The Impact of the Proximity to Water on the Growth of *Betula lutea, Acer saccharum, Abies balsamea,* and *Picea mariana*

BIOS 569 – Practicum in Aquatic Biology

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2004

Abstract:

This survey analyzed the effects of the proximity to water on the growth of *Betula lutea, Acer saccharum, Abies balsamea,* and *Picea mariana* at four different sites on the UNDERC property. Each site had three transects which began in a wetland area and sloped up a 20% grade to a dry, upland area. Four 5m plots were constructed every 30 meters on each transect, and diameter at breast height was measured and cores of each tree greater than 3cm in the plot were taken. Over three hundred trees were analyzed in this project. Black spruce was found primarily in the wetland areas, while balsam fir was found throughout all four plots. However, the average DBH of balsam fir significantly decreased in plots farther away from the wetlands possibly due to competition with sugar maple. Sugar maple was primarily found in the drier areas and seemed to dominate the uplands. Not only was the average DBH of the sugar maple greater in the upland sites, but its average age was greater in these sites as well. The average growth rate of the trees was not significantly different among two sites and therefore is an indicator of a clear-cut forest re-growing at the same rate. This survey allowed for further understanding of the tree species on the UNDERC property and for a study of a diminishing ecosystem.

Introduction:

Natural forest communities contain a large number of species which are not equally successful within their habitat (Whittaker 1965). Within a forest, there can be several variables that favor the dominance of one plant species over others. Variation in the amount of water present in a forest contributes to the biodiversity of the species that grow there. Likewise, a tree's distance from water is one of the many factors affecting its average growth rate per year.

In Northern Wisconsin, trees grow in both wetlands and dry land. The wetlands are typically bog-like, primarily composed of sphagnum moss, yet also contain small shrubs and even some trees. Likewise, the dry lands, which are upland from the bogs, contain tree species which adapt better to the drier habitat. In this analysis of field data, *Betula lutea* (yellow birch), *Acer saccharum* (sugar maple), *Abies balsamea* (balsam fir), and *Picea mariana* (black spruce) were surveyed in both the wet and dry areas on the property of the University of Notre Dame Environmental Research Center, UNDERC.

Yellow birch is a deciduous tree that has a geographical location from Delaware to Iowa. Another deciduous tree, sugar maple, can be found from Virginia to Georgia to Texas. Balsam fir, a conifer, has ranges from New England to Minnesota. Another conifer, black spruce, can be found from Alaska to New Jersey (Petrides 1972). Although these trees have a wide geographical range, this survey analyzed the ecological preferences of these four trees in the

Northwoods of Wisconsin and the Upper Peninsula of Michigan. Comparisons were made among the diameter of each tree species in lowland bogs versus upland, dry areas.

The purpose of this survey was to analyze the correlation between the diameter at breast height and the age of four different tree species and their proximity to water within the UNDERC property. Other current surveys have analyzed the diversity of tree species in forests over a long period of time or the diversity of immature forests versus mature forests. One field analysis found that during the primary succession of a forest in Glacier Bay, Alaska, the diversity of tree species rapidly increased during the first 100 years. After a century, the diversity of the community gradually reached a maximum and then leveled off (Reiners *et al.* 1971). Although this survey only analyzed the diversity of four current tree species at UNDERC, GPS coordinates were taken in order to allow future students to note the changes in diversity over time.

Another survey analyzed forests from the Great Smoky Mountains in the east coast to Siskiyou Mountains in Oregon. The data found that the diversity in the immature, disturbed forests can be as high as the diversity in the mature, stable forests (Whittaker 1965). This survey conducted on the UNDERC property focused more on analyzing different ecological habitats within one forest instead of analyzing differences among multiple forests.

In this project, I analyzed the tree abundance and average growth per year in both the wet and dry lands of Northern Wisconsin and the Michigan Upper Peninsula. I predicted to find the two conifer species in or close to the bogs and the two deciduous tree species in the dry, uplands. I also hypothesized that the diameters at breast height of the trees in the bogs would be smaller than the diameters of the trees in the upland. Likewise, I expected that the trees found in the bogs would be younger than the trees in the dry, upland areas. The average growth rate per year was expected to be the same among the trees of both areas, indicating an early successional forest.

It is important to study the effects of the proximity to water on the growth of different tree species in order to understand the development of forests. Since the UNDERC property was heavily logged during the last half century, the DBH and average growth rate of the current trees species should be indicators of an early successional forest (Guide to UNDERC 1999). If this study were to continue over an extended period of time, further patterns of the forest could be observed as it transitioned through various stages of succession. This survey allowed for further investigation of the trees on the UNDERC property and a better understanding of the Northwood forests. Since the number of wetlands continues to decline, the opportunities to study this type of ecosystem are diminishing, and therefore it is important to survey and analyze the forests that remain.

Materials and Methods:

This study was conducted during June and July 2004 on the University of Notre Dame Environmental Research Center property. In order to complete this survey, four sites on the UNDERC property were randomly selected. All sites consisted of a wetland area that sloped up to a drier, upland. A clinometer was used to measure the slope and minimize potential differences between sites. Each site had a minimum slope of 20% grade. Three stakes were set up 15 meters apart along a baseline that paralleled the wetland bog shore.

From each stake, a 90 meter transect was constructed perpendicular to the shore with a stake placed at 30 meters, 60 meters, and 90 meters, thus forming three total transects at each site. At each stake, a 5 meter radius plot was measured, creating four plots along each transect. Within each plot, any tree of the four species (*Betula lutea, Acer saccharum, Abies balsamea,* or *Picea mariana*) over 3 centimeters in diameter was measured for diameter at breast height and was cored. Measuring tape that already had diameter at breast height conversions on it was used to measure the DBH of each tree, and then was recorded. Cores were taken with an increment borer to ensure that trees of the same age were compared. This prevented comparisons of the diameters of young and old trees and analyses that concluded water proximity solely caused the difference in diameter in this case. At each plot, GPS coordinates were also recorded in order to provide the option for continuing to survey these four sites in future years (D.B. Botkin, personal communication).

