

National Park Service
U.S. Department of Interior



Great Lakes Inventory and Monitoring Network
Ashland, Wisconsin

Vegetational Analysis of Grand Portage National Monument from 1986 – 2004

MacLean and Gucciardo
April 2005



**VEGETATIONAL ANALYSIS OF
GRAND PORTAGE NATIONAL MONUMENT
FROM 1986 - 2004**

By

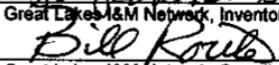
David B. MacLean, Ph.D.
Grand Marais, MN

L. Suzanne Gucciardo, Ph.D.
Grand Portage National Monument

Great Lakes Network Report
GLKN/2005/07

Contract No. P2105040041

Final Report
Submitted
April 8, 2005

Reviewed by:		Date:	4/18/05
	GRPO, Chief, Resource Management		
Recommended by:		Date:	4/11/05
	Great Lakes I&M Network, Inventory Specialist		
Approved by:		Date:	4/11/05
	Great Lakes I&M Network, Coordinator		

Suggested citation:

MacLean, D. B. and L. S. Gucciardo. 2005. Vegetational analysis of the Grand Portage National Monument from 1986-2004. National Park Service Great Lakes Inventory and Monitoring Network Report GLKN/2005/07

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ABSTRACT

Four permanent vegetation monitoring plots, two control and two treatment plots, were established in 1986 within Grand Portage National Monument, Cook County, Minnesota to monitor changes in the vegetation. Nine permanent quadrats in each plot were sampled in 1986 and again in 1992, 1996 and 2004. Within each quadrat, species and diameter at breast height (DBH) of living and dead large trees were determined, the number of woody stems counted, and the percent herbaceous cover was estimated. Descriptive statistics of abundance and basal area showed balsam fir increased dramatically at all plots, and paper birch and quaking aspen declined. Clear cutting on adjacent land in 1980 was not correlated with the decline of birch and aspen. Based on Sørensen dissimilarity coefficients, all plots were dissimilar in 1986 and by 2004 had undergone considerable changes that increased their dissimilarities. Bray-Curtis ordination was used to evaluate the divergence of plots over time. The increasing dominance of balsam fir raises questions regarding future management protocol for the forest within Grand Portage National Monument.

INTRODUCTION

This report presents the results of an analysis of vegetation data collected from 1986 to 2004 at 4 permanent plots at Grand Portage National Monument (GRPO). The plots were established in 1986 and sampled in 1986, 1992, 1999 and 2004. The Monument, located in extreme northeastern Cook County, Minnesota, includes the reconstructed North West Company Stockade and Great Hall on the shores of Lake Superior, adjacent Mount Rose (920 ft/283 m msl) and the Grand Portage trail. The trail extends 8.5 miles (14.2 km) from the stockade to the former site of Fort Charlotte on the Pigeon River. Monument property extends 300 feet (92 m) from either side of the trail and is embedded in Grand Portage Reservation forestry lands (NPS 2004)(Fig. 1).

Grand Portage occurs on the North Shore Highlands and the extreme eastern portion of the Borders Lakes (Minnesota Ecological Classification subsections), and includes two Land Type Associations (LTA), the North Shore Till Plain and the Swamp River Till Plain (Minnesota Department of Natural Resources 2001). The former is characterized by rolling topography and clayey soil and the latter by thick deposits of loamy till and clayey lake sediments. Within the Monument, the transition between the two LTAs occurs in the area between Old Hwy 61 and Cowboys Road. A history of the classification of the forest associations of GRPO is given by White and Host (2003). These authors currently classify the matrix forest of most of the GRPO as mesic birch-aspen-spruce-fir. Aspen-birch associations currently make up 64% and spruce-fir 26% of the trail corridor. Red pine (*Pinus resinosa* Ait.) is infrequent and individual and small groves of white pines (*Pinus strobus* L.) occur throughout the corridor. An old growth stand of white cedar (*Thuja occidentalis* L.) occurs along the trail west of Cowboys Road. Currently, aspen (*Populus* sp.) is more abundant and conifers are less prevalent than during the presettlement era (White and Host 2003).

The near-boreal forests of the Grand Portage area are disturbance-adapted ecosystems where more-or-less frequent ground fires, infrequent stand-replacing fires, and occasional blowdown events are critical factors in creating a mosaic of habitats (White and Host 2003). Journal entries dating from the fur trade era suggest the landscape of Grand Portage was more open than at the current time because of these natural processes (Thompson 1986). Extensive logging of pine beginning in the late 1800s, followed by fire suppression throughout the last century, and prohibition of logging on Monument lands for half a century have resulted in a nearly uniform aspen-birch-spruce-fir forest cover along the trail corridor.

The Organic Act of 1916 stipulates that the National Park Service must strive to maintain natural ecosystems and processes on lands within park units. For some time that was interpreted to mean non-interference and passive management of backcountry areas such as the Grand Portage trail corridor. In contrast, all Grand Portage Reservation lands immediately surrounding the Monument trail corridor (Fig. 1) have been managed for commercial forestry purposes since early in the 20th Century. Harvests occasionally result in cut-over areas lying adjacent to Monument lands. What effect, if any, this has on forest communities in the Monument is not clear. This issue was addressed in a vegetation monitoring project begun in 1986 by Walter Loope, then biologist for Pictured Rocks National Lakeshore. In his 1986 annual report, he stated:

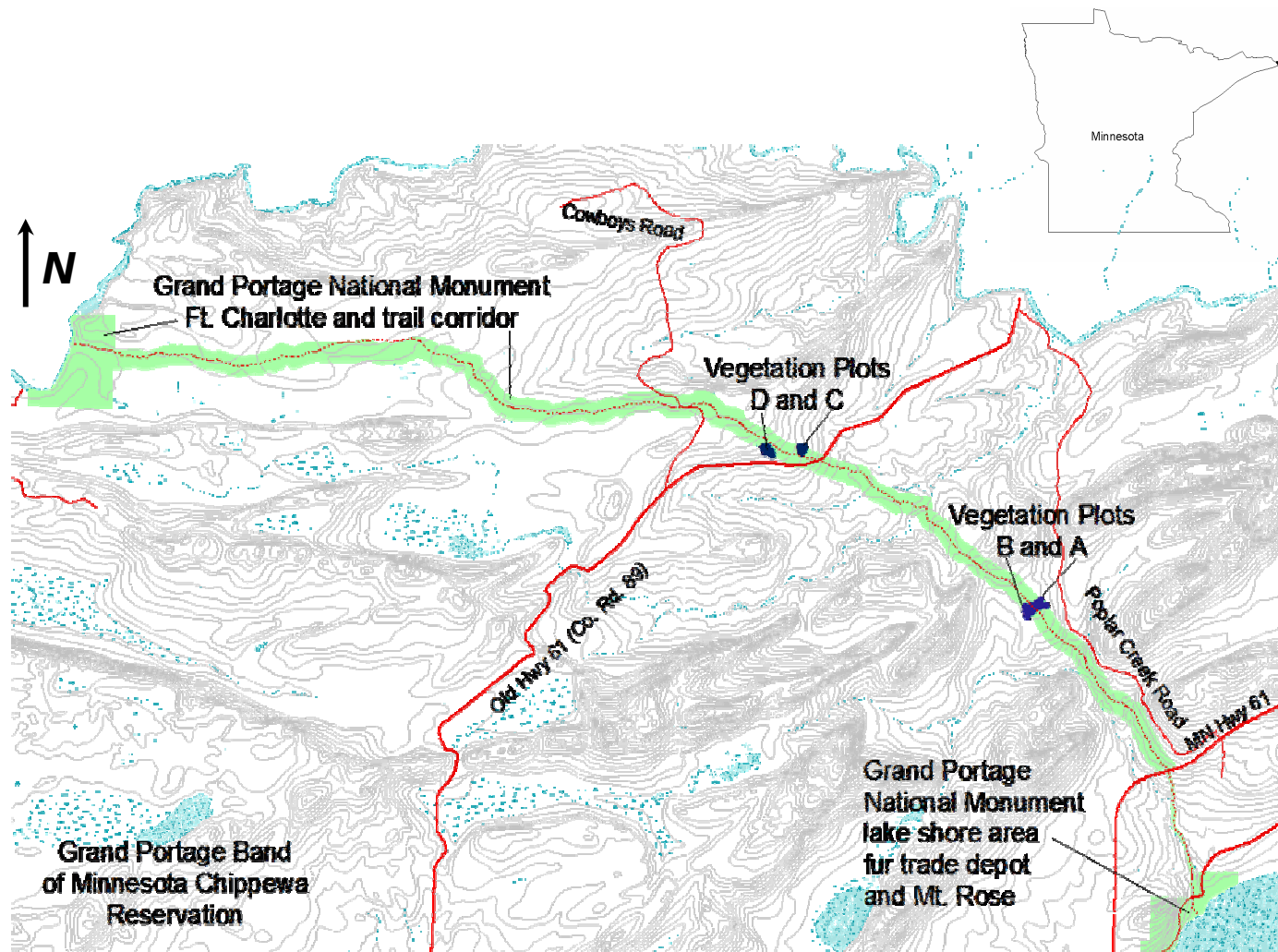


Figure 1. Location of Grand Portage National Monument within the Grand Portage Reservation, Cook County, MN. Locations of vegetation plots established along the trail corridor in 1986 were related to ease of access from county or reservation roads.

"The primary purpose of this project is to characterize forest composition and structure in terms of extant species density, cover, frequency and relative dominance at several places along the Portage Trail.... In addition to providing a general base line of information for future comparisons, the project should provide some basis for assessing the influence of land use practices on surrounding lands."

Criteria used to select the location of four sample plots were: "1) areas representative of the contrast in land use practices between Monument and tribal lands; and 2) ease of access and extent to which the [sites] would be relocatable" (GRPO 2004). Two plots (A and B) adjacent to Reservation lands clear cut in 1980 served as a treatment, and two others (C and D) adjacent to undisturbed tribal lands served as a control.

A combination of factors led to a change in NPS management policies, in general, and Grand Portage National Monument resource management, in particular. In recent decades, the importance of fire and other disturbance events in maintaining northern mixed hardwood-coniferous forests have become better understood by the scientific community (Frelich 2002). It is now recognized that active intervention may be required to restore or maintain natural processes which have been disrupted by activities of modern man, and such management may be permissible in national parks. The formation of a resource management division within the Monument provided support for full-time staff focused on understanding and addressing natural resource issues of the park. As a result of this improved knowledge, on both a general and local scale, the management goal for the trail corridor and Ft. Charlotte areas of Grand Portage National Monument is to restore the historic forest landscapes to the conditions that would have prevailed during the fur trade era, or about 200 years ago. These desired future conditions rely on return or simulation of natural disturbance events essential for developing a mosaic of forest communities. In this regard, clear cut harvests on adjacent Reservation lands are viewed as a substitute for stand-replacement fires, and could provide enhanced effects on Monument forests.

The current 4 sample plots may not be representative of the forests throughout the corridor; this criterion was rejected in the selection of plots in 1986 (Loope 1986). Plots A and B (treatments) were positioned adjacent to land clear cut in 1980. Little documentation exists that explains the selection of plots C and D (control) from among other areas of the trail corridor adjacent to undisturbed (at that time) Reservation lands. More complete environmental information now available suggests these two pairs of plots may not have been suitably matched for a comparative study. Treatment plots are well within the North Shore Till, while control plots lie on the transition into the Swamp River Till Plain. Although the environmental conditions between these two land type associations is subtle (Minnesota Department of Natural Resources 2001), they are likely to be enhanced by site-specific differences. Treatment plots occur on nearly level, poorly drained soils while the control plots are situated on a well-drained ridge, with plot C facing east and plot D facing southwest. Plots A and B are closer to the moderating effects of Lake Superior with its cooler, more humid summer conditions, while plots C and D, 2.7 and 3 km farther inland and sheltered by intervening highland ridges, experience warmer and drier growing seasons.

There are plans for developing a vegetation management strategy for Grand Portage National Monument that would restore the historic scene. Essential aspects of such a plan are an understanding the current forest communities resulting from previous passive management and long-term monitoring of the effects produced by future management actions. To support these needs, GRPO resource managers have a choice between continuing and expanding the current vegetation monitoring protocol, or implementing a different protocol that would provide better information in support of management decisions. The first step in making this choice is determining what information is provided in the data collected from 1986 to 2004. The purpose of this statistical study is to evaluate the suitability of the current sampling protocol as a means of tracking forest composition on existing sample plots over time.

The goals of this project were to analyze data collected during the four sampling periods to determine:

- Goal 1. The dissimilarity within and between treatment and control plots at initiation of the study in 1986 and in subsequent sampling periods, based on number and diameter of overstory trees.
- Goal 2. Trends in abundance and basal area of dominant overstory tree species in treatment and control plots. This will indicate what changes are taking place and provide information for future forest management decisions.
- Goal 3. Changes in overstory tree mortality in treatment plots based on number of standing dead and downed trees. Evidence of increased mortality will allow for inferences about the impact of clear cutting on adjacent land on the forest within the Monument.
- Goal 4. Trends in community composition in treatment and control plots based on stem counts of woody understory trees and estimated percent ground cover of the herbaceous layer. These data were included in the sampling design to make inferences about the effect of light availability at ground level and its impact on community composition.

METHODS

Data collection

A 100 m base-line transect was measured from the trail to the Monument boundary for each vegetation plot. Three sample transects were located at right angles along each base-line transect that were parallel to the trail and a random distance from it. Three sample quadrats, with 10-meter sides, were randomly located along each sample transect for a total of 9 sample quadrats at vegetation plots A, B and C. Vegetation plot D had only 8 sample quadrats. Permanent markers specifying the plot number and transect were placed at the northeastern corners of the sample quadrats and at the ends of the base-line transect. Within each sample quadrat, species of living and standing dead trees were determined and their diameters at breast height (DBH) measured for individuals greater than 6 cm DBH. Downed trees greater than 6 cm DBH and apparently originating within the quadrat were counted and identified to species. The number of woody stems between 1.25 and 6 cm DBH were counted. Herbaceous cover was estimated for all species within two 1 m² sub-quadrats nested within the northeast and northwest corners of each sample quadrat.

