fragmentation is a change in landscape structure that typically, but not universally, includes smaller patch sizes, smaller patch perimeter lengths, greater distances between patches, more edge habitat, and less interior habitat (habitat not affected by human-created boundaries) (Reed et al. 1996).

Fragmentation consequentially causes the creation of additional edge habitat. This may cause the alteration or reduction of species richness and abundance in comparison to that of the interior (Patterson et al. 1995). By reducing of the size of undisturbed area, the number of species that can persist declines (Klyza et al. 1994). Fragmentation also changes conditions in the fragment as a result of its proximity to disturbance. These edge effects occur due to alteration of physical conditions, such as changes in wind and temperature, as well as changes in the biological characteristics near the border of the patch (Klyza et al. 1994). The effects of fragmentation to a forest ecosystem are numerous and habitat fragmentation will continue to be a concern to us for at least two reasons. First, extensive fragmentation and increased edge results in less stable habit for nesting birds. Birds are one means of seed dispersal for trees and also help control tree parasites (Patterson 1995). Second, fragmentation and increased edge are major factors contributing to the reduced distribution and abundance of wildlife species on a broad geographic scale (Temple 1986 in Yahner 1988).

Defining edge species and measuring edge dimensions are difficult. There is no general consensus as to how edge effect is best measured (Yahner

1988). One researcher concluded that "the forest edge is considered to be a distinct community because it is inhabited by a characteristic set of species..." (Johnston 1947 in Harris 1988). To study edge-patterns, Matlack (1994) censured forest herbs, shrubs, and tree seedlings at five distances from human-generated edges in southeastern Pennsylvania and northern Delaware. Edge-related pattern was observed in overall species composition, and in distributions of 15 different species. Edge-related pattern was most frequently observed at recently created sites, but persistent pattern was also observed at older edges, including those closed for 55 years by succession (Matlack 1994).

Some species-specific edge/interior differences could be related to timing of critical life history stages (such as germination and early establishment) relative to the temporal stability of edge microclimate regimes. Thus regularly shaped forest fragments less than 9.0 ha are dominated by edge patters and processes (Young et al. 1994). While past ecologists have considered edges as beneficial to wildlife because species diversity generally increases near habitat edges, opinions have reversed as edges generally result in accompanying reductions in size and possible isolation of patches and corridors (Harris 1988).

St. Olaf College, located in central southeastern MN is home to both Norway Valley and Manitou Woods. Norway Valley (Site 1) consists of primarily local native hardwoods species such as oaks, maples, and ash. A relatively small forest, Norway Valley's greatest width measures about 600 feet and stretches about 900 feet in length. Interwoven throughout all sides of the forest is a dirt path less than two meters in width. The south edge of the forest is bordered by Highway 19 and the forest extends northward to a paved road on the campus; there are several buildings past the road. To the west lies a mowed lawn intersected by another small paved road. The eastern edge is bordered by another mowed lawn followed by a stand of hardwood trees (planted in 1994). Manitou Woods (Site 2) contains similar tree species as Norway Valley. Most of this forest is only about 250 feet in width and 700 feet in length, though a transect was done in the one small section 400 feet wide by 200 feet long. Again though, a dirt path winds through the forest. A prairie (restored in 1993) borders the southern edge of the Manitou Woods and the northern edge is bordered by a parking lot. A grove of hardwood trees (planted in 1989) lies along the western edge of the forest. A building on campus halts the forest along the majority of its eastern edge. Edge effects should be able to be seen even in these small forests.

The aim of this study is to compare the edge habitat and the interior forest composition at two small sites in southeastern Minnesota on the St. Olaf College campus. In this study I will determine if there is a significant difference in species diversity and density of seedlings, saplings, and mature trees between the interior and exterior areas and between the two study sites.

Materials and Methods

On the campus of St. Olaf College, two existing forest sites, Norway Valley and Manitou Woods, were examined between October 28 and November 22. Forest sites were sampled using the belt transect method as described in Field and Laboratory Methods for General Ecology (Brower, Zar, von Ende 1989). Two transects measuring 2 m in width and 60 m in length marked off with long metric tapes and flags were used to sample mature trees (greater than 13 cm DBH) and saplings (greater than 0.5 m tall and less than 13 cm DBH). Plots were marked every 5 m or 12 plots/transect for a total of 24 plots in each site. Subsamples of seedlings were taken in $1m^2$ plots along the transect. Belts were at least 20 m apart from each other in order to get a more random sampling.

From the data of these plots ANOVA tests were used to analyze the following: mean density among species; density among seedlings, saplings, and mature trees; density between sites; density between interior and exterior habitats, and diameter of mature trees. Seedling data from the $1m^2$ plots was multiplied by a factor of ten in order to be compared with mature tree and sapling data from the $10m^2$ plots. The Simpson's test yielded analysis of species diversity between sites and between interior and exterior habitats.