Cores were stored in plastic drinking straws and returned to the lab for analysis. Conifer rings were counted fairly easily with the naked eye. Fine grain sand paper was needed to sand down the deciduous cores in order to observe the rings, and a dissecting scope was needed at times for extra clarification of the count.

Data was analyzed using analysis of variance (ANOVA) tests in SYSTAT. Any test with a P value < 0.050 was found to have a significant statistical relationship.

Results:

On the UNDERC property, four sites were randomly chosen for analysis (Figure 1). The number of trees in the plot in the wetland area, Plot 1, among all four sites is relatively smaller than the number of trees in each of the other plots going up the slope (Figure 2). Black spruce is primarily found in the bogs, while sugar maple dominates the upland areas. Balsam fir is evenly spaced across the four plots and yellow birch is found only in the upland plots, yet in small amounts.

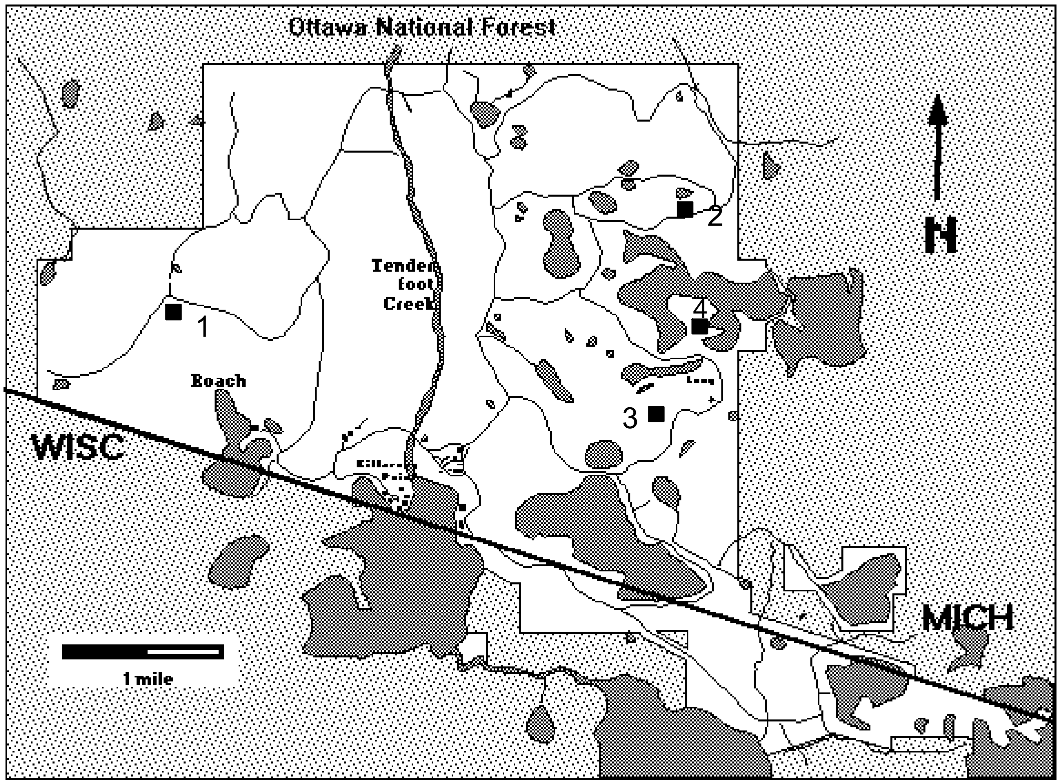

Figure 1. Location of the four sites on the UNDERC property.

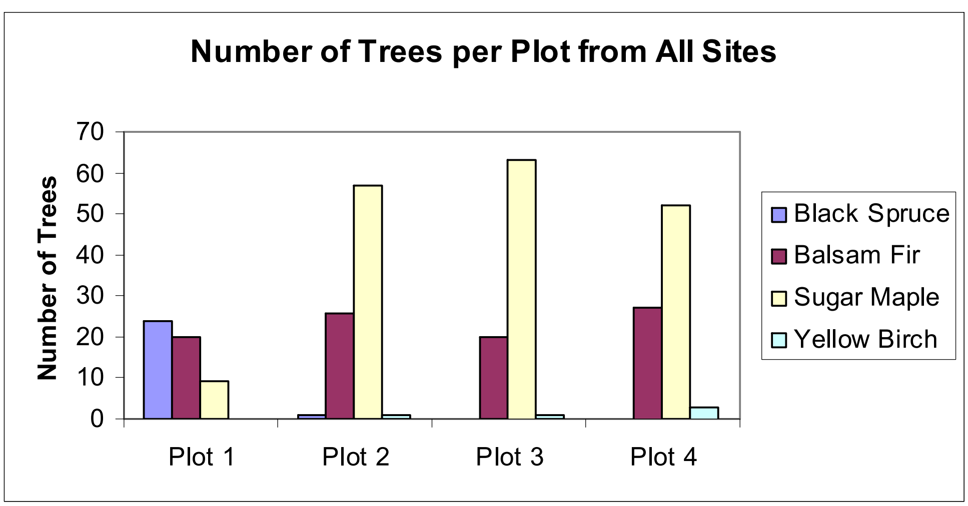

Figure 2. Total number of each tree species from all sites separated by plot.