Data for this project were collected in 1986 by the initial primary investigator (Loope) assisted by GRPO seasonal staff. In 1992, the same seasonal staff (in part) collected data in consultation with Loope. During 1999 and 2004, the current GRPO ecologist was primary investigator (PI), assisted by the Chief of Resource Management and seasonal staff. The current PI entered data from all years into Excel spreadsheets to evaluate data quality and prepare for statistical analysis. The 1992 data is problematic for two reasons. All four corners of sample quadrats were not permanently marked until 1999. "Disappearance" of large trees from sampling quadrats in 1992, that later reappeared in 1999 and 2004 suggest that quadrat layout may have been skewed in 1992. This has been addressed by interpolation of the tree sizes for 1992 (Appendix A-1). The field staff in 1992 had limited botanical training, although this only presented a difficulty for unusual species such as immature herbaceous plants; tree species considered in the statistical analysis were readily identifiable by them.

All scientific names follow Gleason and Cronquist (1991).

Statistical analysis

Goal 1. Dissimilarity within and between treatment and control plots

Sørensen's dissimilarity coefficient D was used to compare the dissimilarity between pairs of plots in 1986 and 2004. Values of D were based on the 5 most abundant species recorded in plots: balsam fir (*Abies balsamea* (L.) Mill.), paper birch (*Betula papyrifera* Marsh.), white spruce (*Picea glauca* (Moench) Voss), quaking aspen (*Populus tremuloides* Michx.), and white pine, and were calculated (MS Works spreadsheet) using two variables (1) the number of trees at a plot for each species and (2) the summed basal area of each species at each plot. Basal area was calculated for individual trees by $[\pi d^2]/4$, where d = DBH, then summed by species and plot. Values of D were calculated as

$$D_{i,h} = \frac{\sum (abs[a_{i,j} - a_{h,j}])}{\sum (a_{i,j}) + \sum (a_{h,j})}$$

where a is either the number of trees or basal area of species j , and i and h are the plots in the comparison. It was possible to make pair-wise comparisons among all plots since all were dissimilar in 1986.

Pearson's product moment correlation coefficient (r) was used to examine for associations between the dissimilarity values for plots in 1986 and 2004. Values of r were calculated (Minitab Version 8.2) as

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{n}}{\sqrt{\left(\sum X^2 - \frac{(\sum X)^2}{n}\right)\left(\sum Y^2 - \frac{(\sum Y)^2}{n}\right)}}$$

where Y equals the values of D in 1984, and X is the values of D in 2004. Six plot comparisons (A vs B, A vs C, A vs D, B vs C, B vs D and C vs D) were used to test the null hypothesis H_0 : there was no association between the dissimilarity of vegetation plots in 1986 and 2004. Differences were considered significant if $p \leq 0.05$.

Bray-Curtis ordination (polar ordination) was used to illustrate the changes in dissimilarity within and between treatment and control plots over the 4 sampling periods. While many newer ordination methods have been developed, Bray-Curtis with the appropriate distance measure (Sørensen) and variance-regression endpoint selection has been shown to give results as good as or better than others (Beals 1984, McCune and Beals 1993). It is appropriate for multivariate analysis of phytosociological and ecological data, such as examined here. The restricted size of the sample set (16 samples over 4 years) can also be adequately accommodated, while the data may be too limited for more sophisticated methods.

Ordination uses a matrix of Importance Values (IVs) which describes the relative position of a sample, compared to all samples in the data set, in a multi-dimensional space. For this analysis, the number of trees and their DBH were used to calculate IVs of a tree species for each plot in each sample year. A species IV is the sum of its relative density and relative dominance and has a maximum value of 2.0 when a quadrat includes only that species. Relative density was calculated as the number of individuals of a species recorded from a quadrat divided by the total number of trees for all species from the same quadrat. For example, paper birch represented by 4 individuals in a quadrat with a total of 20 trees has a relative density of $4/20 = 0.2$. Relative dominance values were calculated for all species in a quadrat by dividing the sum of each species basal area by the total basal area for all species. If the DBHs of the 4 paper birch trees in the above example are 20.3, 22.9, 25.4 and 30.5 cm, the summed basal area of this species = $1971.1 \text{ cm}^2/10 \text{ m}^2$. If the total basal area of all species for this quadrat is 3500 cm^2 , the relative dominance of paper birch = $1971.1/3500 = 0.56$. Thus the Importance Value of paper birch in this quadrat is relative density (0.20) + relative dominance (0.56) = 0.76.

Importance values were calculated from the relative abundance and relative basal areas for the 5 most abundant tree species in a total of 140 vegetation quadrats sampled in 1986, 1992, 1999 and 2004 (MicroSoft Works spreadsheet). Each plot was coded according to a collection period, i.e. A86...D86, A92...D92, A99...D99, A04...D04 and treated as a separate plot. In other words, plot A86 consisted of IVs for the 6 tree species in 1986, D99 for plot D in 1999, B04 for plot B in 2004, etc. The resulting 6 (species) x 16 (plots) matrix was entered into PC-ORD (Version 4, MjM Software) as the primary data matrix for a Bray-Curtis ordination on three axes (McCune and Mefford 1999).

Goal 2. Trends in dominance of overstory trees

A 4 X 5 contingency table was used to evaluate changes in the numbers of live trees at each plot from 1982 to 2004. This approach was used since presence or absence of trees > 6 cm DBH is assumed to be categorical data, rather than continuous data derived from a measurement of individual trees. Each plot was analyzed separately to test the null hypothesis H_0 : there was no significant difference between the observed and expected number of live trees for each species and the year sampled. A Chi square (χ^2) goodness of fit test was used to test for significance where there was a deviation from the expected values. Chi square (χ^2) was calculated (Minitab Version 8.2) as

$$\chi^2 = \sum \sum \frac{(f_{ij} - \hat{f}_{ij})^2}{\hat{f}_{ij}},$$

where f_{ij} is the measure (count) for sampling period i and tree species j ; and where $\hat{f}_{ij}$ is the expected values of the measure in sampling period i and tree species j , if H_0 is true. Expected values are calculated as

$$\hat{f}_{ij} = \frac{(R_i)(C_j)}{n},$$

where R_i equals the sum of measures in row i and C_j equals the sum of measures in column j . Differences were considered significant when $p \leq 0.01$ level, or highly significant when $p \leq 0.001$.

Trends in dominant overstory trees were further examined by graphically displaying the number of live and standing dead trees for each species by plot and year. The summed basal area of species by plot and year were also graphed for visual inspection. This approach was to demonstrate changes in dominance among the 5 most abundant tree species by indicating the direction and rate of change for each species. The ecological implications of such changes should be apparent without further statistical analysis of rates or direction of change.

Goal 3. Changes in overstory tree mortality

The myriad causes of tree mortality result in one of two states in affected individuals; they are either standing dead or downed trees. Trees in both states were analyzed to test for increased mortality in treatment plots. Standing dead trees were graphed by species and year in conjunction with live trees. The limited number of

downed trees made it inappropriate to examine the data by species, so plot totals were graphed by year for visual inspection of trends. To further examine these data, the total number of standing dead and downed trees in plots was compared over time among the treatment and control plots with a two way analysis of variance (ANOVA, general linear model, SigmaStat Version 2.0, SPSS Inc.). The null hypothesis was H_0 : there was no significant difference in the number of standing dead/downed trees among plots or sample years. Differences were considered significant when $p \leq 0.05$, and were followed by pair-wise multiple comparisons (Tukey Test) when significance was found.

Unprotected exposure to high winds might increase the number of downed trees on treatment plots compared to control plots. Other mortality factors may also be related to the distance from the clear cut area, but in a less dynamic way, resulting in standing dead trees. Insect or disease spread, alteration of available light, increased heating or drying might affect trees closer to the clear cut edge. In order to evaluate this possibility, a Pearson product-moment correlation coefficient (r) was calculated to test the following null hypothesis H_0 : there is no association between the number of standing dead birch in quadrats of plot A in 1986 and distance from the plot edge. Data from the 1986 sample were chosen to test the hypothesis as this was the sample period closest to the date of clear cutting. Paper birch is less tolerant of environmental disturbance than other species so may reflect a response to subtle changes (Tim Miller, Grand Portage Reservation forester, pers. comm.). Plot A was selected because the 13 standing dead birch recorded in 1986 were distributed among 6 of the 9 quadrats; plot B had only 2 dead birch. The distance of each quadrat from the park boundary was estimated from an ArcView GIS mapping of GPS locations for plot A. Values of r were calculated (Minitab) where Y was equal to the number of standing dead trees in a quadrat, and X the distance of the quadrat to the Monument boundary. Differences were considered significant if $p \leq 0.05$.

Goal 4. Changes in understory community composition

The contribution of understory shrubs with $DBH\ 1.25 \leq x \leq 6\text{ cm}$ to community composition was analyzed by species with a two way ANOVA (general linear model, SigmaStat Version 2.0, SPSS Inc.) using the null hypothesis H_0 : there is no difference in the mean number of stems for a woody understory species among plots or years. Differences were considered significant when $p \leq 0.05$, and were followed by pair-wise multiple comparisons (Tukey Test) when significance was found. ANOVA was used in this test, instead of χ^2 as with trees $\geq 6.0\text{ cm DBH}$, because it was assumed the number of smaller woody stems in a quadrat could range from 0 to infinity. Based on changes in species recorded, the 5-year sampling interval permitted sufficient turnover in the $1.25 \leq x \leq 6\text{ cm}$ sample range that the same individuals were likely not counted during successive sample periods.

Data obtained from the 1 m^2 sub-quadrats for ground and herbaceous plant cover is problematic. The number of samples is small relative to the number of species encountered (44) and the variability in mean estimated canopy coverage for most species is large. As a result, the sample size used in the current project lacks sufficient statistical power to estimate yearly abundances. It is only possible to provide presence/absence data for herbaceous layer species by sample plot (George Host, NRRI, pers. comm.). This information can provide a limited description of the understory community.

RESULTS

Appendix A presents all raw data for live and standing dead trees (Table A-1), understory shrubs (Table A-2) and herbaceous plant canopy cover estimates (Table A-3). Ten species and 1 genus of woody plants with DBH > 6 cm were recorded from vegetation plots A, B, C and D from 1986 to 2004 (Table 1). Alders (*Alnus* sp.) were identified only to genus because of the similarity of local species. Balsam fir, paper birch, white spruce, quaking aspen and balsam poplar (*Populus balsamifera* L.) were recorded from all plots. White pine was present at all plots except plot A. Sugar maple (*Acer saccharum* Marsh.) and mountain maple (*Acer spicatum* Lam.) were recorded only at plot B. Black spruce (*Picea mariana* (Mill.) BSP) was recorded only at vegetation plot A and red pine only at plot B. Alders were recorded only from plots A and B.

Table 1. Woody plant species recorded from vegetation plots A, B, C and D from 1986 - 2004, Grand Portage National Monument.

Species		Plots where recorded
<i>Abies balsamea</i>	balsam fir	A B C D
<i>Acer saccharum</i>	sugar maple	B
<i>Acer spicatum</i>	mountain maple	B
<i>Alnus</i> sp.	alder	A B
<i>Betula papyrifera</i>	paper birch	A B C D
<i>Picea glauca</i>	white spruce	A B C D
<i>Picea mariana</i>	black spruce	A
<i>Pinus resinosa</i>	red pine	C
<i>Pinus strobes</i>	white pine	B C D
<i>Populus balsamifera</i>	balsam poplar	A B C D
<i>Populus tremuloides</i>	quaking aspen	A B C D

Goal 1. Dissimilarity within and between treatment and control plots

Values of Sørensen's dissimilarity coefficient (D, expressed as % by multiplying by 100) are given in Table 2 for comparing the dissimilarities among pairs of plots for all sampling periods. Field observations in 1999 and 2004 suggested that sufficient dissimilarity exists within the paired treatment and control plots that pooling data for statistical comparison may not be appropriate. At initiation of the study, dissimilarity within the pair of treatment plots (24.2%) was as great as dissimilarity within control plots (24.0%) based on tree abundance. Dissimilarity in basal area for treatment plots was slightly greater (28.8%), while control plots were less dissimilar (16.0%). Based on the degree of dissimilarity within treatments and controls in 1986, all plot data were used individually for pair-wise comparisons. In order to keep the discussion of dissimilarities between plots manageable, only differences between 1986 and 2004 will be addressed.

Except for plots A and C based on tree species abundance, all plot comparisons were more dissimilar in 2004 than in 1986. When this project was initiated in 1986, plots A and B were 24.2% dissimilar based on tree abundance and 28.8% dissimilar based on tree basal areas. In 2004, plots A and B were 36.2% and 35.7% dissimilar based on these

variables. In 1986, the two control plots, C and D, were 24.0% dissimilar based on tree abundance but only 16.0% dissimilar based on tree basal areas. Based on these variables in 2004, plots C and D were 36.4% and 27.3% dissimilar. When the project was initiated, the most dissimilar plots were A and C (35.3% and 41.3%) and the two least dissimilar plots were A and D (17.3% for tree species abundance). Plots A and D were much more dissimilar in 2004 based on tree species abundance (39.4%) and somewhat more for basal area (31.7%). In 2004, Plot B was considerably more dissimilar with plot C for basal area (43.2%), and with plot D for abundance (45.4%).

Table 2. Values of Sørensen's dissimilarity coefficient, D, based on tree abundances and basal area for Grand Portage National Monument vegetation plots A, B, C, and D, 1986-2004.