Results

Two-way ANOVA tests showed a significant difference among seedling, sapling, and mature tree mean densities between sites and tree type. Interaction was significant ($p = < .001$), in that the density pattern of tree types varied by site (figure 1). Norway Valley (site 1) had very few seedlings as compared to Manitou Woods (site 2). Norway Valley also had fewer saplings. The mean densities of mature trees were very small in both sites. Norway Valley showed a trend of mature trees with larger diameters than in those counted in Manitou Woods (figure 2). Scotch pines, found only in Norway Valley had the largest diameters. Northern red oaks and sugar maples had the next largest diameters, respectively. Interaction of mean diameter between each site and species was not statistically significant.

A significant difference ($p = < .001$) in seedling density was found between sites, but not between the exterior and interior areas of the forests (figure 3). Norway Valley had very few seedlings. A significant difference in sapling density ($p = < .001$) was also found between sites (figure 4). The exterior showed a slight trend of higher sapling density than the interior. No significant difference of mature trees was found between sites or between exterior and interior (figure 5).

Saplings had a much lower species diversity index (.31) than seedlings (.51) or saplings (.60) in Norway Valley (table 1). Evenness of distribution among seedlings (.62), saplings (.73), and mature trees (.68) was much more even in the Manitou Woods forest. However, the species richness of seedlings

(6), saplings (9), and mature trees (4) was much higher in Manitou Woods as compared to that of Norway Valley (values of 3, 2, and 4 for seedlings, saplings, and mature trees, respectively). Sugar maples were overwhelmingly the most common tree found at both sites in all tree types. White ash, northern red oak, and hackberry were also found at each study site. The mean density of sugar maples were significantly different between sites (p= .0002), but not among the exterior and interior. White ash did not show a significant difference between sites or between exterior and interior of forest areas.

Discussion

The underlying assumption of this study was that edge habitat changes or reduces species richness and abundance in comparison to that of the interior. Given these assumptions the results were inconclusive regarding differences between exterior and interior, but did show a significant difference among seedling, sapling, and mature tree mean densities varied between sites (figure 1). Several factors may have influenced these differences including microclimate, soil composition, and disturbance patterns. The lack of seedlings found in Norway Valley (figures 1 and 3) may be due to the influence of canopy trees. Canopy trees influence the amount of water, light, and nutrients (from root competition) that seedlings and saplings get (Woods 1984). Seedlings (figures 1 and 4) did vary between sites, but were not significantly different between exterior and interior. However, forest edges would probably have more light, a big factor in seedling establishment. The relatively few mature trees in Manitou Woods (figures 1 and 5) show a lack of canopy tree cover, accounting for the high number of seedlings found there. Sugar maples, a very shade-tolerant species, are naturally found in moist, fertile soils (Kupfer and Runkle 1996). The abundance of seedlings and saplings in both sites suggests the soils are favorable conditions for both maple and white ash (figures 6 and 7). White ash thrives in both moist-well drained forests and dry upland forests, and is intermediate in shade tolerance.

In this study, the two forest sites were not equally suitable for examining edge effects between the exterior and interior areas of each site or between sites. Norway Valley especially, had many disturbed and open areas. Two of the six transects (one in each site) were intersected by a path, likely creating edge effects from the opposite direction. Humans have caused serious disturbances in Norway Valley by walking off the paths, selecting for some tree species over others, as well as planting species in some areas of the forest. In other transects, many gaps existed between the few trees; shrubbery and undergrowth comprised the majority of coverage in several areas. Manitou Woods also had many dead trees (mostly sugar maple), though this was probably due to an overpopulation of trees for the small area. The thick carpet of fallen leaves on the forest floor may have been an inhibiting factor in determining the number of seedlings present at both sites, but mainly in Norway Valley. It would be wise to do this study again earlier in the year. (The nearby, larger and less disturbed Cannon River Wilderness Area may be a better site in which to study edge effects between exterior and interior of a forest.)

Perhaps the definition of mature trees (> 13 cm DBH) should also be adjusted in future studies, since many trees had diameters of only 12 cm. It would also be interesting to core some of the mature trees. This would give definite proof of the forest's relative age. Though the Norway Valley pines had larger diameters (figure 2), we do not what stage of their lifecycle they are in. The moderately fast growing pines would have been able to establish themselves in large gaps with expanded areas, thus cutting down on resources available for other species. The result of increased light at the soil surface would be a rapid and marked increase in shade intolerant species because of the temporary lessening of competition for available light (Kupfer and Runkle 1996). The impact of edge effects may be difficult to see in trees with long lifetimes, such as maples and oaks, since seedlings take advantage of canopy gaps that create edges (Shea in press). Aging species in the forest would give data on the life history of the forest, enabling more accurate predictions as to what stage the forest is in, and therefore future forest composition.