The Average Diameter at Breast Height of Trees at Each Site

At site one, black spruce has the smallest average diameter at breast height, while sugar maple continues to increase in DBH as the transect moves farther up the slope (Figure 3). A two-way analysis of variance, using the factors tree species and plot against average DBH, showed that average DBH is significantly different in the different plots by species ($p=0.041$).

At Tuesday Lake, site two, black spruce also has the smallest average DBH. Balsam fir was not present as this site. The three yellow birch found at this site had the largest average DBH. Sugar maple continued to increase in average DBH as the plots moved farther away from the bog (Figure 4). A two-way ANOVA was completed using tree species and plot as the factors, against DBH. The test proved that DBH is not significantly different by tree species along the four plots, but has a strong trend ($p=0.065$).

At Ed's Bog, site three, black spruce has the smallest average DBH. Sugar maple, like balsam fir, decreased in DBH in Plot 3, yet increased again in DBH in Plot 4 (Figure 5). The two-way ANOVA, with tree species and plot as factors against DBH, was highly significant ($p<0.001$) and showed that the DBH per species is highly variable between different plots along the slope.

At the fourth site by Bay Lake, no black spruce was found. Balsam fir was present in all four plots and its average DBH gradually decreased the further the plots were from the wetland area. The one yellow birch found in Plot 4 was

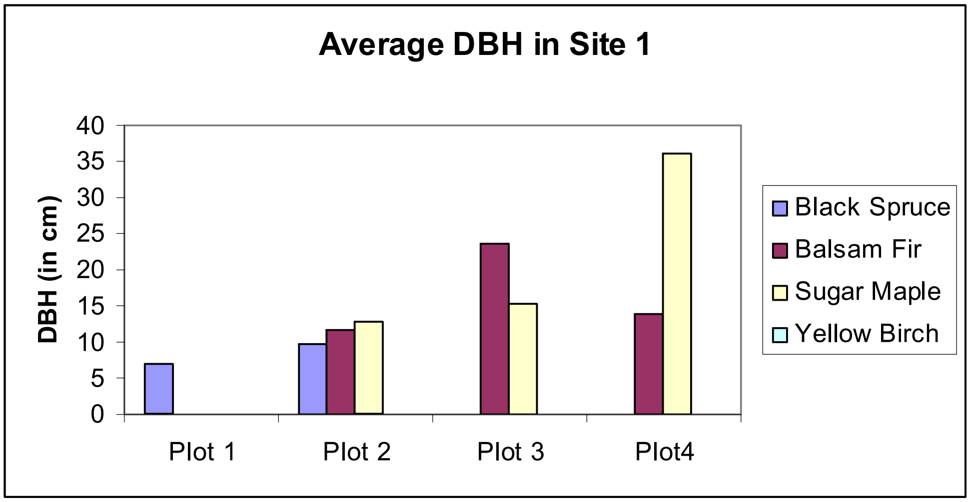

Figure 3. The average diameter at breast height of each species at Site 1 separated by plot.

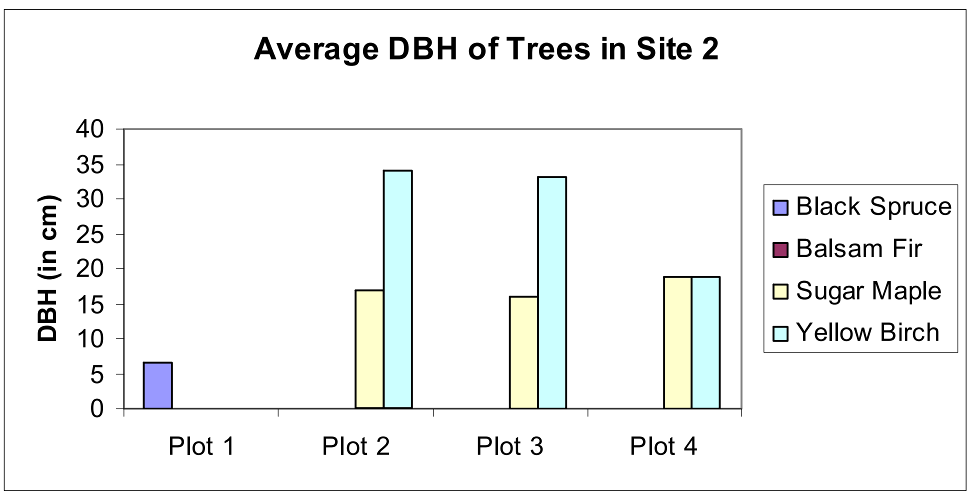

Figure 4. The average diameter at breast height of each species at Site 2 separated by plot.

the largest tree found at this site (Figure 6). The two-way analysis of variance, with tree species and plot as factors, found that the DBH significantly differs among all species going up the slope ($p<0.001$).

The Average Age of Trees at Each Site

At site one, the oldest black spruce trees are in Plot 1, yet it is the youngest tree out of the four species analyzed. Sugar maple gradually increases in age as it grows farther away from the bog (Figure 7). The maximum age of the trees in this stand is 60 years old. A two-way ANOVA was run using both tree species and plot as factors. The test found that the age is significantly different per species as the plots move farther away from the wetland ($p=0.005$).

At site two, the average age of black spruce in Plot 1 is similar to the average age of sugar maple in plots two, three, and four. Yellow birch is also similar in age in plots two, three, and four, and is relatively older than both sugar maple and black spruce (Figure 8). The maximum age of the trees in this stand is 67 years old. The two-way ANOVA showed that the average age is not significantly different against tree species and plot ($p=0.319$).