	Comparison					
	A vs. B.	A vs. C	A vs. D	B vs. C	B vs. D	C vs. D
Abundance						
1986	0.242	0.353	0.173	0.234	0.280	0.240
1992	0.354	0.256	0.397	0.299	0.203	0.298
1999	0.259	0.364	0.382	0.278	0.339	0.178
2004	0.362	0.342	0.394	0.248	0.454	0.364
Basal area						
1986	0.288	0.413	0.280	0.306	0.260	0.160
1992	0.360	0.363	0.234	0.689	0.410	0.162
1999	0.308	0.334	0.276	0.362	0.154	0.226
2004	0.357	0.432	0.317	0.432	0.449	0.273

Calculation of Pearson correlation coefficients, r , showed that plot dissimilarities in 1986 were not significantly associated with plot dissimilarities in 2004. The correlation of D values for plot comparisons based on tree species abundance was 0.003, and for basal area it was 0.669. As the critical value for $r_{0.05, 4} = 0.811$, H_0 was not rejected for either tree abundance or basal area. Based on species abundance, the degree of dissimilarity that existed among plots in 2004, (e.g., A vs B) was not associated with the degree of dissimilarity that existed in 1986. In other words, this supports an interpretation that each plot is changing independently of others. Correlation of D values for basal area approached the significant level, which was expected since many of the same individuals contributed to total basal area of species in consecutive samples. Even with steady recruitment and attrition of overstory trees, complete turnover of individuals in sample quadrats could take centuries.

Results of Bray-Curtis ordination are shown in Table 3 and Figure 2. The 3 axes accounted for nearly 90% of the distance matrix based on tree importance values. Axis 1 accounted for nearly 50%, axis 2, 28% and axis 3, 12% of the total. Plots chosen as endpoints for each axis were: axis 1, A86 and C04; axis 2, C86 and B04 and axis 3, A92 and D04. The selection of plots sampled in 1986 (2), 1992 (1) and 2004 (3) as axis endpoints reflects the changes at these plots from 1986 to the present.

Table 3. Results of a Bray-Curtis ordination of 16 vegetation plot samples based on the six most abundant tree species in 1986, 1992, 1999 and 2004 at Grand Portage National Monument.

Axis no.	Percent of distance matrix extracted		Sum of squares of residual distances remaining	Plots chosen as endpoints	
	original	cumulative			
1	49.53	49.53	12.062	A86	C04
2	27.90	77.43	2.722	C86	B04
3	12.05	89.48	1.269	A92	D04

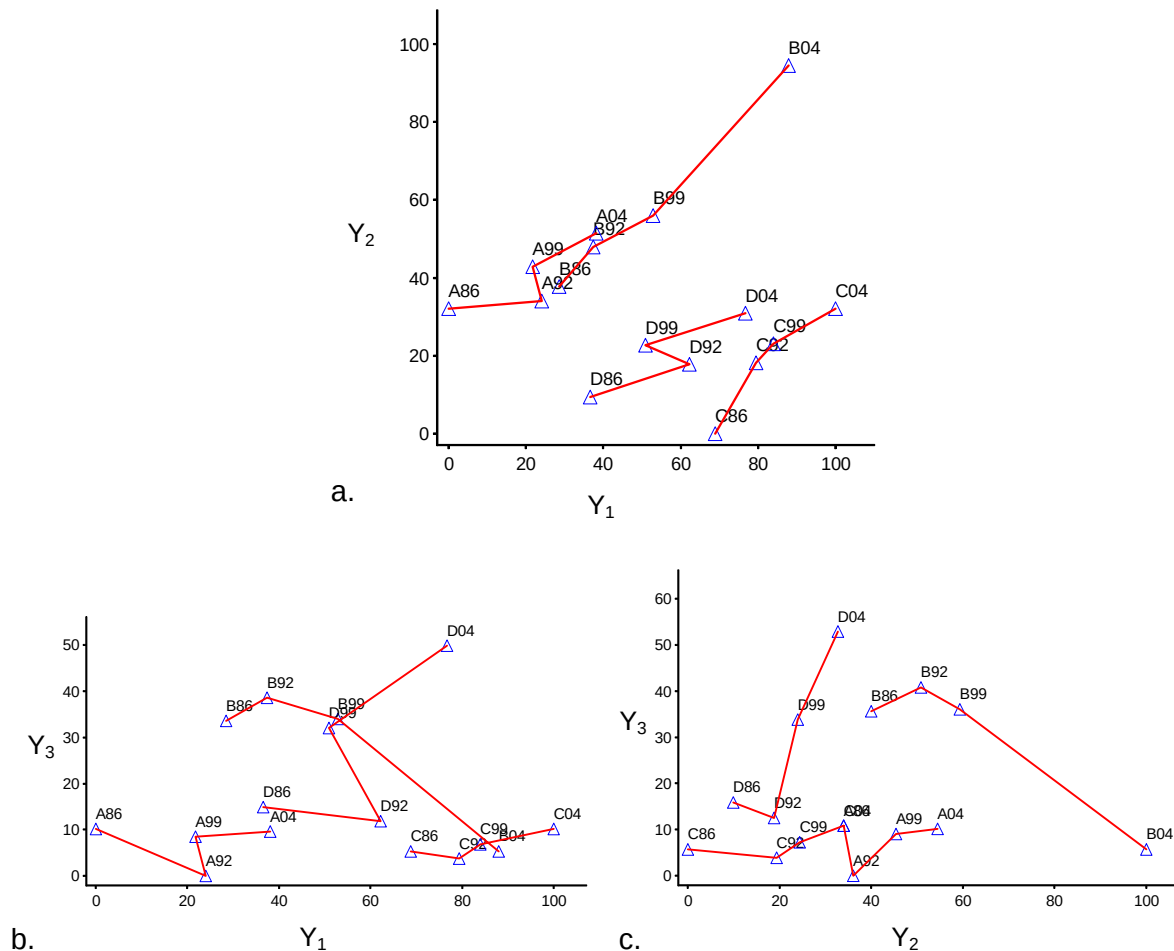


Figure 2. Pair-wise plots of Bray-Curtis ordination scores for 16 vegetation plots in Grand Portage National Monument. Points are labeled with plot identifiers (A through D) and last two digits of year sampled. Axes scales are proportion of maximum value. Lines connect individual plots over time. In 2c, A86 and C04 are superimposed.

Ordination scores, i.e., position of each plot on an axis, were plotted as two dimensional ordinations for axis 1 vs. axis 2, axis 1 vs. axis 3, and axis 2 vs. axis 3 (Fig. 2). Figure 2a shows a clear separation along axes 1 and 2 of the treatment plots A and B with the control plots C and D. Also evident is the separation of plots within each of these groups from 1986 to the present, e.g. A86 and B04. This suggests that the composition of these plots has changed considerably since the initiation of the study in 1986. Clumping of plots is evident for axis 1 vs. axis 3 (Fig. 2b) and axis 2 vs. 3 (Fig. 2c); however, treatment and control plots are not always separate. This overlap is not considered important as axis 3 accounted for only 12% of the extracted distance matrix.

In order to compare changes both within and among plots from 1986 to 2004, the position of each plot on an axis, i.e. its score, was graphed as a three dimensional ordination (Fig. 3). Each point was labeled as to its plot (A, B, C and D) and year sampled (86, 92, 99 and 04). The relationship among plots and years can be interpreted according to the location of plots within the ordination space and the distance (Euclidean) between them. In 1986, when the project was initiated, all plots were clearly different, including the two control plots A and B. By 2004 plots A and B, while still different, had converged somewhat. However, the increased separation of plots C and D in 2004 compared to 1986 indicates that these plots have diverged over time. Inspection of Figure 3 reveals that this difference is due to changes at plot D rather than plot C, which changed relatively little from 1986 to 2004. For most plots, the greatest difference between years occurred from 1999 to 2004, i.e. the Euclidean distance between a plot sampled in 2004 and 1999 was greater than in previous years. This was especially evident at plot D.

As a means to better interpret the relationships (distances) among plots, an overlay of the main matrix was generated for the 6 tree species (Figs. 4-9). The size of the plotting symbol (▲) reflects the importance of a species at a plot. The side scatter plots show the relationship between the chosen species and ordination scores along the axis. Each scatter plot shows a simple linear regression line and the 95% confidence interval (curved blue line)(McCune and Mefford 1999). Values of Pearson's correlation coefficient r and Kendall's Tau (rank correlation) coefficient measure the strength of this association.

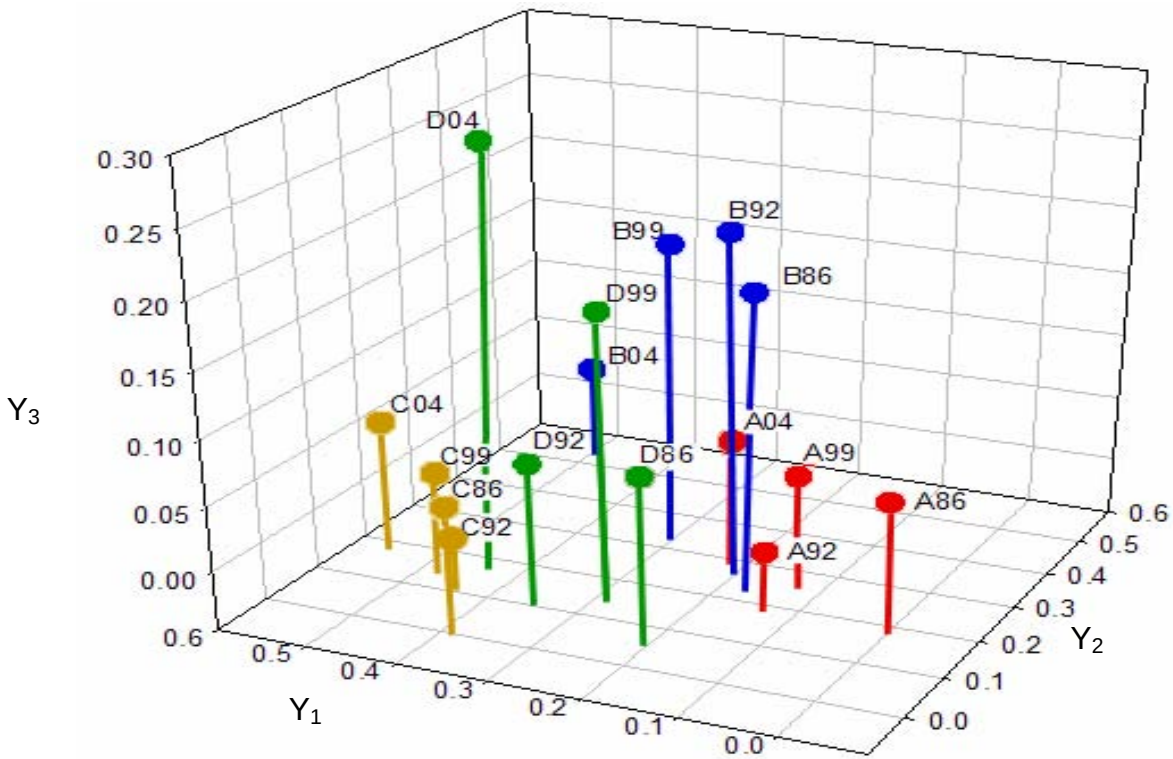


Figure 3. Three dimensional plot of Bray-Curtis ordination scores for 16 vegetation plots in Grand Portage National Monument. Points are labeled with plot identifiers (A through D) and last two digits of year sampled.

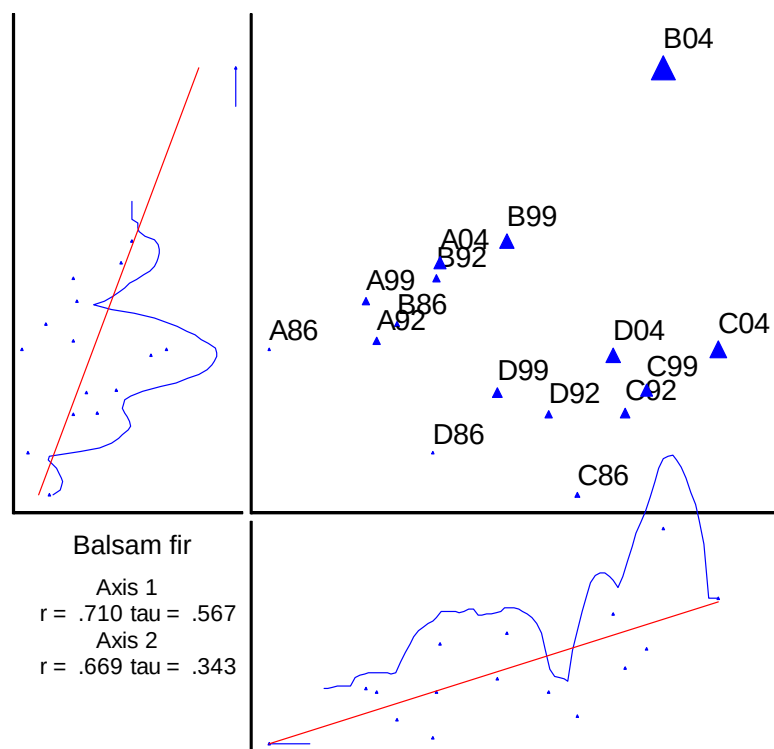


Figure 4. Bray-Curtis ordination of balsam fir for 16 vegetation monitoring samples obtained between 1986 and 2004 at Grand Portage National Monument.

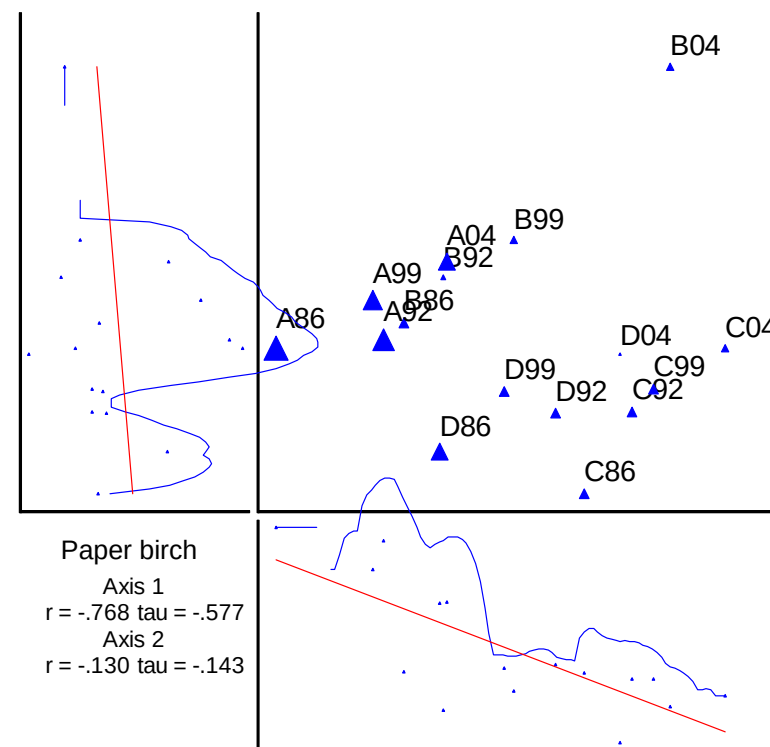


Figure 5. Bray-Curtis ordination of paper birch for 16 vegetation monitoring samples obtained between 1986 and 2004 at Grand Portage National Monument.