Additional studies on other factors influencing forest composition would be extremely useful in explaining the distribution and diversity of forest species. Some species-specific edge/interior differences could be related to timing of germination and early establishment, and are relative to the temporal stability of edge microclimate regimes (Young et al. 1994). Microclimate changes could alter or reduce species richness in a given area. Measures of light intensity and soil percentage type determination (i.e. soil pH, percent of moisture, and organic content) would be valuable. Microclimate also is a strong factor in determining the species diversity and density of herbaceous vegetation present at forest edges. Plant composition in gaps is closely liked to site conditions, including slope, soil condition, and site exposure (Kupfer and Runkle 1996). Because of the modifying influences of many other factors, climatic changes nevertheless cause changes of variation among vegetation (Grimm 1983). Thus vegetation is another element that could be studied to examine the impact of edge effects.

Measurements of fauna, especially birds, present at forest edges would provide additional information on edge effects. In one study (Patterson et al. 1995) three was strong and significant variation in bird numbers and species richness with tree age. The number of individual birds detected was consistently higher at the edges than in the centers of plots measured. Species richness and relative abundance of forest birds were higher in landscapes with low forestry impact (Edenius and Elmberg 1996). Such differences can be explained by differences in age composition of forest and composition of tree species. Manitou Woods is a forest comprised of two overlapping rectangles, forming an "L" shape. Minimizing the amount of edge and impact of edge effects is thus reduced by this layout. Norway Valley, on the other hand, is more oval in shape, thereby increasing the amount of available edge. Thus it would be interesting to see if bird activity affected the forest edge composition of Norway Valley and Manitou Woods. Obviously, such a study would need a number of years to be completed.

Data was not sufficient to accurately assess the impact of edges on interior composition, however tree types did vary significantly between the two study sites. Norway Valley found to be a disturbed forest with many areas of dead trees. Relatively few seedlings were found in this aging forest. It consists primarily of moderately fast growing and shade tolerant species. The majority of the species have moderate life spans, though the northern red oaks and sugar maples are much longer-lived species. Since oaks grow slower and need more light than maples for seedling establishment, maples can outcompete oaks initially. However, oaks tolerate fire, low nutrient levels, and low moisture availability better than maples (Shea, in press). We would expect the oaks to remain established in Manitou Woods due to the number of mature species established (table 1). Norway Valley has relatively fewer mature oaks as compared to maples, and would thus be more susceptible to competition. Overall, we will probably see more white ash, green ash, and maples in the future forest composition of Norway Valley.

Manitou Woods consists of species more shade tolerant than those found in Norway Valley. Species diversity and richness is much higher in

Manitou Woods. The slow (maple and basswood), moderate (buckthorn) and fast growing species (ashes, oak, boxelder) help the diversity of the forest. Due to the numbers of seedlings and saplings, continued basswood, maple, and buckthorn will comprise this forest in the future. Buckthorn, however, is presently being controlled by eradication efforts, since even small stands can prevent growth and establishment of other species.

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Table 1. Seedling, sapling, and mature tree species diversity and richness in Norway Valey and Manitou Woods. Each site includes twelve 10m2 plots.

	Norway Valley			Manitou Woods		
Species	Seedling	Sapling	Mature	Seedling	Sapling	Mature
Ash- Green		4				
Ash- White	20			270		
Ash- Prickly					21	
Basswood				50	60	
Boxelder				10		
Buckthorn				10	73	
Cherry- Black					1	
Dogwood					2	
Hackberry		3	1			1
Hickory- Bitternut					2	
Ironwood				50	60	3
Oak- Northern Red			3		2	6
Pine- Scotch			4			
Maple- Sugar	20	43	12	370	159	9
Species Richness	2	3	4	6	9	4
Simpson's Diversity Index	0.51	0.31	0.6	0.62	0.73	0.68
Shannon Diversity Index	0.69	0.64	1.06	1.19	1.52	1.16