The average age of balsam fir in site three decreases the further away the plots get from the wetland. Plot 2 has the oldest balsam fir, while Plot 4 has the youngest. Unlike balsam fir, sugar maple continues to gradually increase in age as the plots move towards the upland (Figure 9). The maximum age of trees in

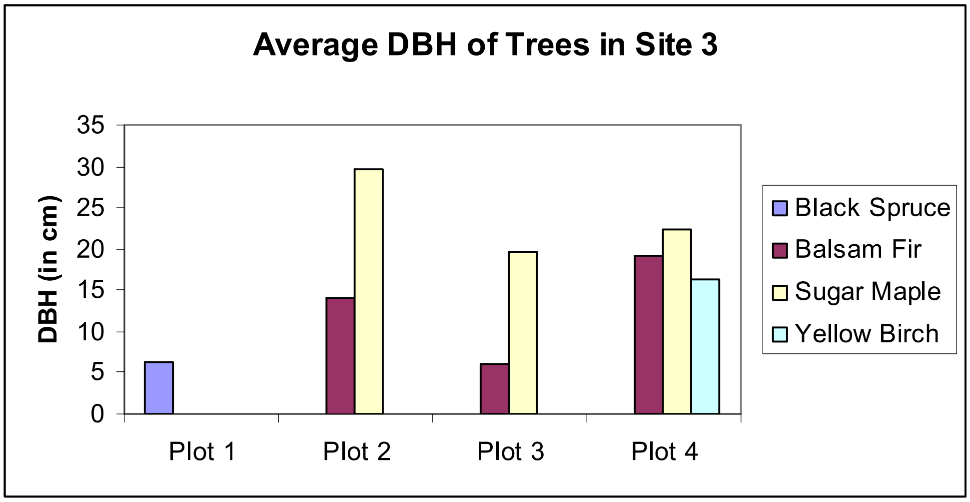

Figure 5. The average diameter at breast height of each tree species at Site 3 separated by plot.

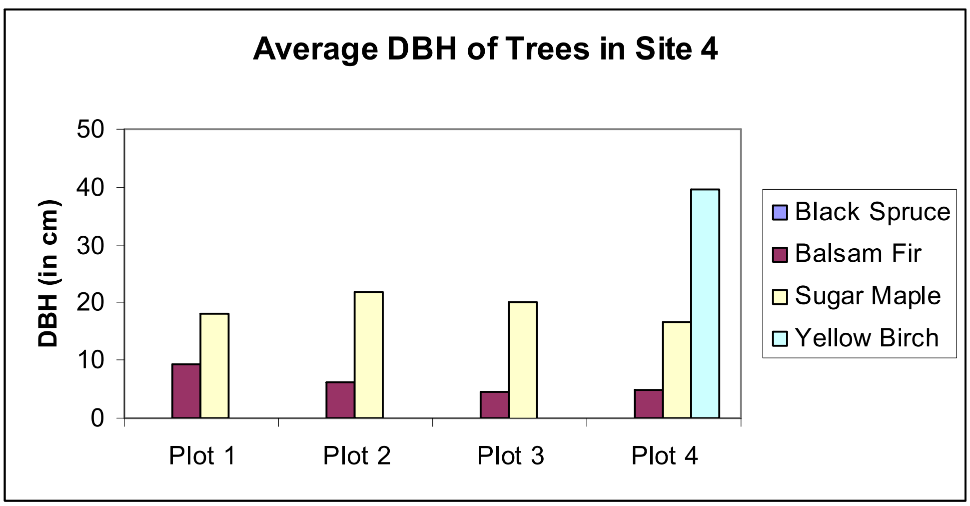

Figure 6. The average diameter at breast height of each tree species at Site 4 separated by plot.

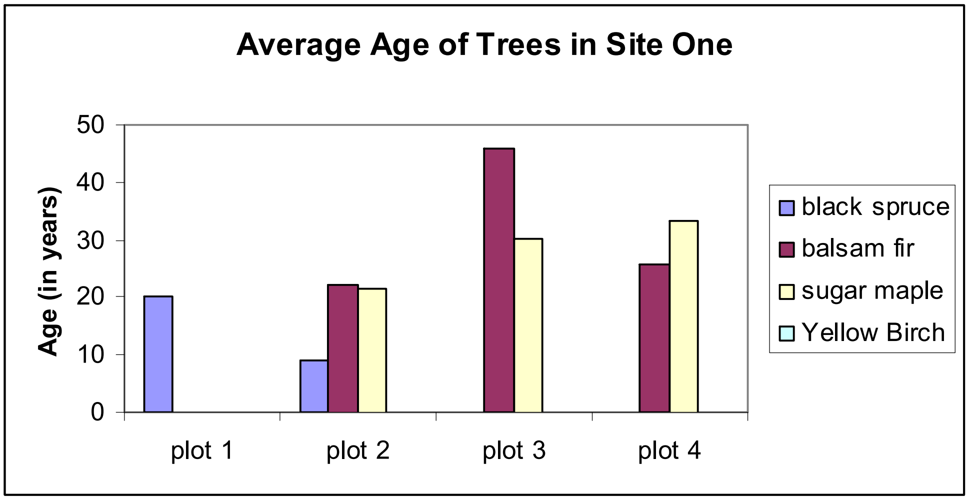

Figure 7. The average age of each tree species at Site 1 separated by plot.