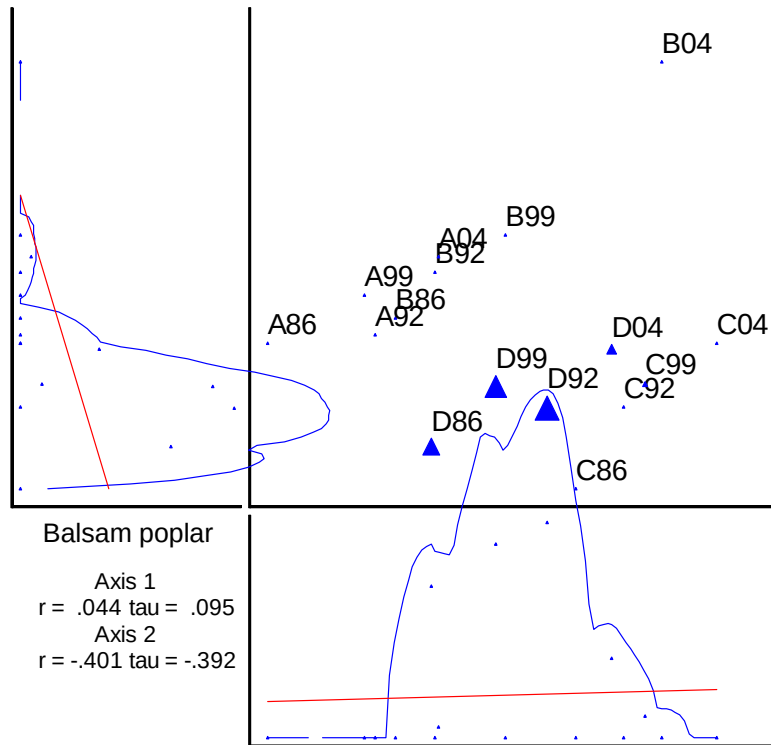


Figure 6. Bray-Curtis ordination of balsam poplar for 16 vegetation monitoring samples obtained between 1986 and 2004 at Grand Portage National Monument.

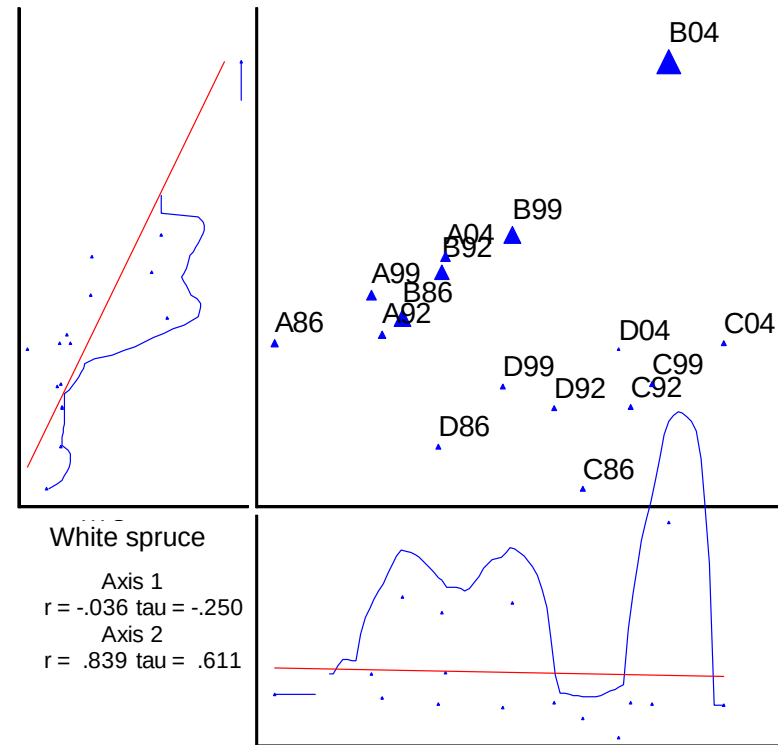


Figure 7. Bray-Curtis ordination of white spruce for 16 vegetation monitoring samples obtained between 1986 and 2004 at Grand Portage National Monument.

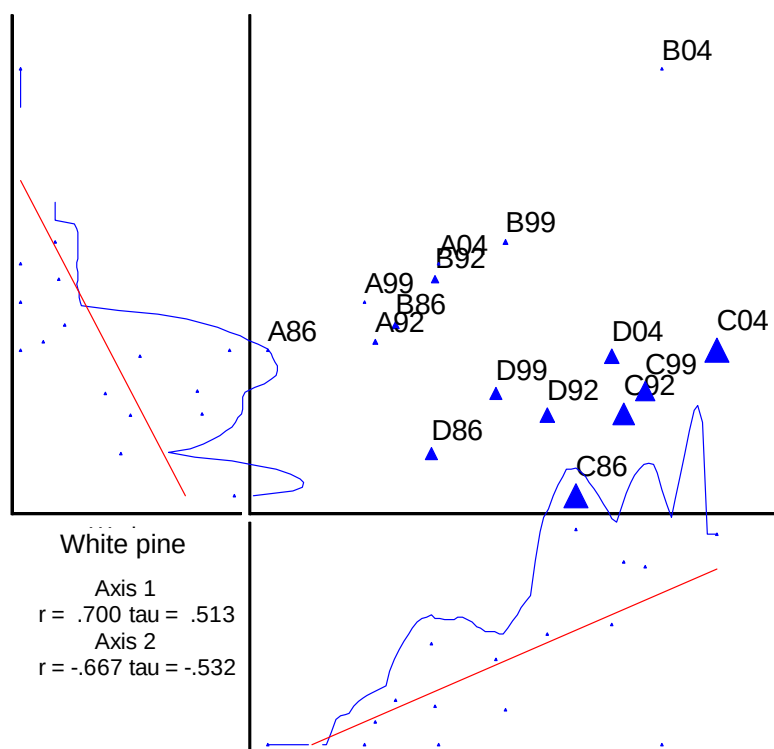


Figure 8. Bray-Curtis ordination of white pine for 16 vegetation monitoring samples obtained between 1986 and 2004 at Grand Portage National Monument.

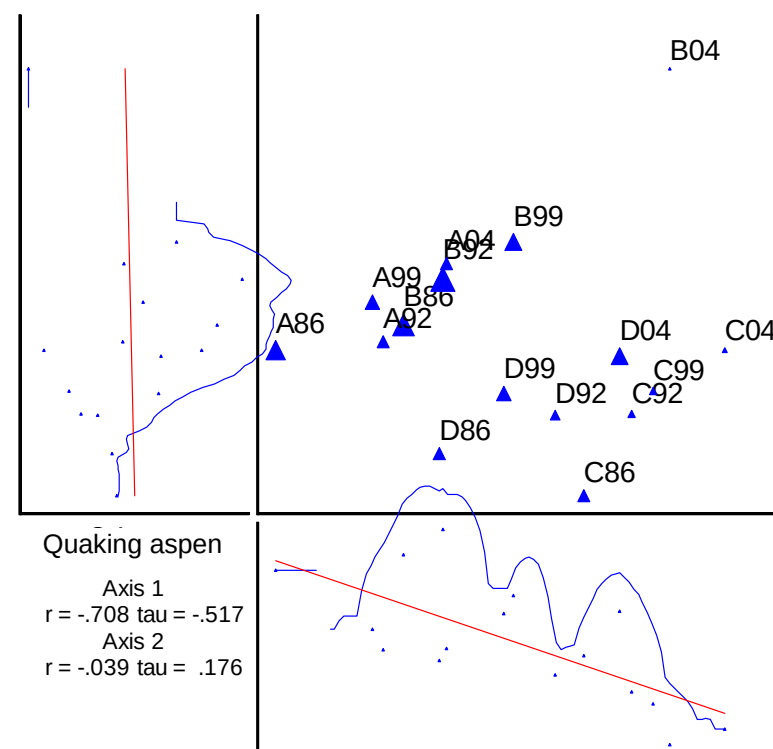


Figure 9. Bray-Curtis ordination of quaking aspen for 16 vegetation monitoring samples obtained between 1986 and 2004 at Grand Portage National Monument.

Balsam fir showed a high positive correlation with both axes (axis 1 = 0.710 and axis 2 = 0.669). Symbols in the ordination graph show that balsam fir steadily increased from plots sampled in 1986 to plots sampled in 2004. The separation of plot B04 from all the others is clearly due to the importance of balsam fir at this plot in 2004. Paper birch was strongly associated with axis 1, and weakly with axis 2. However, unlike balsam fir, the relationship was negative (axis 1 = -0.768 and axis 2 = -0.130). The size of the plotting symbols in Figure 5 and the scatter plots clearly show that paper birch was most important at plots A and B in 1986 but declined strongly in subsequent years. Birch, which was not as important at plots C and D in 1986, also declined there in subsequent years. Balsam poplar was present at only several plots and showed a negative relationship with axis 2 (Fig. 6). The positive relationship of white spruce with axis 2 was due to the increasing importance of this species at plot B from 1986 to 2004 (Fig. 7). White pine showed a strong positive correlation with axis 1 ($r = 0.700$) and a strong negative correlation with axis 2 ($r = -0.667$) (Fig. 8). The importance of white pine at plots C and D is the main reason for the distinct separation between plots A and B, and C and D. The importance of white pine did not change as much at plots C and D as most other species did at other plots, e.g. balsam fir and paper birch. Quaking aspen, like paper birch, exhibited a strong negative correlation with axis 1 ($r = -0.708$) that reflected its lesser importance at plots C and D (Fig. 9). The importance of this species remained relatively high from 1986 to 1999 but declined dramatically at plot B in 2004.

Goal 2. Trends in dominance of overstory trees.

Tree abundance

The numbers for observed and expected live trees by species, plot and year are presented in Table 4. Significant results, as determined by a χ^2 goodness of fit test are indicated in as ** ($p < 0.01$) and *** ($p < 0.001$). There was a significant increase in the numbers of balsam fir from 1986 to 2004. The number of fir was less than expected at all plots in 1986 but by 2004 was significantly greater than expected. For example, only 6 individuals of balsam fir were recorded from plot B in 1986 but 50 (28 expected) were recorded in 2004. In addition, in 2004 the number of quaking aspen was significantly less than expected (11 vs. 27) at plot B. The same was true in 2004 for paper birch (3 vs. 14) at plot D.

The numbers of live and standing dead trees are plotted in Figure 10, where the number of live trees is plotted above and the number of dead trees below the X axis. The most obvious trend was the sharp increase in the number of balsam fir at all plots from 1986 to 2004. This was most pronounced at plot B where the number of balsam increased from 6 in 1986 to 50 in 2004. The number of paper birch at plot A fluctuated between 36 in 1986 and 29 in 1992 and 2004. Paper birch numbers remained high at plot A in spite of the number of dead trees recorded at this plot. The number of paper birch at plot B was considerably less than plot A and generally declined from 16 in 1986 to only 9 in 2004. Paper birch declined slightly at plot C from 16 in 1986 to 13 in 2004. At plot D, paper birch declined sharply from 29 in 1986 to 11 in 1992, increased to 14 in 1999 and declined to 3 in 2004. The number of dead paper birch clearly showed the decline of this species at plot D.

Table 4. Number of live trees greater than 6 cm DBH recorded at vegetation plots A, B, C and D from 1986 - 2004. Figures for trees present represents total number in 9 quadrats for plots A, B and C, 8 quadrats for plot D. Results of χ^2 goodness-of-fit-test, calculated on individual plots, are significant at $p < 0.01$ (**) and $p < 0.001$ (***). Values in parenthesis are expected values.

Plot/Year	Balsam fir		Paper birch		White spruce		Quaking aspen		White pine		Year totals
Plot A											
1986	3**	(14)	36	(29)	3	(4)	28	(24)	0	(0)	70
1992	12	(12)	29	(25)	3	(3)	16	(20)	0	(0)	60
1999	18	(18)	33	(37)	5	(5)	34	(30)	0	(0)	90
2004	27**	(17)	29	(36)	5	(4)	26	(29)	0	(0)	87
Totals	60		127		16		104		0		307
Plot B											
1986	6***	(23)	16	(10)	7	(6)	31	(22)	2	(1)	62
1992	10	(17)	7	(8)	4	(4)	24	(17)	1	(1)	46
1999	28	(26)	10	(12)	6	(6)	27	(26)	1	(1)	72
2004	50***	(28)	9	(12)	6	(7)	11**	(28)	0	(1)	76
Totals	84		42		23		93		4		246
Plot C											
1986	8**	(21)	16	(14)	1	(2)	24	(17)	17	(12)	66
1992	17	(19)	15	(13)	2	(2)	16	(16)	11	(11)	61
1999	22	(20)	15	(14)	2	(2)	15	(17)	11	(12)	65
2004	37**	(24)	13	(17)	2	(2)	14	(20)	11	(14)	65
Totals	84		59		7		69		50		269
Plot D											
1986	4**	(14)	29	(19)	2	(1)	21	(21)	7	(7)	63
1992	8	(8)	11	(10)	1	(1)	8	(11)	5	(4)	33
1999	12	(11)	14	(14)	1	(1)	15	(15)	4	(5)	46
2004	19**	(10)	3**	(14)	0	(1)	18	(15)	5	(5)	45
Totals	19		3		0		18		5		45

The number of quaking aspen at Plot A showed a trend similar to that of paper birch. The number of quaking aspen at plot B declined from 30 in 1986 to 11 in 2004 (Fig. 10). The decline of quaking aspen at this plot is also reflected by the steady increase in the number of dead aspens. Low numbers of white spruce (1 - 7) occurred at all plots. Only 2 were recorded at plot D in 1986 and none in 2004. White pine was not recorded at plot A and only 2 were recorded at plot B in 1986. None were found there in 2004. The largest number of white pine occurred at plot C. Seventeen were recorded at this plot in 1986 and 11 from 1992 to 2004. The number of white pine declined from 7 in 1986 to 5 in 2004 at plot D.