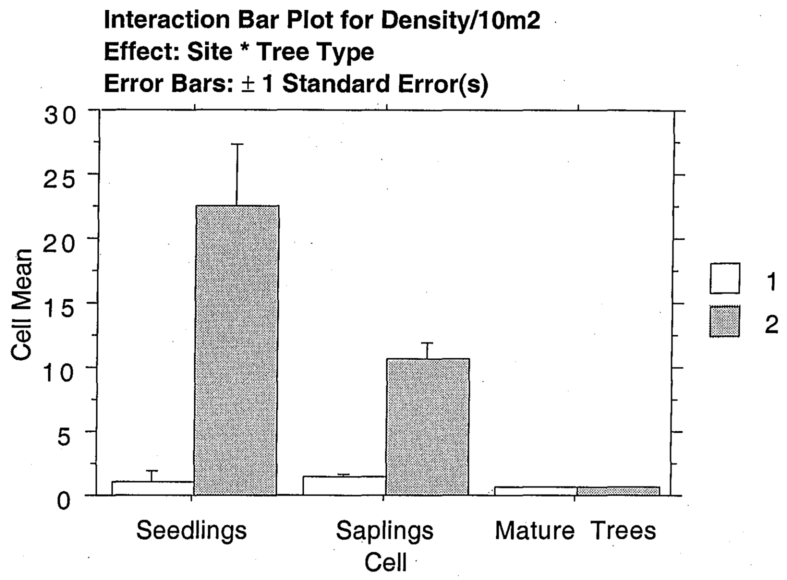

Figure 1. Mean density (+/- std. err.) of all tree types in Norway Valley (cell 1) and Manitou Woods (cell 2). Two-way ANOVA tests showed a significant difference in site (p= <.001) and tree type (p= <.001). Interaction was significant (p= <.001).

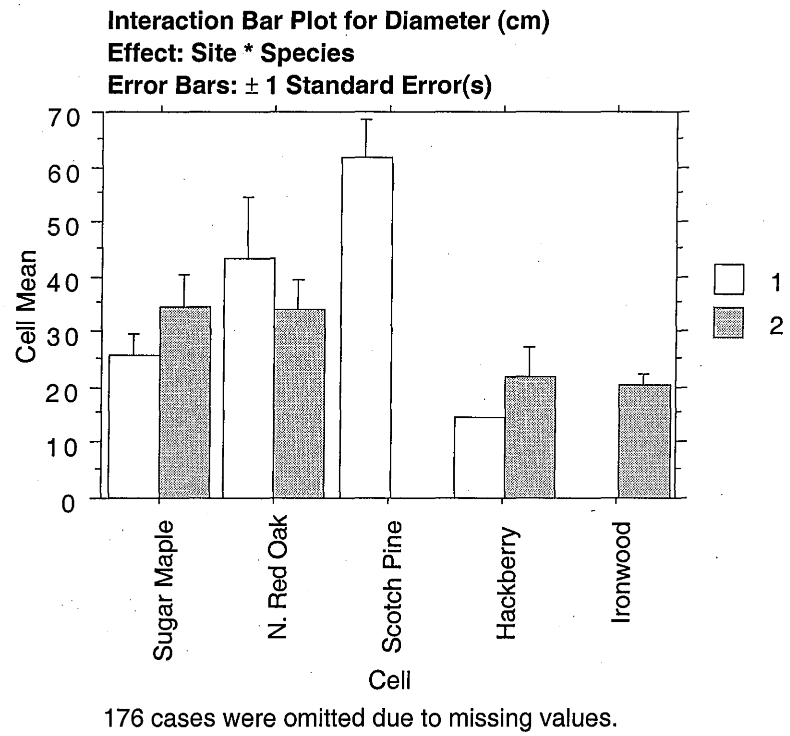

Figure 2. Mean diameter (+/- std. err.) of mature trees Norway Valley (cell 1) and Manitou Woods (cell 2). Two-way ANOVA tests did not show a significant difference between site or species. Interaction was not significant.

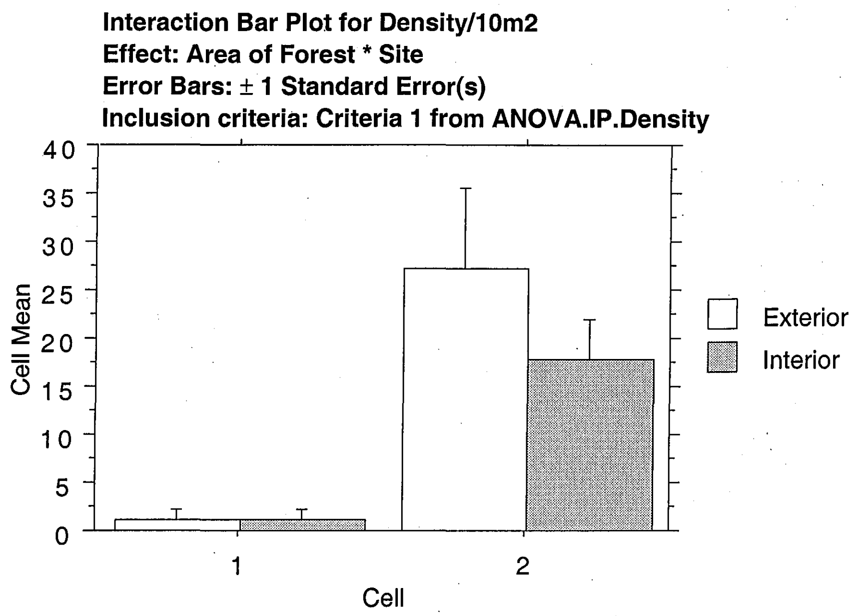

Figure 3. Mean density (+/- std. err.) of seedlings in Norway Valley (cell 1) and Manitou Woods (cell 2). 36 plots were sampled. Two-way ANOVA tests showed a significant difference (p= <.001) in seedling density between sites, but not between exterior and interior. Interaction was not significant.