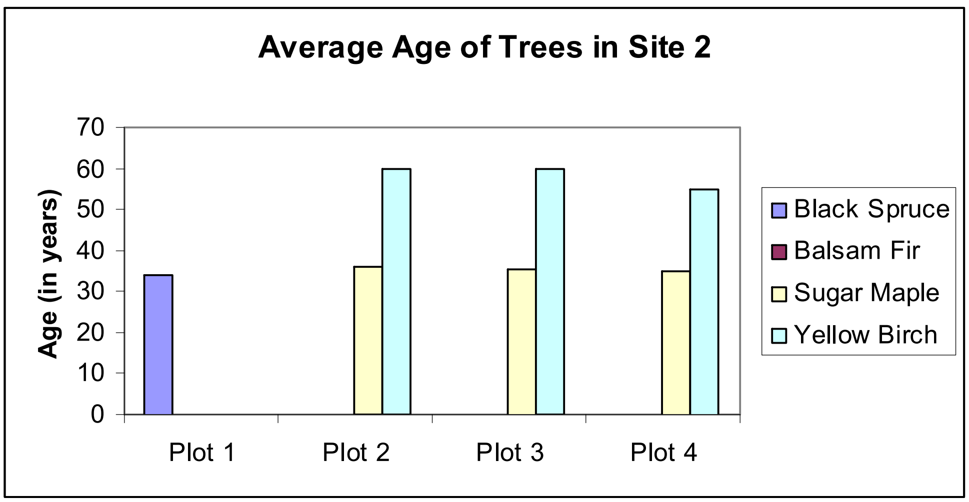

Figure 8. The average age of each tree species at Site 2 separated by plot.

this stand is 62. The ANOVA test ran to analyze the effects of tree species and plot on the average age of the trees in site three showed a significant difference ($p=0.001$).

At site four, the average ages of balsam fir and sugar maple remain relatively constant among the four different plots. The one yellow birch found at this site is the oldest tree at this site (Figure 10). The maximum age at this site is 61 years old. The two-way analysis of variance test ran to analyze the effects of tree species and plot on the average age of the trees showed a significant difference ($p<0.001$).

The Average Growth Rate per Year of Trees at Each Site

At site one, the average growth per year of each tree species in each plot was relatively the same (Figure 11). A two-way analysis of variance was run in order to confirm this visual similarity and when the average growth per year was tested against different tree species and different plots, a significant difference was not obtained ($p=0.277$), as expected.

At site two, the average growth rate per year of sugar maple is relatively the same in plots two and three, and increases in plot four. The average growth rate per year of yellow birch is highest in plots two and three, and decreases in plot four (Figure 12). The two-way ANOVA with tree species and plots as the

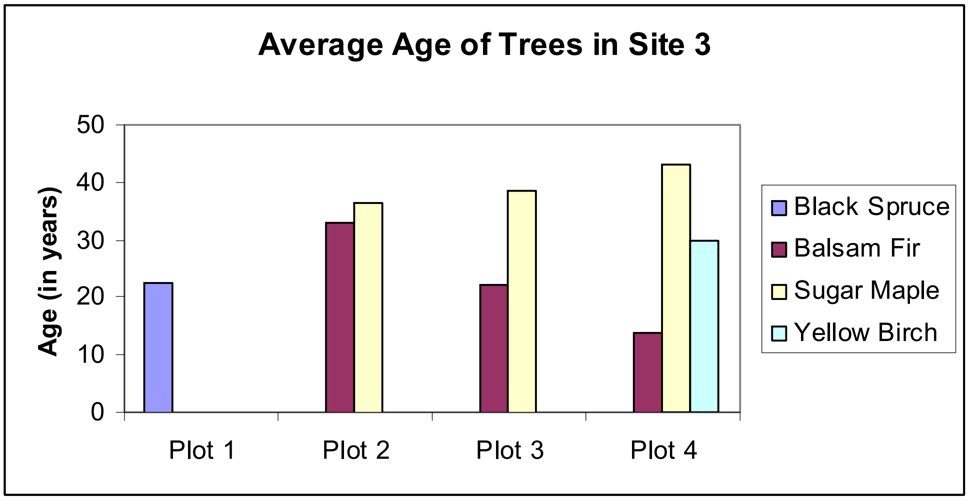

Figure 9. The average age of each tree species at Site 3 separated by plot.

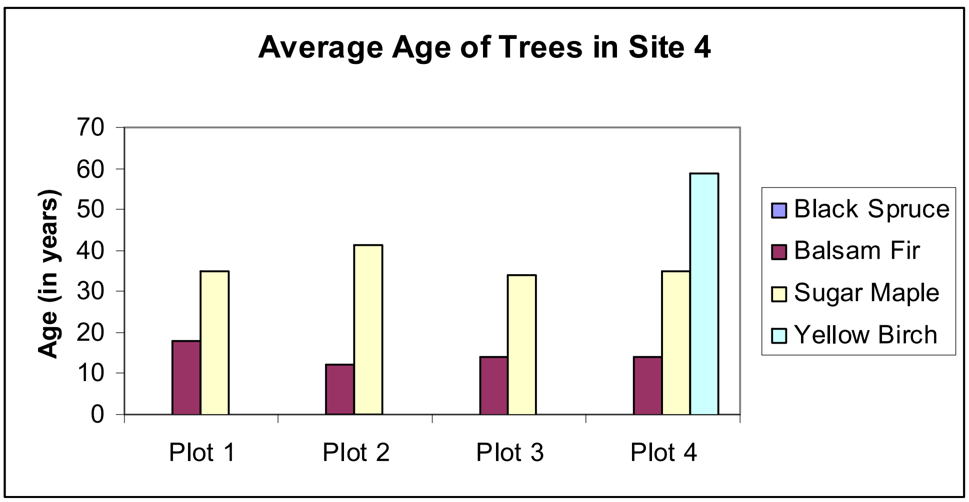

Figure 10. The average age of each tree species at Site 4 separated by plot.

two factors against average growth rate per year showed that there is only a trend towards a significant difference ($p=0.075$).