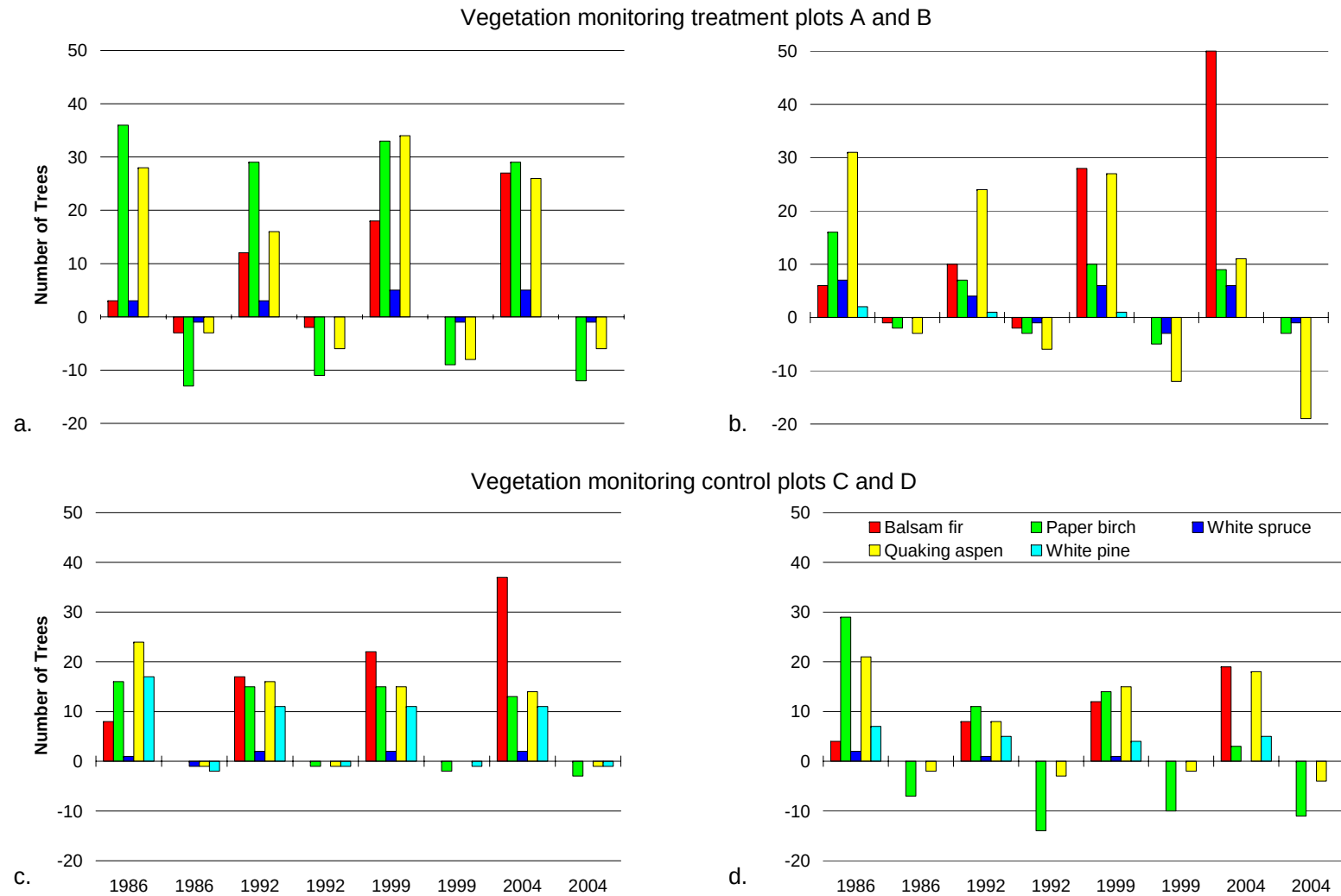


Figure 10. Number of trees for the 5 most abundant species recorded in vegetation monitoring plots, Grand Portage National Monument, 1986-2004. The number of live trees is shown above and the number of dead trees below the X axis. Plots A (10a) and B (10b) were adjacent to clear cut areas and were considered treatment plots; plots C (10c) and D (10d) were considered control plots.

Tree basal areas

Summed basal areas for the 5 major tree species in all sample plots are shown in Figure 11. Trends in basal area reflected changes in species dominance throughout the period from 1986 to 2004. An increase in basal area of balsam fir was evident at all vegetation plots. However, summed basal areas of paper birch, quaking aspen and, in some plots, white pine far surpassed that of fir.

Even though plots A and B are adjacent, species dominance at these plots differs considerably. In plot A, quaking aspen and paper birch were nearly codominant. The basal area of paper birch generally declined in plot A between 1986 and 2004. The basal area of quaking aspen declined after 1986 in plot A but then leveled off. This was largely the result of the death of 45 birch trees and 23 aspen trees in plot A during this period. The basal area of paper birch was slightly exceeded in plot B by white spruce, but the plot was dominated by quaking aspen. The basal area of quaking aspen remained high at plot B from 1986 to 1999 and then declined sharply by 2004. This decline was primarily due to the death of 40 aspen trees, more than 75% of which were recorded in 1999 and 2004.

Based on summed basal area values, plots C and D were much different from A and B. Quaking aspen and white pine were dominant at vegetation plots C and D. Since declining from highs in 1986, the basal areas of quaking aspen has remained steady in plot C. In contrast, the basal area of white pine suffered a decrease between 1986 and 1992, but is now showing a steady increase in plot C. The basal area of quaking aspen has remained very high and that of white pine has remained relatively stable in plot D from 1986 to the present.

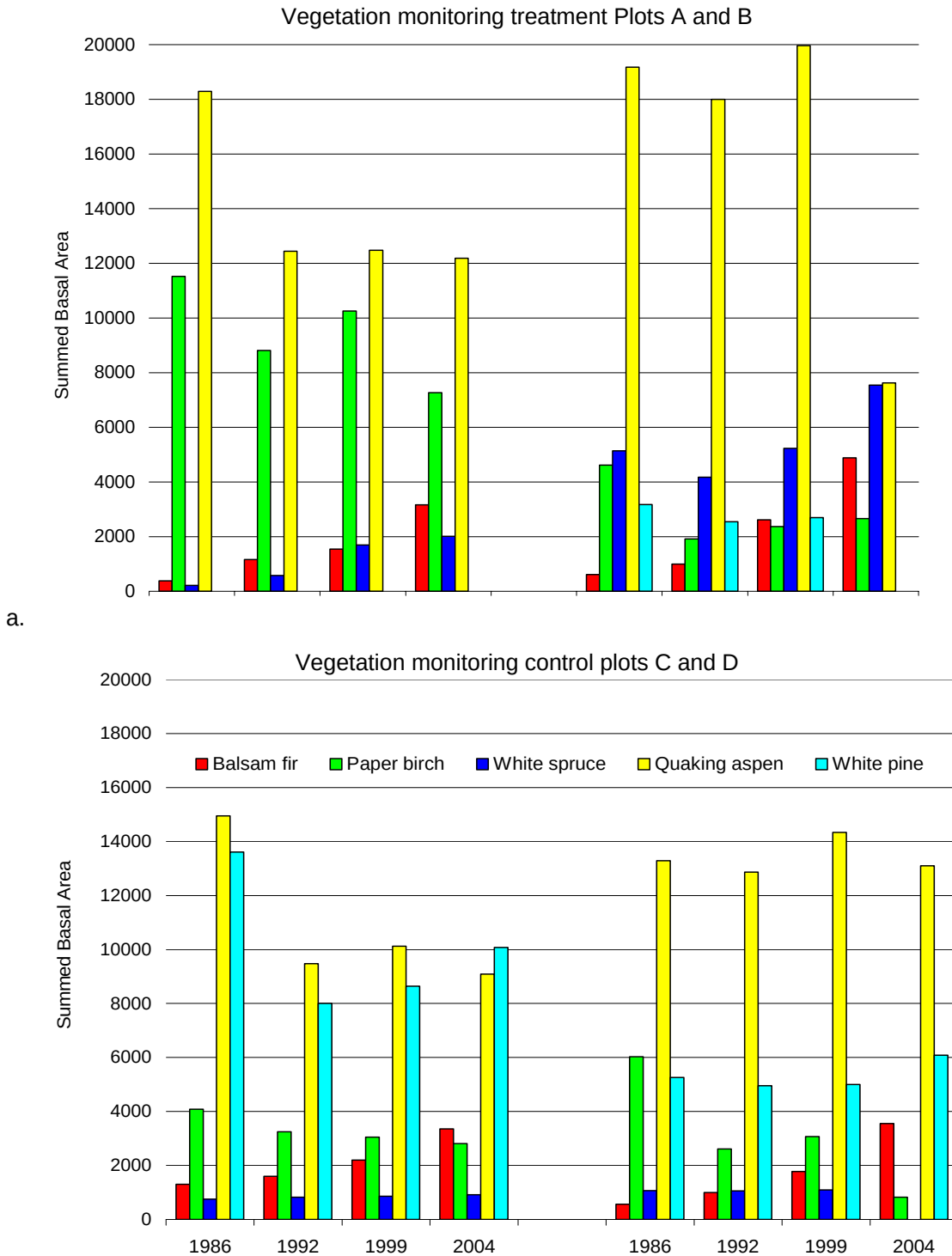


Figure 11. Summed basal areas for the 5 most abundant tree species recorded from vegetation monitoring samples plots, Grand Portage National Monument, 1986-2004. Plots A and B (11a) are adjacent to areas clear cut in 1980 and are considered treatment plots. Plots C and D (11b) are considered the controls.

Goal 3. Changes in overstory tree mortality

The numbers of dead trees in sample plots, irrespective of species, are graphed in Figure 12. The contribution of standing dead and downed trees to the total is illustrated by stacked bars. Plots A and C had a relatively uniform number of standing dead trees in all samples, while plot B demonstrates an increasing trend and plot D has variable numbers of standing dead trees. Plots A, B and D experienced an increase in downed trees, with peak numbers occurring in the 1999 sample. Downed trees in plot C are few relative to other plots in all sample periods, and no marked increase in downed trees occurred in 1999.

Two way ANOVA results for standing dead and down trees are summarized in Table 5. Differences in the mean number of standing dead trees per plot is greater than would be expected by chance after allowing for effects of differences in years. Plot C differed significantly from all three other sample plots. The power of the test for this analysis, with $\alpha = 0.05$, is 0.951. For downed trees the differences in mean numbers per plot was significant for both year and plot, after allowing for effects of differences in the other. The year 1999 differed significantly from 1986 in the mean number of downed trees in sample plots. Plot B differed from both plot C and D, while plot A only differed from Plot C in the number of down trees occurring within plots. The analysis for differences between years should be interpreted cautiously since the test just missed having sufficient statistical power (0.792), with $\alpha = 0.05$. Power of the test performed for difference among the plots was 0.943.

Table 5. Results of two way ANOVA (general linear model, SigmaStat) on the total number of standing dead or downed trees in two treatment and two control sample plots, Grand Portage National Monument, 1986-2004. Post hoc multiple comparisons (Tukey test) revealed which pairs of plots differed significantly (*) when $p \leq 0.05$.

Source of variation		Significant comparison	F	P
Total standing dead trees/plot	Year		1.317	0.328
	Plot		9.921	0.003*
		Plot A vs. Plot C		0.003
		Plot B vs. Plot C		0.015
		Plot D vs. Plot C		0.041
Total number of downed trees/plot	Year		6.513	0.012*
	Plot		9.587	0.004*
		1999 vs. 1986		0.009
		Plot B vs. Plot C		0.005
		Plot B vs. Plot D		0.045
		Plot A vs. Plot C		0.014

The Pearson correlation coefficient evaluating an association between the number of standing dead birch trees and distance to the clear cut in plot A during 1986 was not significant. The calculated value of r (0.486) was less than the critical value ($r_{0.05, 4 \text{ df}} = 0.811$), so H_0 was not rejected. Except for quadrats 195 and 198, most standing dead birch were recorded in Plot A in 1999 and 2004 (Appendix Table A-1). While not significant, clear cutting may have been partly responsible for the large number of standing dead birch recorded in 1986 at quadrat 198 which was near the Monument boundary.