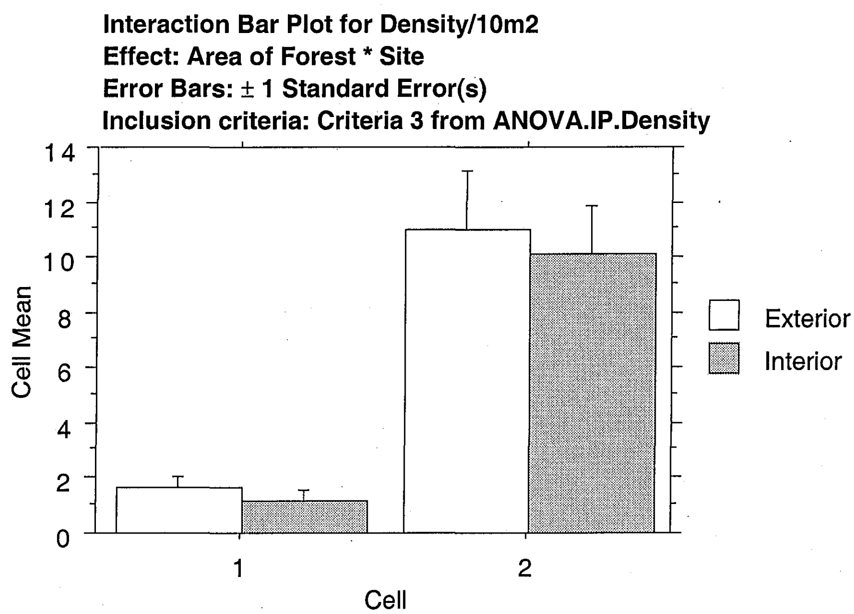

Figure 4. Mean density (+/- std. err.) of saplings in Norway Valley (cell 1) and Manitou Woods (cell 2). 36 plots were sampled. Two-way ANOVA tests showed a significant difference (p= <.001) between sites, but not between exterior and interior. Interaction was not significant.

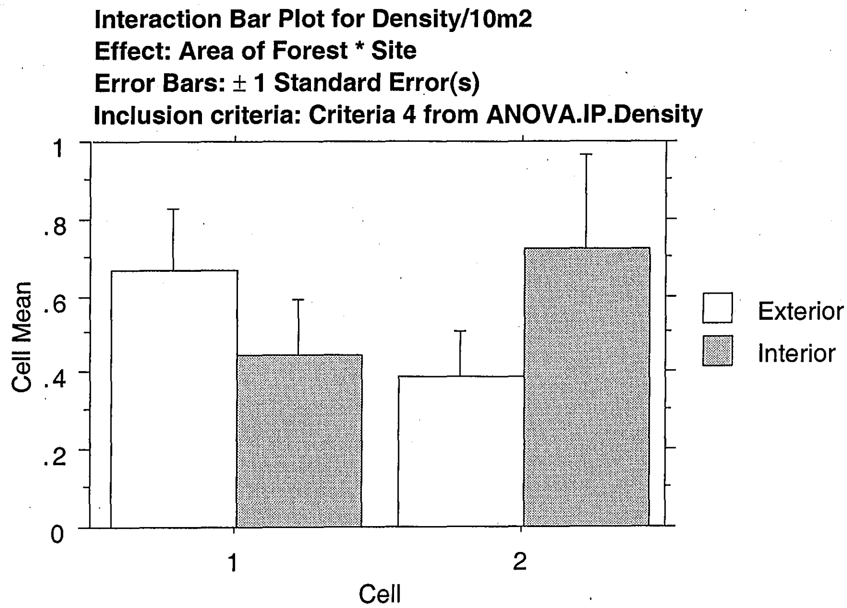

Figure 5. Mean density (+/- std. err.) of mature trees in Norway Valley (cell 1) and Manitou Woods (cell 2). 36 plots were sampled. Two-way ANOVA tests did not show a significant difference in mature trees between sites, or between exterior and interior. Interaction was not significant.