At site three, the average growth rate per year of sugar maple is widely varied in each plot. Black spruce is only found in Plot 1, and Yellow birch is only found in Plot 4, and therefore they cannot be compared to different plots. Balsam fir has a relatively similar average growth per year in plots two, three, and four, and the highest growth rate in Plot 4 (Figure 13). The two-way ANOVA test of tree species and plot against average growth rate per year showed there was a highly significant difference ($p<0.001$).

At the fourth site, the average growth rate per year among balsam fir and sugar maple were very similar in plots one and two, and became more variable in plots three and four. Yellow birch was only present in one site and black spruce was not present at all (Figure 14). The two-way analysis variance test showed that there was a significant difference between growth rate per year between different tree species going up the slope in the four different plots ($p<0.001$).

An ANOVA test was also used to test the difference between the average means of the diameter at breast heights at all the sites. There was no significant difference ($p=0.864$).

The GPS coordinates have also been recorded in Table 1.

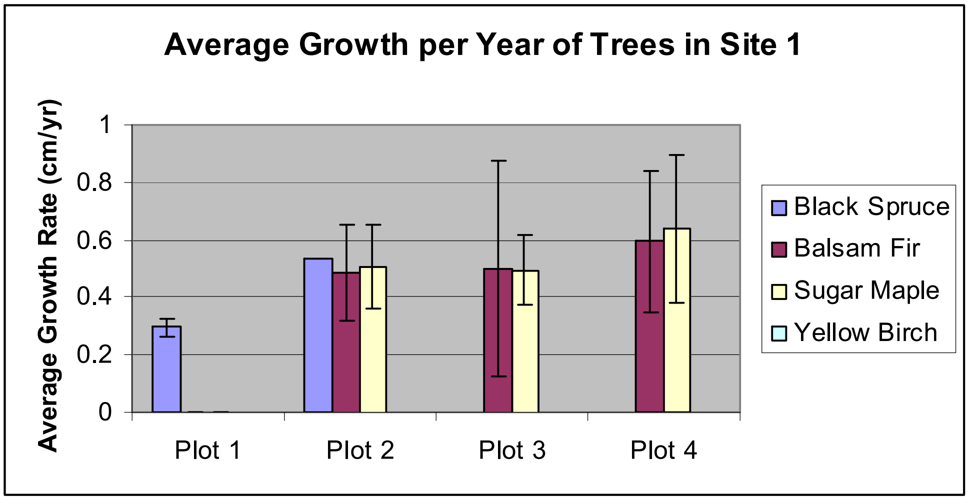

Figure 11. The average growth rate per year of trees at Site 1 separated by plot.

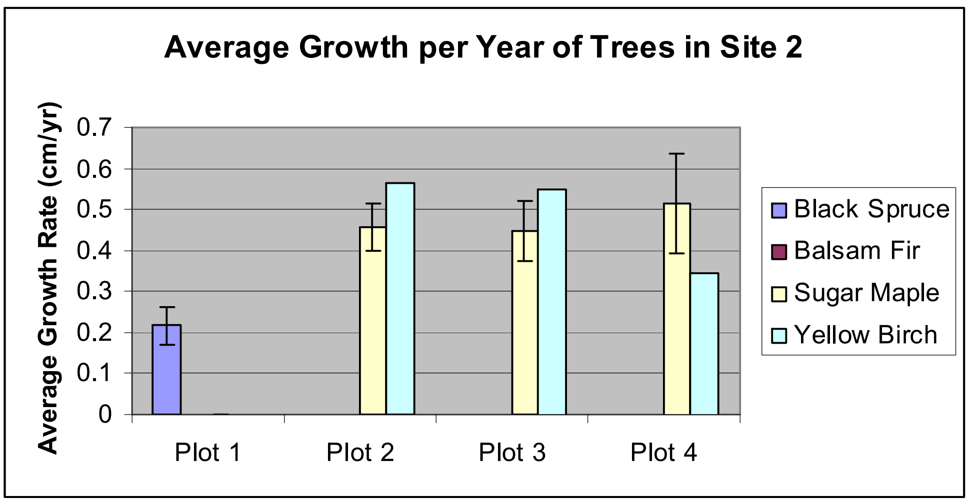

Figure 12. The average growth rate per year of trees at Site 2 separated by plot.

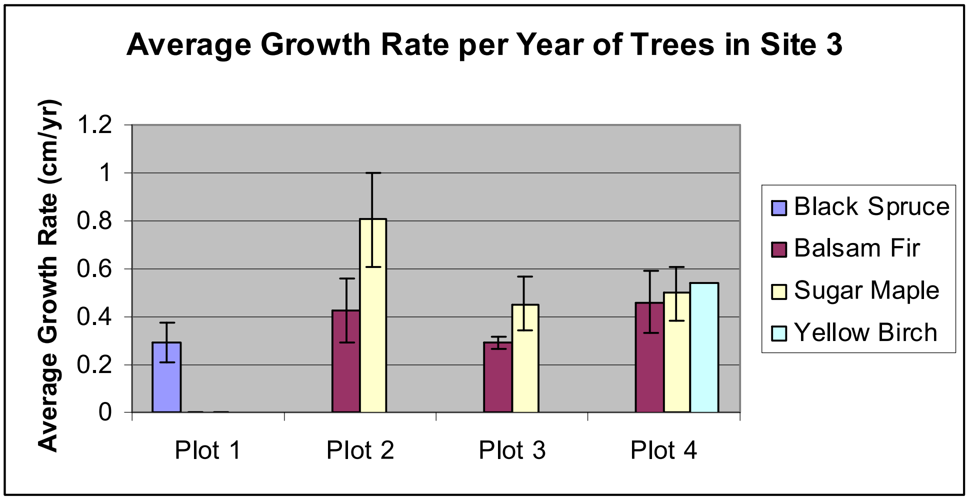

Figure 13. The average growth rate per year of trees at Site 3 separated by plot.