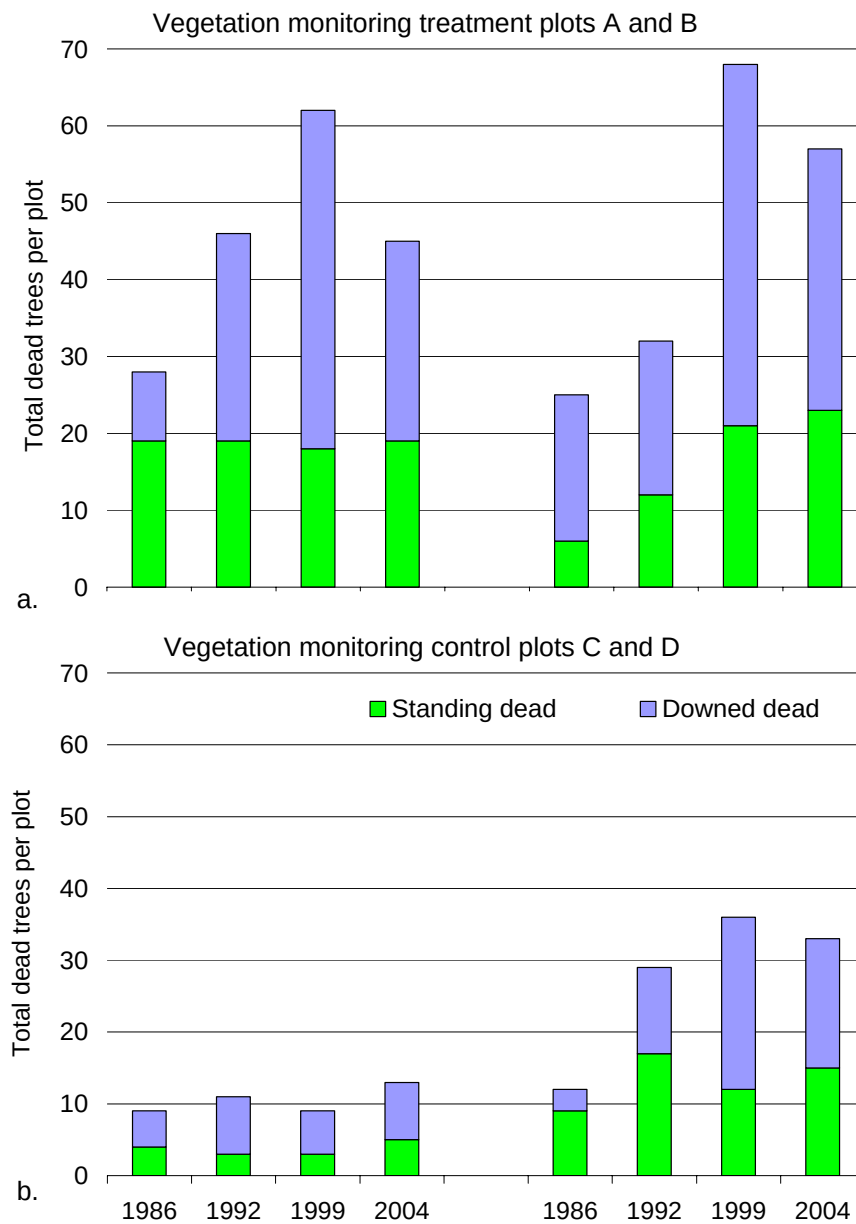


Figure 12. Summed standing dead and downed trees recorded from vegetation monitoring samples plots, Grand Portage National Monument, 1986-2004. Plots A and B (12a) are adjacent to areas clear cut in 1980 and are considered treatment plots. Plots C and D (12b) are considered the controls.

Goal 4. Changes in understory community composition

The shrub layer

The number of woody stems (1.25 - 6.0 cm DBH) recorded in 1986, 1992, 1999 and 2004 are presented in Appendix Table A-2 for all species encountered in vegetation plots A, B, C and D. Total stem counts for the 5 most abundant species are graphed by sample plot and year in Figure 13. Alder sp. had the greatest number of stems at vegetation plots A and B in all years except for 2004 at plot B. The next most numerous species in the shrub layer at plots A and B were mountain maple, balsam fir, hazel (*Corylus cornuta* Marshall) and quaking aspen. The number of stems increased from 1986 to the present for balsam fir and mountain maple, but decreased for alder at plot B, and hazel and quaking aspen at both plots. Alder also dominated the shrub layer at plots C and D. However, in both control plots and treatment plots, the number of alder stems was lower in 2004 than in previous years. In fact, the number of alder stems at plot C in 2004 declined by 87%. The number of hazel stems declined at plots C and D from 1986 to the present. In 2004 hazel was still present in the shrub layer at plot D but had disappeared from plot C.

Two way ANOVA of total stem counts by species indicates whether the trends presently graphically (Fig. 13) are significant, or not. Results for the 5 most abundant shrub species are summarized in Table 6, along with the significant pair-wise comparisons (Tukey test) made post hoc when significant differences were found. By interpreting these data in conjunction with the graphical display of totals, it is clear that plot B has a significantly higher understory component of balsam fir compared to all other plots. In contrast, plot C has a significantly reduced mountain maple component compared to all other plots.

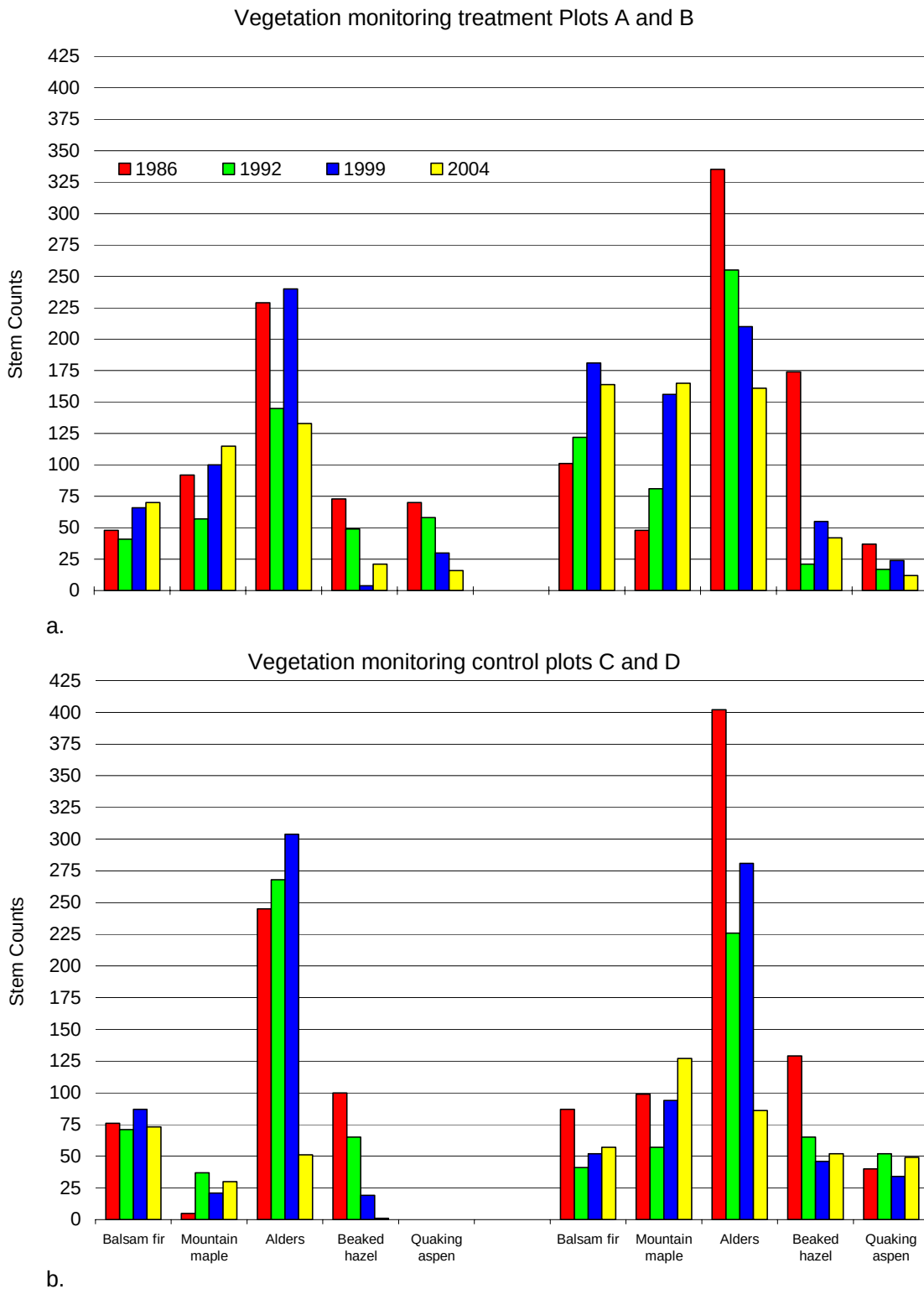


Figure 13. Total number of stems between 1.25 and 6 cm DBH for the 5 most abundant woody species in vegetation monitoring sample plots, Grand Portage National Monument, 1986-2004. Plots A and B were adjacent to clear cut areas and are considered treatment plots. Plots C and D were not adjacent to clear cut areas and are considered controls. The X axis is species categories to demonstrate changes within a species over time.

Table 6. Summary of two way ANOVA (general linear model, SigmaStat) on the total number of stems by species for vegetation sampling plots in Grand Portage National Monument, 1986-2004. When significance (*) was found at $p < 0.05$, pair-wise comparisons were applied post hoc to determine the source of differences.

Species	Source of variation	Significant comparison	F	P
Balsam Fir	Year		1.387	0.308
	Plot		14.071	<0.001*
		Plot B vs. Plot A		0.002
		Plot B vs. Plot D		0.002
		Plot B vs. Plot C		0.009
Mountain maple	Year		3.097	0.082
	Plot		7.648	0.008*
		Plot B vs. Plot C		0.007
		Plot D vs. Plot C		0.027
Alder species	Year		7.845	0.007*
	Plot		0.866	0.493
		1986 vs. 2004		0.006
		1999 vs. 2004		0.025
Hazel	Year		10.769	0.002*
	Plot		2.087	0.172
		1986 vs. 2004		0.004
		1986 vs. 1999		0.004
Quaking aspen	Year		1.513	0.276
	Plot		9.753	0.003*
		Plot D vs. Plot C		0.006
		Plot A vs. Plot C		0.006

The herbaceous layer

The estimated percent cover for components of the herbaceous layer from two 1-meter square subquadrats is presented in Appendix Table A-3 by sampling plot and year. Over the course of fieldwork, 44 species were recorded from vegetation plot A, 40 from plot B, 34 from plot C and 41 from plot D. Histograms of the 7 most reported species, based on the mean estimated percent cover over all 4 sampling periods, are presented in Figure 14. These graphs should be interpreted cautiously because they represent only a generalized impression of the herbaceous layer over time, not any specific point in time. All plots were dominated by large-leaf aster (*Aster macrophyllus* L.), with sarsaparilla (*Aralia nudicaulus* L.) the second most prevalent species in all plots except plot D, where dewberry (*Rubus pubescens* Raff.) was more prevalent. Woody seedlings of alder and balsam fir each made up less than 10% of the herb layer in all plots. Mountain maple, a plant typical of partially shaded edges, was recorded in plots A and B, but absent from plots C and D. Conversely, bunchberry (*Cornus canadensis* L.), a typical boreal forest component, was only recorded in plots C and D.

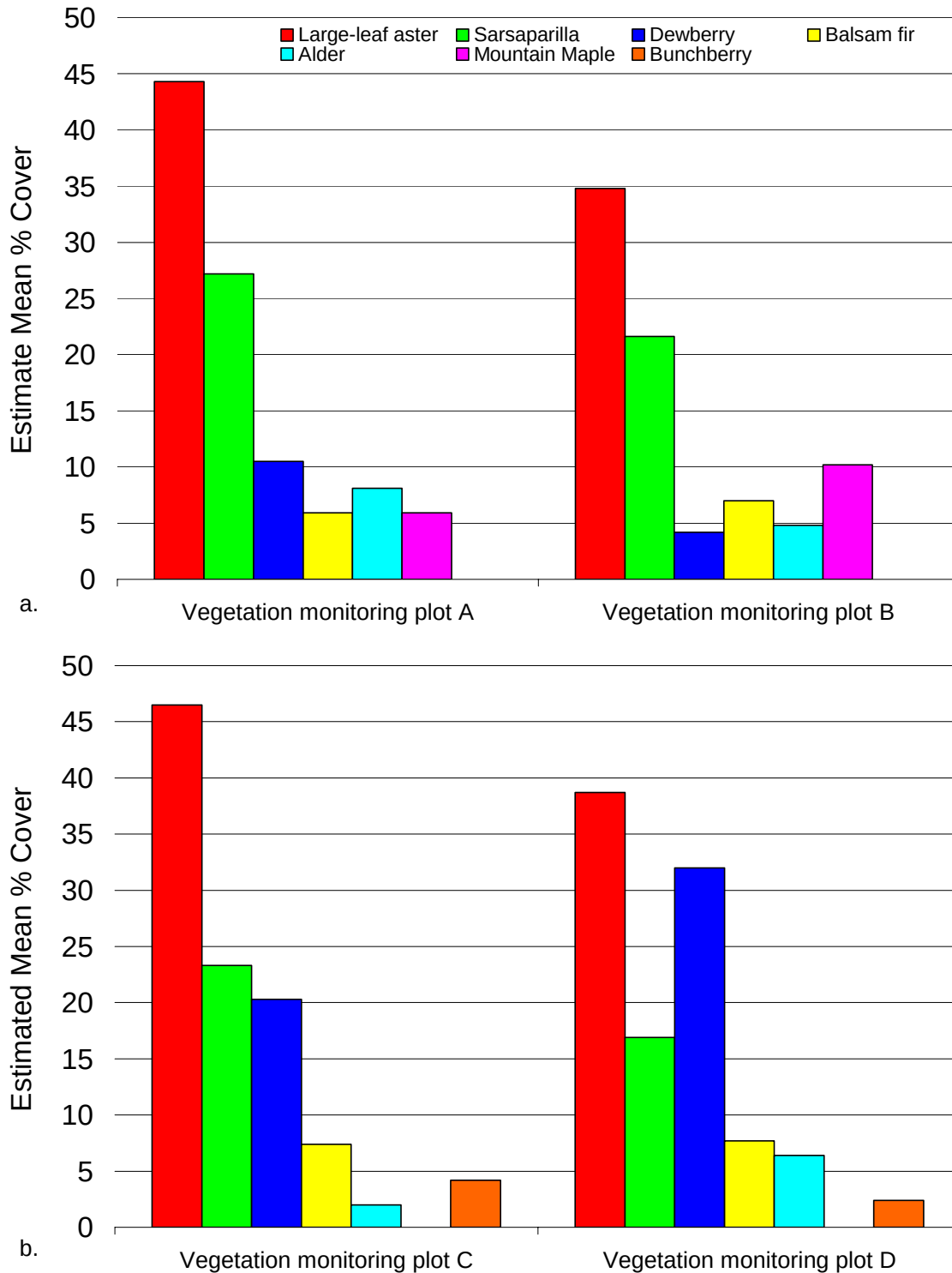


Figure 14. The 7 most prevalent species in herbaceous layer samples for vegetation monitoring plots, Grand Portage National Monument, 1986-2004. Estimated percent cover is combined reports for all 4 sample periods. Plots A and B (14a) are adjacent to areas clear cut in 1980 and are considered treatment plots. Plots C and D are control areas not adjacent to clear cut areas.