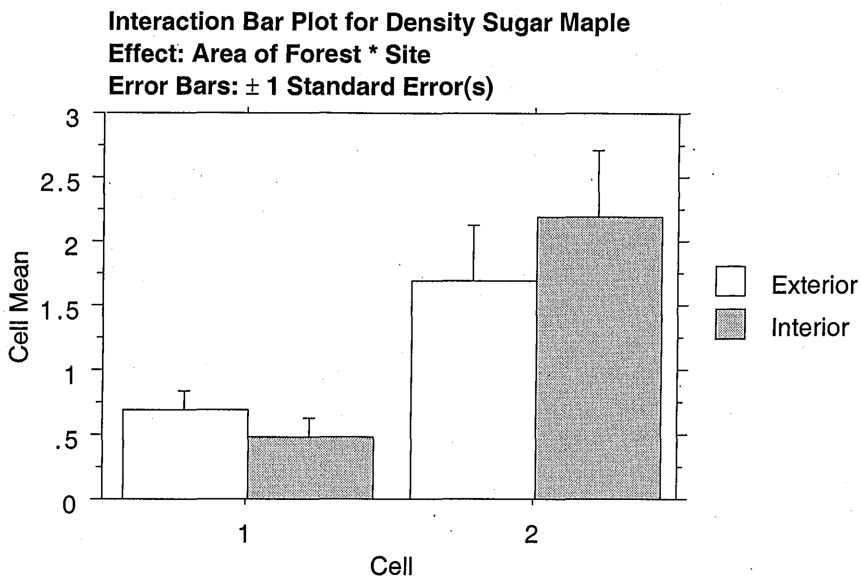

Figure 6. Mean density (+/- std. err.) of sugar maples in Norway Valley (cell 1) and Manitou Woods (cell 2). Two-way ANOVA tests showed a significant difference (p=.0002) in density between sites, but not between exterior and interior of forest. Interaction was not significant.

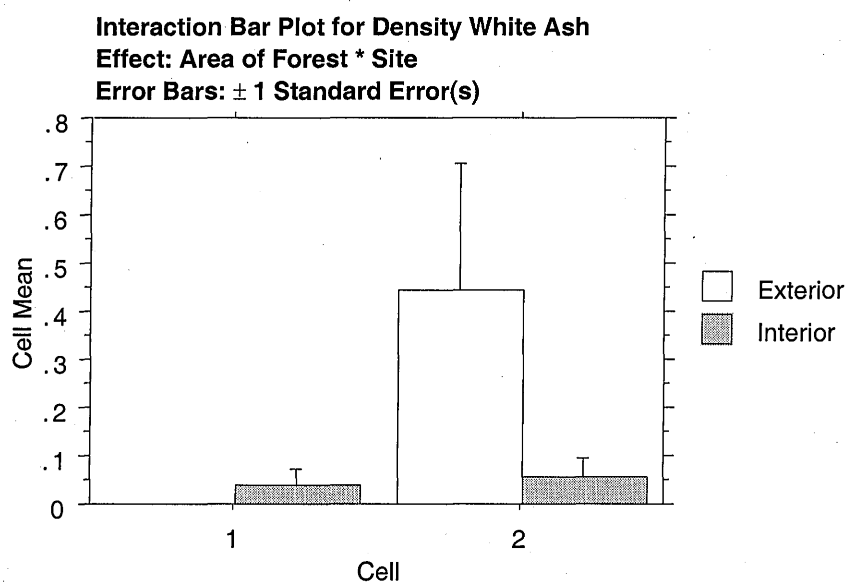

Figure 7. Mean density (+/- std. err.) of white ash in Norway Valley (cell 1) and Mantiou Woods (cell 2). Two-way ANOVA tests did not show a significant difference in density between sites or between exterior and interior of forest. Interaction was not significant.

Appendix 1. Raw data of tree diameters.

Site 1= Norway Valley, Site 2= Manitou Woods. Only diameter of mature trees recorded.						
Site	Transect	Plot	Species	Diameter (cm)		
1	1	1				
1	1	2	Sugar Maple	52.8		
1	1	3				
1	1	4				
1	1	5				
1	1	6				
1	1	7	N. Red Oak	57.5		
1	1	8				
1	1	9				
1	1	10				
1	1	11				
1	1	12	Sugar Maple	38.7		
1	2	1	Sugar Maple	14.6		
1	2	1	Sugar Maple	31.6		
1	2	2	Sugar Maple	16.7		
1	2	2	Sugar Maple	21.7		
1	2	3	N. Red Oak	21.7		
1	2	4				
1	2	5	Sugar Maple	25.9		
1	2	5	Sugar Maple	14.9		
1	2	6	N. Red Oak	51.1		
1	2	7	Sugar Maple	16		
1	2	8				
1	2	9				
1	2	10				
1	2	11				
1	2	12	Sugar Maple	23.2		
1	3	1	Scotch Pine	48.2		
1	3	2	Sugar Maple	16.3		
1	3	3	Sugar Maple	15.4		
1	3	4				
1	3	5	Scotch Pine	49.8		
1	3	6				
1	3	7				
1	3	8	Hackberry	14.8		
1	3	9	Red Pine	70.5		
1	3	10				
1	3	11				
1	3	12	Scotch Pine	66.3		

Appendix 1. Raw data of tree diameters.