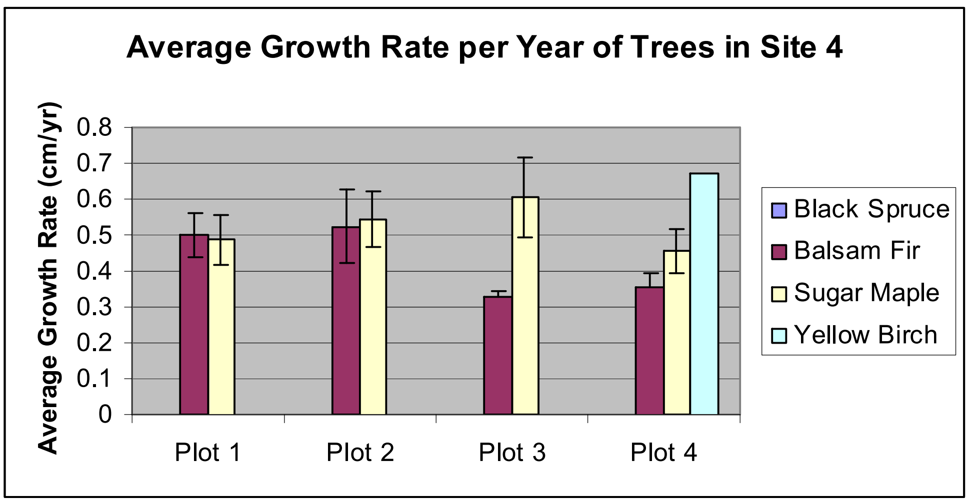

Figure 14. The average growth rate per year of trees at Site 4 separated by plot.

Site One

	Plot One	Plot Two	Plot Three	Plot Four
Transect 1- 16T	0302746	0302688	0302688	0302659
Transect 1- UTM	5123682	5123669	5123669	5123679
Transect 2- 16T	0302760	0302749	0302718	0302716
Transect 2- UTM	5123678	5123655	5123628	5123626
Transect 3- 16T	0302772	0302765	0302752	0302731
Transect 3- UTM	5123684	5123633	5123600	5123585

Site Two

	Plot One	Plot Two	Plot Three	Plot Four
Transect 1- 16T	0307430	0307411	0307390	0307361
Transect 1- UTM	5124755	5124745	5124720	5124693
Transect 2- 16T	0307429	0307409	0307399	0307349
Transect 2- UTM	5124751	5124731	5124710	5124708
Transect 3- 16T	0307452	0307425	03074707	0307399
Transect 3- UTM	5124732	5124712	51246821	5124583

Site Three

	Plot One	Plot Two	Plot Three	Plot Four
Transect 1- 16T	0307697	0307672	0307639	0307621
Transect 1- UTM	5122994	5122976	5122973	5122953
Transect 2- 16T	0307686	0307668	0307632	0307602
Transect 2- UTM	5123010	5122987	5122986	5122974
Transect 3- 16T	0307689	0307659	0307639	0307622
Transect 3- UTM	5123026	5123009	5122985	5122969

Site Four

	Plot One	Plot Two	Plot Three	Plot Four
Transect 1- 16T	0307694	0307655	0307629	0307608
Transect 1- UTM	5123510	5123508	5123500	5123518
Transect 2- 16T	0307690	0307661	0307631	0307608
Transect 2- UTM	5123524	5123529	5123540	5123549
Transect 3- 16T	0307687	0307644	0307637	0307601
Transect 3- UTM	5123543	5123609	5123535	512361

Table 1. GPS Coordinates at the four plots along the three transects at each one of the four sites.

Discussion:

The total number of black spruce in the plot nearest the wetland is significantly higher than all the other plots (Figure 2). This result was expected since black spruce needs a moist environment in order to grow. The other conifer, balsam fir, was found in all four plots of the transect (Figure 2). However, both the average age and DBH of balsam fir in all four sites at the fourth plot is noticeably less than sugar maple, suggesting that although saplings and small trees may grow well, they will soon be out competed by sugar maple. Sugar maple was found in great abundance in the upland areas, as expected, and seemed to dominate the sites. Yellow birch was not found in as great abundance as expected, and seemed to prosper well in the upland environment, though generalizations are hard to confirm with so few yellow birch found.

Analysis of the Diameter at Breast Height of Trees at Each Site

Site one, near the road to Cranberry Bog, supports the hypothesis that the diameters at breast height of trees in the bog are smaller than the diameters at breast height of the upland trees. Black spruce has the smallest average DBH and sugar maple continues to increase in average DBH as the plots move away from the wetland (Figure 3). Site two did not directly support the hypothesis, but it is possible that the lack of balsam fir at this site had a major impact and allowed for sugar maple to dominate closer to the wetlands (Figure 4).

Site three had no obvious trends, but was statistically different in average DBH among different tree species and plots (Figure 5). In plot three, both balsam fir and sugar maple had lower average DBHs than in plots two and four, so it is feasible that other factors that were not tested for, besides proximity to water, affected their diameters at breast height. In site four, there were significant differences in average DBH between species in the various plots. Balsam fir is smaller in the uplands than the wetlands (Figure 6). It is interesting that this site had transects that went from Bay Lake to 90 meters upland and that no black spruce was found at this entire sight. Likewise, although there are differences among the diameters of the different trees, the average diameters of each tree species going up the transect relatively stays the same. This could be indicative that a lake has a different effect on the upland area than a bog.