DISCUSSION

Goal 1. Dissimilarity within and between treatment and control plots

The two treatment plots were somewhat dissimilar (Sørensen's $D = 0.242$ based on tree abundance and $D = 0.288$ based on basal area) when the project was initiated in 1986. It should be noted that these differences may not be of much importance as the numbers and sizes of trees recorded from sample quadrats varied considerably at both plots. Plot A was about as dissimilar from plot C as it was from plot B, but was least dissimilar to plot D in 1986. Plot B was about as dissimilar to plots C and D as it was to plot A. The difficulty in this retrospective analysis is an understanding of what factors contributed to the dissimilarity among the sample plots at initiation of the study, and what has increased this dissimilarity over the last 18 years. This is an essential first step before determining the usefulness of this protocol for future monitoring of forest vegetation.

No doubt, some of the original dissimilarity between treatment and control plots was the result of differences in soil and topography. White pine and white spruce were much more important at plots C and D which were located on well drained soil of an east and southwest-facing ridge. Paper birch and quaking aspen were most abundant and conifers relatively scarce at the two treatment plots that were situated on nearly level, poorly drained soils. In fact, white pine was absent from plot A and only two were recorded from plot B in 1986. Such differences made it difficult to evaluate the causes of vegetation changes at these plots. Thus, the selection of plots C and D were not a good choice as controls for this project.

Ideally in experimental design, all sample areas should be randomly drawn from a more or less uniform population of all possible sample plots. In this instance, plots were first limited by the location of areas clear cut on adjacent Grand Portage Reservation lands since this condition served as the treatment. Second the decision to locate control plots in areas easily accessible, rather than areas most representative of the forest communities within the Monument, further limited available control sample locales. Finally, environmental factors that affect plant growth and health, such as soils, drainage characteristics and topography, were not factored into the plot siting process. Ignoring these environmental factors may be defended as a means of randomly selecting control plot plots. Since much of the upland forest in Grand Portage National Monument is aspen-birch-spruce-fir forests, with only scattered small groves of pine (White and Host 2003), location of control plots on a pine community could be attributed to random chance. However, when selecting field-based sample locations, a stratified random sampling method that controls for the variability of site conditions and community structure, should be used to better match treatment and control plots.

Even if plot conditions had been uniform, historical factors may have contributed to differences between the control and treatment plots in overstory species abundance and basal area. Overstory trees are long-lived and contribute to numerous sampling events, even when sampling intervals are several years. Past fire history could mediate the species and size of trees currently present in sample plots. Many fires occurred throughout the region during the settlement (1870-1910) and post settlement (1910-1940) periods. Fires burned most of the Grand Portage area in 1873, 1878 and again in the

1880s. In spite of efforts to suppress wildland fire during the 20th Century, major fires burned large tracts of land in and around Grand Portage and the Grand Portage Indian Reservation in 1917, 1919 and 1936. Except for the western trail corridor and the area around Fort Charlotte, most of the current forest of the Monument originated following fires after 1870 (White and Host 2003).

The distance between treatment and control plots could have placed one set on lands burned several times in the late 1800s and early 1900s, while the other plots were on land spared these events. Maps of some fires in the 20th Century are available, but are crudely detailed. It is not known, with certainty, whether treatment plots are on burned-over land. The presence of large pines on control plots suggests they have been spared from the most devastating fires during the last century or more.

On the other end of the time spectrum, the 6-year lapse between the clear cut harvest and initiation of this study may have missed crucial first stages in the developing dissimilarities within and between treatment and control sample plots. Herbaceous and understory changes would be expected to be detected sooner than changes in the overstory trees, so for analysis of tree abundance and basal area, this delay between treatment and first sample collection is probably not of much consequence.

Given that the reasons for the initial dissimilarity between treatment and control plots will never be fully understood, are these plots still useful for monitoring vegetation changes? Current knowledge can be used as benchmarks for describing the overstory components of the forest communities on treatment or control plots, and for tracking changes in those communities over time by examining trends in canopy tree dominance and composition. However, drawing inferences about causal mechanisms for change (i.e., clear cutting) is not appropriate based only on overstory species abundance and basal area.

Goal 2. Trends in dominance of overstory trees

Of all the changes in the vegetation since 1986, the most striking is the pronounced increase of balsam fir. There was a significant increase in the number and dominance of balsam fir at all plots (Table 4). The increase was especially pronounced at plots A and B. Other changes were the decline of paper birch at plots B and D, quaking aspen at plot B and white spruce at plot D.

In the Lake States, balsam fir is a nearly ubiquitous component of most upland and lowland forests (Johnston 1986). It is a late successional species that tolerates a wide variety of site conditions from dry uplands to swamps (Uchytel 1991), and soils from heavy clay to gravel. Seedlings are shade tolerant and readily colonize seedbeds under a canopy of hardwoods and conifers (Uchytel 1991). In the absence of fire over long periods, balsam fir may become dominant as mature aspens and birches begin to die. Eventually it can form pure stands, excluding species with shade intolerant seedlings. Balsam fir is easily killed by fire; however, fire creates soil conditions favorable for the establishment of seedlings and if seed is available, balsam fir will readily colonize burned sites. Where external seed sources are necessary, balsam fir is generally absent for several decades following a fire and appears 30 to 50 years later under a mixed canopy of aspen, birch and spruce (Bakuzis et al. 1965, MacLean 1960).

Based on the results of this study and previous work by White and Host (2003), replacement of paper birch and to some extent quaking aspen by balsam fir seems to be well under way throughout the forest of Grand Portage National Monument. The forests are characterized by mature trees typical of late successional stages with a well developed canopy composed of large and sometimes senescent trees. Based on tree core dates, trees in the southern portion of the Monument (plots A and B) are between 73 - 120 years old. Decline, and at some plots the absence, of shade intolerant species such as alder, hazel and quaking aspen suggests that light reaching the forest floor has decreased due to closure of the canopy (White and Host 2003).

The desired future conditions for the forest along the Grand Portage National Monument trail corridor is restoration of the historic scene as it may have looked during the fur trade era of 200 years ago. Current understanding of that scene is the presence of a mosaic of habitats representing various successional stages in the local forest type. Management actions need to disrupt the trend to balsam fir by setting back the successional stage. Means of doing this include mechanical methods to simulate the effects of fire or other disturbance events and careful use of prescribed or wildland fire use fires in collaboration with Grand Portage Band forestry practices. Part of this may be embracing clear cutting on adjacent lands as a substitute for stand replacing fires.

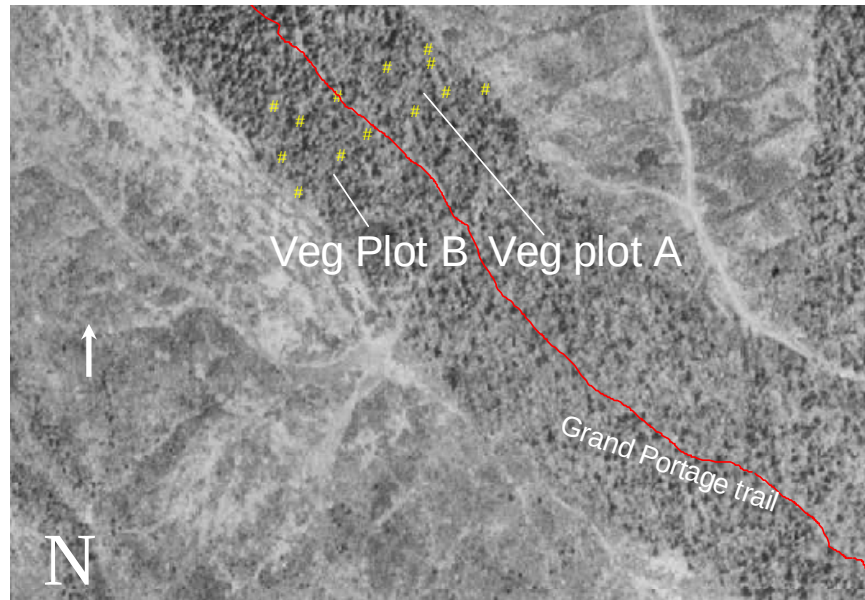
The current sampling protocol provides some information on trends in the overstory component, but is it the most appropriate method of sampling forests? There is some concern that the limited size of the 10-m² sample quadrats misrepresents the density of mature trees because of the dynamics of competition for light and other resources in this size class (George Host, pers. comm.). Other sampling methods, such as the Forest Inventory and Analysis (FIA) used by the US Forest Service since the 1930s or the point-based sampling method developed by the UW-Madison Plant Ecology Laboratory in the 1940s (Curtis 1971), sample larger plot areas and are intended to accurately represent overstory characteristics such as tree size and density. Given the limited width of the trail corridor, sufficient area may not be available within Monument boundaries for siting these sampling designs in locations managed for restoration efforts. Use of the current protocol to track abundance and basal area of overstory trees may provide an index to dominance, but the limitations of the data obtained should be kept in mind. An index of dominance may be sufficient information to track effectiveness of management actions under the limiting conditions found at Grand Portage National Monument.

Goal 3. Changes in overstory tree mortality

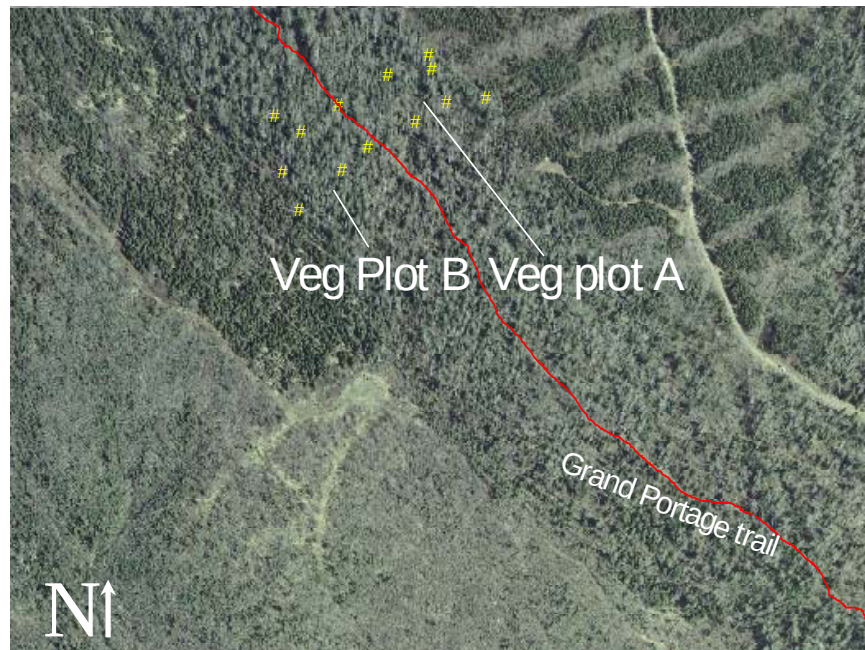
A major reason for establishing these sampling plots was to evaluate the impact that clear cutting on adjacent land had on the forest structure of the Monument. An aerial photograph taken the early 1980s (Fig. 15a) clearly shows the extent of clear cutting adjacent to vegetation plots A and B. A similar aerial photograph taken May of 2003 (Fig 15 b) shows red pine plantations planted northeast of plot A and southwest of plot B. The planted trees have reached 8-10 m in height and of sufficient size that thinning of the plantations was necessary in 2004.

The number of standing dead trees remained fairly uniform within plots over all sample periods, except for plot B which had an increasing number over time. Examination of the raw data (Appendix Table A-1) shows the constant attrition and

recruitment of individuals contributed to plot totals as revealed by recorded species and diameters. Plot C had significantly fewer standing dead trees, which may be accounted for by fewer birch and quaking aspen being located in this plot. White pine made a major contribution to the overstory in plot C and was not as likely to be or become standing dead trees.



a.



b.

Figure 15. Location of treatment plots A and B in relation to area clear cut in 1980. Grand Portage trail corridor, trail (in red) and adjacent areas of Grand Portage Reservation. 15a. From false color infrared aerial photography obtained on July 22, 1983, by the Minnesota Department of Natural Resources. 15b. True color, leaf-off aerial photography obtained in May 2003, by Ayers Associates.

Twenty standing dead trees were recorded from plot A in 1986, 65% (13) of which were paper birch. The absence of a significant correlation ($r = 0.486$) between the distance of standing dead birch trees and the Monument boundary implies that clear cutting had no effect on tree mortality factors at this plot. However, the number of standing dead birch recorded in plot A remained between 11 and 12 for the next 18 years, the result of either clear cutting effects or natural mortality of birch at this plot. The average DBH of these trees (21.7 cm) suggests that they were mature trees. The best evidence of that clear cutting may have increased mortality of paper birch at Plot A was the large number of standing dead birch recorded at quadrats 195 and 198 in 1986 and 1992. Quadrat 198 was within a short distance of the Monument's northeast boundary and thus close to the clear cut. However, birch mortality was low in quadrats 196 and 197 that were also located near the Monument boundary. Quadrat 195 was located along the next transect line further removed from the boundary.

While fewer dead birch were recorded in plot B, 38 standing dead quaking aspen were recorded in this plot from 1982 to 2004. Again the greatest numbers were recorded in 1999 and 2004. The large average DBH of these trees (31.6 cm) with one reaching 51cm, suggests that natural mortality was responsible for their death rather than clear cutting many years earlier. It is possible that the effects of clear cutting were either localized (quadrat 198 in 1986) or that establishment of plots A and B six years after clear cutting may have been too late to record all of the dead birch. However, it appears that the decline of mature paper birch and quaking aspen at plots A and B were the result of natural mortality of mature trees rather than the effects of clear cutting.