2	4	1				
2	4	2				
2	4	3				
2	4	4				
2	4	5	Ironwood	22.3		
2	4	6				
2	4	7	Sugar Maple	20.2		
2	4	8				
2	4	9				
2	4	10	Ironwood	16.5		
2	4	11				
2	4	12				
2	5	1	Sugar Maple	38.6		
2	5	2				
2	5	3	Sugar Maple	36.3		
2	5	4				
2	5	5				
2	5	6	Ironwood	22		
2	5	7				
2	5	8				
2	5	9	Sugar Maple	34.3		
2	5	10	Sugar Maple	34.1		
2	5	11	Sugar Maple	68		
2	5	12				
2	6	1	Sugar Maple	13.6		
2	6	2				
2	6	3				
2	6	4				
2	6	5	N. Red Oak	39		
2	6	5	N. Red Oak	27.4		
2	6	5	Sugar Maple	25.9		
2	6	6				
2	6	7	N. Red Oak	37		
2	6	7	Hackberry	16.2		
2	6	7	Sugar Maple	15.8		
2	6	8	N. Red Oak	47.2		
2	6	9	N. Red Oak	33		
2	6	9	N. Red Oak	13.2		
2	6	10				
2	6	11				
2	6	12	Sugar Maple	58.9		

Appendix 2. Raw data of tree densities in Norway Valley (site 1).

Density table among seedlings, saplings, and mature trees. Site 1= Norway Valley, Site 2= Manitou Woods				
Site	Tree Type	Transect	Plot	Density/10m2
1	Seedling	1	1	0
1	Seedling	1	2	0
1	Seedling	1	3	0
1	Seedling	1	4	0
1	Seedling	1	5	0
1	Seedling	1	6	0
1	Seedling	1	7	0
1	Seedling	1	8	0
1	Seedling	1	9	0
1	Seedling	1	10	0
1	Seedling	1	11	0
1	Seedling	1	12	20
1	Sapling	1	1	6
1	Sapling	1	2	3
1	Sapling	1	3	2
1	Sapling	1	4	2
1	Sapling	1	5	1
1	Sapling	1	6	3
1	Sapling	1	7	4
1	Sapling	1	8	4
1	Sapling	1	9	3
1	Sapling	1	10	2
1	Sapling	1	11	3
1	Sapling	1	12	1
1	Mature Trees	1	1	0
1	Mature Trees	1	2	1
1	Mature Trees	1	3	0
1	Mature Trees	1	4	0
1	Mature Trees	1	5	0
1	Mature Trees	1	6	0
1	Mature Trees	1	7	1
1	Mature Trees	1	8	0
1	Mature Trees	1	9	0
1	Mature Trees	1	10	0
1	Mature Trees	1	11	0
1	Mature Trees	1	12	1

Appendix 2. Raw data of tree densities in Norway Valley (site 1).

Site	Tree Type	Transect	Plot	Density/10m2
1	Seedling	2	1	0
1	Seedling	2	2	0
1	Seedling	2	3	0
1	Seedling	2	4	0
1	Seedling	2	5	0
1	Seedling	2	6	0
1	Seedling	2	7	0
1	Seedling	2	8	0
1	Seedling	2	9	20
1	Seedling	2	10	0
1	Seedling	2	11	0
1	Seedling	2	12	0
1	Sapling	2	1	3
1	Sapling	2	2	2
1	Sapling	2	3	1
1	Sapling	2	4	0
1	Sapling	2	5	1
1	Sapling	2	6	0
1	Sapling	2	7	0
1	Sapling	2	8	1
1	Sapling	2	9	0
1	Sapling	2	10	0
1	Sapling	2	11	1
1	Sapling	2	12	1
1	Mature Trees	2	1	2
1	Mature Trees	2	2	2
1	Mature Trees	2	3	1
1	Mature Trees	2	4	0
1	Mature Trees	2	5	2
1	Mature Trees	2	6	1
1	Mature Trees	2	7	1
1	Mature Trees	2	8	0
1	Mature Trees	2	9	0
1	Mature Trees	2	10	0
1	Mature Trees	2	11	0
1	Mature Trees	2	12	1

Appendix 2. Raw data of tree densities in Norway Valley (site 1).