Analysis of the Age of Trees at Each Site

At site one, black spruce is younger than all the other tree species at the three other plots, and therefore confirms the hypothesis that the trees in the bogs are younger than the upland trees (Figure 7). This could be due to the fact that the trees in the bogs are subjected to more disturbances, such as high wind, and are more likely to get knocked over and survive for a shorter time period. Trees in the uplands are not subjected to disturbances of the same force and are less likely to get knocked down. At site two, the opposite was found. Black spruce is found to have approximately the same average age as sugar maple, even though they are found in different plots (Figure 8). This could be the result of trees in this bog being subjected to fewer disturbances, relative to site one. Sugar maple could also be older in the plots closer to the bog (plot 2) since there was no balsam fir present at this site. Without the presence of balsam fir, the dynamics of the age of the trees at this site could vary noticeably from other sites.

At site three, black spruce is relatively young compared to the trees in the other four plots, therefore confirming the hypothesis. Sugar maple continues to increase in average age as the plots get farther away from the bog. On the contrary, balsam fir continues to decrease in age as the plots get farther away from the bog. The youngest trees found at this site are balsam firs in plot four (Figure 9). The hypothesis did not predict that young balsam fir would be found in the fourth plot, so this find is interesting, though unexpected. At site four, even though the relative ages of the different species differ significantly, the ages of each species on the transect does not vary much between each plot. This lake site, unlike the previous bog sites, does not support the hypothesis that the younger trees are found only in the wetlands and that the older trees are only found in the uplands. This site does support the hypothesis when the old yellow birch is found in the upland plot, but there is only one yellow birch found and so conclusions cannot be supported (Figure 4).

The maximum age at each stand is similar, ranging from 60 to 67 years old. This suggests that the trees were all clear-cut around the same time at the four different sites in the 1940s.

Analysis of the Average Growth Rate per Year of Trees at Each Site

At site one, the average growth rate per year of each tree species in each plot was relatively the same (Figure 11). This could indicate that the trees, especially in plots two, three, and four, were logged around the same time and are growing at the same rate, indicating an early successional forest. Site two does not have significantly different average growth rates, like site one, which could also indicate that this site was clear-cut and the trees grew back at the same rate (Figure 12).

Site three has a widely varied average growth rate per year. Not only do the growth rates vary per plot, but the growth rates vary per tree species up the transect (Figure 13). This could be indicative of a stand that was not clear-cut and that has been around for a longer period of time. However, the average ages of the trees in this site does not indicate an obvious difference in age (Figure 9). Therefore, other factors that were not tested for probably affected the difference in the average growth rate per year. In site four, the average growth rate is also significantly variable between tree species as one analyzes the different plots

(Figure 14). This could be indicative of the differences among the bogs and lakes, or could also be the result of other factors that were not tested for.

There are several ways that this project could have been improved. Instead of clumping bogs and lakes together into "wetlands", it would have been appropriate to distinguish the two since differences were found. For a future project, it would be interesting to analyze the differences in average diameter at breast height, age, and growth rate per year in transects that stretch from a bog to uplands versus transects that stretch from a lake to uplands.

Another noticeable problem was that, although the transects intersected the shore where the wetland met dry land, the plots did not. Therefore, no sampling was done from the shore. The shoreline would be an important area to analyze since it included many tree species that did not exist 20 meters upland from the shore. A future project could construct transects from a wetland to an upland area by starting at the shoreline and walking 30 meters into the wetlands and then 60 meters to the upland area. This would ensure that the shoreline would be evaluated.

In conclusion, the bogs that I analyzed, most particularly site one, confirmed the originally proposed hypotheses. The trees in the moist environments are typically black spruce and the larger balsam fir, and tend to out compete other deciduous trees. On the other hand, the uplands are dominated by sugar maple and have the occasional yellow birch present. Sugar maple is also larger than the balsam fir present in the upland areas, suggesting that competition will soon drive out the younger, smaller balsam fir. The youngest trees are not necessarily going to be found in the bog areas, although they are relatively young in the wetlands, since the youngest trees were balsam firs that were growing in the uplands. The average growth rate per year of areas that had been clear-cut is relatively similar between the different tree species in the different plots. This project found important patterns within the wet and dry habitats of the UNDERC property. Other surveys done on similar forests, especially those that were not clear-cut in the past century, would be interesting to compare to the results found in this project. If more variability was found among average DBH, age, and growth rate of the trees in non clear-cut forests, that survey could help argue against clear-cut logging. If future surveys were conducted, more forest patterns could be determined and there would be a better understanding of the Northwood forests.

Acknowledgements:

I thank Dr. Botkin for his guidance and helpful instruction in designing this survey. I also thank my fellow UNDERC students for aiding me in my project; most especially, Adam Anderson, Meredith Sheperd, Trisha Shrum, and Sarah Nuske for coring a large number of sugar maple trees and for keeping me sane during long days of data collection. I am also grateful to the Bernard J. Hank Family Endowment for funding this project.

References Cited:

Guide to UNDERC: University of Notre Dame Environmental Research Center. Notre Dame, IN, Department of Biological Sciences, 1999.

Petrides, G.A. 1972. *A Field Guide to Trees and Shrubs: Northeastern and North-central United States and Southeastern and South-central Canada.* Houghton Mifflin Company, New York.

Reiners, W.A., I.A. Worley and D.B. Lawrence. 1971. Plant Diversity in a Chronosequence at Glacier Bay, Alaska. Ecology. 52:55069.

Whittaker, R.H. 1965. Dominance and diversity in land plant communities. Science. 147:250-260.