Site	Tree Type	Transect	Plot	Density/10m2
1	Seedling	3	1	0
1	Seedling	3	2	0
1	Seedling	3	3	0
1	Seedling	3	4	0
1	Seedling	3	5	0
1	Seedling	3	6	0
1	Seedling	3	7	0
1	Seedling	3	8	0
1	Seedling	3	9	0
1	Seedling	3	10	0
1	Seedling	3	11	0
1	Seedling	3	12	0
1	Sapling	3	1	1
1	Sapling	3	2	2
1	Sapling	3	3	2
1	Sapling	3	4	0
1	Sapling	3	5	0
1	Sapling	3	6	0
1	Sapling	3	7	0
1	Sapling	3	8	2
1	Sapling	3	9	0
1	Sapling	3	10	0
1	Sapling	3	11	0
1	Sapling	3	12	0
1	Mature Trees	3	1	1
1	Mature Trees	3	2	1
1	Mature Trees	3	3	1
1	Mature Trees	3	4	0
1	Mature Trees	3	5	1
1	Mature Trees	3	6	0
1	Mature Trees	3	7	0
1	Mature Trees	3	8	1
1	Mature Trees	3	9	1
1	Mature Trees	3	10	0
1	Mature Trees	3	11	0
1	Mature Trees	3	12	1

Appendix 2.1 Raw Data of tree densities in Manitou Woods (site 2).

Site	Tree Type	Transect	Plot	Density/10m2
2	Seedling	4	1	10
2	Seedling	4	2	10
2	Seedling	4	3	20
2	Seedling	4	4	0
2	Seedling	4	5	0
2	Seedling	4	6	0
2	Seedling	4	7	0
2	Seedling	4	8	0
2	Seedling	4	9	10
2	Seedling	4	10	10
2	Seedling	4	11	20
2	Seedling	4	12	30
2	Sapling	4	1	3
2	Sapling	4	2	1
2	Sapling	4	3	4
2	Sapling	4	4	9
2	Sapling	4	5	8
2	Sapling	4	6	5
2	Sapling	4	7	8
2	Sapling	4	8	4
2	Sapling	4	9	5
2	Sapling	4	10	8
2	Sapling	4	11	5
2	Sapling	4	12	6
2	Mature Trees	4	1	0
2	Mature Trees	4	2	0
2	Mature Trees	4	3	0
2	Mature Trees	4	4	0
2	Mature Trees	4	5	1
2	Mature Trees	4	6	0
2	Mature Trees	4	7	1
2	Mature Trees	4	8	0
2	Mature Trees	4	9	0
2	Mature Trees	4	10	1
2	Mature Trees	4	11	0
2	Mature Trees	4	12	0

Appendix 2.1 Raw Data of tree densities in Manitou Woods (site 2).

Site	Tree Type	Transect	Plot	Density/10m2
2	Seedling	5	1	50
2	Seedling	5	2	100
2	Seedling	5	3	90
2	Seedling	5	4	0
2	Seedling	5	5	10
2	Seedling	5	6	0
2	Seedling	5	7	20
2	Seedling	5	8	30
2	Seedling	5	9	30
2	Seedling	5	10	10
2	Seedling	5	11	0
2	Seedling	5	12	0
2	Sapling	5	1	18
2	Sapling	5	2	37
2	Sapling	5	3	22
2	Sapling	5	4	11
2	Sapling	5	5	1
2	Sapling	5	6	2
2	Sapling	5	7	13
2	Sapling	5	8	13
2	Sapling	5	9	6
2	Sapling	5	10	9
2	Sapling	5	11	4
2	Sapling	5	12	0
2	Mature Trees	5	1	1
2	Mature Trees	5	2	0
2	Mature Trees	5	3	1
2	Mature Trees	5	4	0
2	Mature Trees	5	5	0
2	Mature Trees	5	6	1
2	Mature Trees	5	7	0
2	Mature Trees	5	8	0
2	Mature Trees	5	9	1
2	Mature Trees	5	10	1
2	Mature Trees	5	11	1
2	Mature Trees	5	12	0

Appendix 2.1 Raw Data of tree densities in Manitou Woods (site 2).

Site	Tree Type	Transect	Plot	Density/10m2
2	Seedling	6	1	10
2	Seedling	6	2	20
2	Seedling	6	3	0
2	Seedling	6	4	40
2	Seedling	6	5	30
2	Seedling	6	6	40
2	Seedling	6	7	50
2	Seedling	6	8	20
2	Seedling	6	9	40
2	Seedling	6	10	110
2	Seedling	6	11	0
2	Seedling	6	12	0
2	Sapling	6	1	14
2	Sapling	6	2	13
2	Sapling	6	3	16
2	Sapling	6	4	9
2	Sapling	6	5	3
2	Sapling	6	6	18
2	Sapling	6	7	23
2	Sapling	6	8	14
2	Sapling	6	9	30
2	Sapling	6	10	7
2	Sapling	6	11	7
2	Sapling	6	12	23
2	Mature Trees	6	1	1
2	Mature Trees	6	2	0
2	Mature Trees	6	3	0
2	Mature Trees	6	4	0
2	Mature Trees	6	5	3
2	Mature Trees	6	6	0
2	Mature Trees	6	7	3
2	Mature Trees	6	8	1
2	Mature Trees	6	9	2
2	Mature Trees	6	10	0
2	Mature Trees	6	11	0
2	Mature Trees	6	12	1