Both treatment plots differed significantly from plot C in the number of downed trees, but only plot B differed from control plot D. The confounding factor in interpreting the effect of clear cutting on the number of downed trees, which is assumed to be related to wind throw, is the spike of downed trees recorded in 1999. A late fall storm with high winds out of the west and southwest in 1998 produced numerous wind thrown trees all along the Grand Portage. The severity of this impact is indicated by the spike in plot D, which is on a southwest slope, compared to plot C which was in a more protected location for this storm event. Wind storms sufficient to cause blowdown can occur at any season and impact limited to widespread areas of the Monument. Based on the information obtained from sample data, increased susceptibility to wind throw on areas adjacent to clear cuts seems to be supported; however, these differences are more probably related to the decline of mature paper birch and quaking aspen on plots A and B. While wind throw can affect live trees, as well as standing dead ones, trees stressed, rotted or otherwise in compromised health may be more susceptible than vigorously growing trees.

Goal 4. Changes in understory community composition

Paper birch was not included among the 5 most numerous species in the understory layer at any plot. The number of stems of quaking aspen declined sharply from 1986 to the present at plots A and B, was absent at plot C and moderately high at plot D. The low stem counts for these species indicates that birch and aspen are not reproducing well at these plots and will eventually be replaced by fir. Alder, hazel and quaking aspen are shade intolerant species and their decline or disappearance suggests

that light reaching the forest floor has decreased due to the closure of the canopy at several plots.

Due to a greater number of balsam fir stems, plot B differed significantly from all other plots. The absence of quaking aspen in the understory in plot C also resulted in a significant difference. These differences cannot be attributed to the effects of clear cutting based on the available data and related site-specific information.

Although data from the herbaceous layer lacks sufficient statistical power for meaningful analysis, the underlying presence/absence information may be sufficient to support general assumptions about this study. Habitat typing methods developed at the University of Wisconsin (Tim Miller, pers. comm.) uses herbaceous understory indicator species, in combination with soil moisture and nutrient status, to assign the most likely natural climax community for sites. Bunchberry is among the 20 plants used for indicator species in forests of the Grand Portage area (Tim Miller, pers. comm.). Presence of bunchberry in control plots, but not treatment plots, and the differences in soil moisture regimes suggests that treatment and control plots have different potential natural vegetation. As such, these treatment and control plots were not well suited for a comparative study. This assumption should be investigated further when the habitat typing manual for the Grand Portage Reservation becomes available in spring 2005.

Habitat typing methods may be a useful tool for guiding decisions about forest management activities on Monument lands. Clear cuts, which can be used as surrogates for stand replacing fires, will occur along the Monument boundary from time to time. Understanding what natural forests would be present on sites, were it not for the advent of recent human technology, will make it possible to select the most appropriate target conditions. Integrating clear cuts with complementary actions on Monument land should have the best chance of reaching management goals.

Summary

Clear cutting on Grand Portage Reservation lands in 1980 did not have a detrimental effect on the forest composition on adjacent Monument property. The changes evidenced by sampling in 1986, 1992, 1999 and 2004 can be attributed, to a large degree, on the maturing and senescence of the birch-aspen-spruce-fir forest communities on treatment plots. Control plots were not well matched in forest composition or environmental characteristics with treatment plots. Concomitant changes in forest composition on control plots demonstrates that most forests in the area are succeeding to a balsam fir dominated climax.

The sampling protocol used for data collection provided sufficient information for making general statements about overstory tree dominance based on species abundance and basal area. Tree density and other descriptive features of forest stands are not supported by this sampling method. The sampling protocol provided limited information on the and herbaceous layers. However, this information may be sufficient support for resource decisions at Grand Portage National Monument where limited property size is both a constraint and an advantage in regard to management activities. The disadvantage of the current sampling protocol is the inability to apply this information over a broad landscape scale. It is not comparable to methods used by the US Forest Service in the

FIA program, or those used by other NPS units in the Great Lakes area.

The present forest composition in Grand Portage National Monument is the result of long-term passive management along with the natural decline of the birch-aspen component in a mature woodland. Regeneration of understory trees depends upon adequate seed sources and suitable growing conditions for seedlings. Red and white pines require relatively open conditions and mineral soils, balsam fir and white spruce do not. In light of the increasing dominance of balsam fir, prescribed burns or simulating burns with mechanical methods could be used to restore conditions similar to those during the fur trade era of 200 years ago.

Acknowledgements

The authors wish to thank the National Park Service Great Lakes Inventory and Monitoring Network (GLKN) for funding this statistical analysis of the Grand Portage National Monument vegetation monitoring data. Examining the usefulness of information accumulated over nearly 20 years would probably not have become a priority without their support and assistance. Suzanne Sanders, inventory coordinator, and other anonymous reviewers from the GLKN Ashland, WI, office provided many valuable comments after reviewing the first draft of this report. Their suggestions led to further review and interpretation of the data, and resulted in a much improved product. Our thanks to you.

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APPENDIX:

Vegetation Plot Data

DBH

Table A-1. Diameter at breast height (DBH) in cms for live and standing dead trees in four samples plots in Grand Portage National Monument. Measurements obtained in 1986, 1992, 1999 and 2004 from nine quadrats in plots A, B, and C, and eight quadrats in plot D. When quadrats were laid out in 1986, only the northeast corners were permanently marked; all corners were permanently marked in 1999. In spite of these quadrat markers, variation in laying out the sample area affected the inclusion of trees lying near quadrat edges. This resulted in an “enchanted forest” effect with mature trees apparently disappearing from a sample site, then reappearing for subsequent samples, or large trees springing up with no earlier measurements. In order to include as many individuals in calculations as possible, interpolated DBHs were entered for these few cases; the estimated values appear parenthetically in this table.

Vegetation Plot A	Living trees				Standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
Quad: 190								
<i>Abies balsamea</i>				6.1	33.2	32.3		
<i>Betula papyrifera</i>	16.8	17.0	18.0	17.8				19.8
	17.0	17.0	18.2	18.1				22.5
	17.2	18.8	19.1	19.8				24.2
	18.6	22.6	19.9					
	20.8	25.1	20.1					
	23.2		23.4					
	24.6		26.3					
<i>Picea glauca</i>		17.5	21.0	22.8			33.1	unk 31.0
<i>Populus tremuloides</i>	(18.4)	19.6	20.8	21.0	13.4	12.4	34.3	31.0
	(24.9)	26.4	(27.9)	29.5				
	34.9	(37.5)	(40.2)	42.7				
Quad: 191								
<i>Abies balsamea</i>	(10.7)	12.2		6.9				
	(11.5)	13.5	14.7	17				
	15.4	20.3	22.3	23.7				
<i>Betula papyrifera</i>	15	8.6	9.2	9			27.7	12.2
	20	15.7	12.3	16.1				22.2
	24.9	19.3	15.7	21.2				27.1
			21.1					
			22.6					
<i>Picea glauca</i>	(10.3)	(13.0)	15.4	18.1				
	(13.5)	16.5	19.6	20				
<i>Populus tremuloides</i>	19.1	25.4	26.1		20.5	20.3	20	19.4
	20.2					20.6	21.9	26
	21							
	25.4							
Quad: 192								
<i>Abies balsamea</i>		9.9	6.9	7				
		12.7	15.8	8				
		13		15.8				
				16.8				
<i>Betula papyrifera</i>	23	21.1	24	23.9	14.8		8.9	6.2
	25.1	25.1						8.5
<i>Picea mariana</i>			13.2					
<i>Populus tremuloides</i>	25.6	24.9	29.5	29.1			19.9	18
	26.9	27.7	32.5	32.2			27.1	27
	27.3	30.5					29.8	29.3
	27.9							
	29.7							
	30.6							
Quad:193								
<i>Abies balsamea</i>		7.9	9	11.1				
		6.4	12	16.1				

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Vegetation Plot A	Living trees				Standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
<i>Betula papyrifera</i>	11.5 13.2 22.7	11.2 21.8	11.5 23.2	11.5 22.9	13.2	18.3		
<i>Picea glauca</i> <i>Populus tremuloides</i>	(25.7)	28.4	28.3	29.1			18.3	
Quad:194 <i>Abies balsamea</i>		7.4	7.1 7.5 9.9	7.9 9.1 9.9 11.9				
<i>Betula papyrifera</i>	20.5 21.6 28	21.1 27.4	8 28.8	8		19.1 19.8 21.6	21.3 27.9	
<i>Populus tremuloides</i>	41.9 (40.0)	42.4 (45.0)	43.8 45.4	45.2 45.4				
Quad:195 <i>Abies balsamea</i>			7.6	6.5 7.3 8.4 9.3				
<i>Betula papyrifera</i>	9.5 15.7 17 17.5	16.8 19.6 23.1 24.6	17.6 19.5	17.7 17.9	15.1 18.5 19 21.1	15.7 18 20.6	9.2	
<i>Picea glauca</i>			17.3	21.5	40			
<i>Populus tremuloides</i>	33.5 (36.0)	(35.0) (36.9)	36.6 37.7	36.2 38.5				
Quad:196 <i>Abies balsamea</i>		7.6	8.6	8.9 12.2	31.7	29.7		
<i>Betula papyrifera</i>	9 10.3 27.2	15.7	17.7		16			
<i>Picea glauca</i> <i>Populus tremuloides</i>	33.6							
	7.2 19.8 20 23.5 24.2 25.1 26.8	23.6 26.7 26.9 27.2	25.3 28.6 29.8	25.7 27.6 28.9		16 18.6	16.2	
Quad:197 <i>Abies balsamea</i>		6.4 7.6	7.7 8.3 10.5 10.5 12.8	10.4 10.8 13.8 14.4 15.7				
<i>Betula papyrifera</i>	7 16 18.1 18.7 20.2 22 23 24.5 25 26.9	6.4 8.6 9.8 13.5 16 16.6 18.3 19.8 32.9	7.2 8.3 10.9 11.7 15.8 16.5 18.7 20.4 20.6 32.8 34.3	8 8.1 10.9 14.6 16.6 18.3 20.1 21.3 33.2 34.4	12 15.4			33.4
<i>Populus tremuloides</i>	29.3		7					
Quad:198 <i>Abies balsamea</i>			6.1 7	6.1 6.3				

APPENDIX:

Vegetation Plot Data

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Vegetation Plot A	Living trees				Standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
				8.6 9.1 9.6				
<i>Alnus</i>			7 2.5	7.1				
<i>Betula papyrifera</i>			15.6	6.1	15.5	14.7	18.2	25.1
	(27.9)	28.4	28.9	26.1 30.8	20.3 21.5 24	15.2 15.2 17	22.4 25.6 26.5	
						17.3 19.1		
<i>Populus balsamifera</i>				7.8				
<i>Populus tremuloides</i>	22.3 32.8 42.5		5.5 5.5 6.2 6.3 6.4 6.5 6.5 7 7 7 7 7.2 8 8.5 8.9 9 10 10 10 10.3 10.4	6.8 6.9 7.3 7.5 7.7 7.7 7.8 8.1 8.2 9.9 10.8 11.1 11.8 11.8 12.7	29.5	29.2		

Vegetation Plot B	living trees				standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
Quad: 480 <i>Abies balsamea</i>			6.4 6.7 7.1 9.0 9.0 10.5	6.3 6.8 9.0 9.0 10.5				
<i>Betula papyrifera</i>	11.8 15.7 20.5 22.8	10.7 15.5 19.3 21.3	10.9 16.9 21.0 22.5	10.8 16.4 20.5				21.4
<i>Picea glauca</i>	27.5 34.7	28.2 35.6	36.3 (37.0)	30.6 38.7				
<i>Populus tremuloides</i>	30.8 42.4 (47.8)	31.8 44.2 49.3	33.9 47.9 50.9	34.0 47.0				51.0
Quad: 481 <i>Abies balsamea</i>			9.2 8.3	6.8 6.3 6.7 6.1 11.0	32.5			
<i>Betula papyrifera</i>	36.3 10.0 11.6 15.2 27.9	14.5 9.7			11.4	11.7 9.5 14.6		
<i>Picea glauca</i>	26.3			7.0	24.6	25.6		
<i>Populus tremuloides</i>	34.5	20.3	19.9		20.3			

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Vegetation Plot B	living trees				standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
	20.3 21.0 31.2	30.5 35.6	34.6 37.7	35.4 38.2				
Quad: 482 <i>Abies balsamea</i>	10.6	12.7 7.1	15.3 9.5	18.8 6.3 11.5 12.2				
<i>Acer spicatum</i>			6.2 7 8	7 9.8				
<i>Alnus sp.</i> <i>Betula papyrifera</i> <i>Populus tremuloides</i>	21.6 36.4	28.4 30.7 36.1	30 33.3 38.3		11 19.3			30.1 33.2 38.5
Quad: 483 <i>Abies balsamea</i>	9.2 10.7	11.7 13.5 12.4	7 8.6 13.3 16.2 17.1	9.2 6.5 7.8 15.5 18.4 19.1				
<i>Betula papyrifera</i> <i>Populus tremuloides</i>	27.6 19.8 22.2 23.5 24.5 31.2	9.9 28.7 24.4 32.3	11.6 26.1 29 33.6	11.5 34	19.1	19.4		25.5 19.5 29.3
Quad: 484 <i>Abies balsamea</i>		6.6		7.4 14.9 11.5				
<i>Betula papyrifera</i>	18.7 10	19.8	23	22.1				
<i>Pinus strobus</i> <i>Picea glauca</i>	(55.2) 31.6	56.9 36.1	58.6 20.6	60.1			15	
<i>Populus tremuloides</i>	19.3 43.5 25 24.6	44.2	46.1 36.5 10	37.1 46.2				
Quad: 485 <i>Abies balsamea</i>	18.1 6	9.1	6.8 6.2 9 11.5	7.8 8.5 7 13.7 7 7 10.5 6.1				
<i>Acer spicatum</i> <i>Betula papyrifera</i> <i>Populus tremuloides</i>	15.6 23.5 24.5 34.7 26.2	24.4 25.1 (36.4) (28.2)	26.1 25.8 38 30.1		35.5	22.4	22	26 25.6
Quad: 487 <i>Abies balsamea</i>	10.5	13.7 7.4	13.5 10.5 18.1 7.1	13.5 22.5 9.5 6.5 9 16.2	40.2	39.1		
<i>Alnus</i>			7.6					

APPENDIX:

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DBH

Vegetation Plot B	living trees				standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
<i>Betula papyrifera</i>	23.8		24.7	25.1				
<i>Picea glauca</i>							38.2	38.2
<i>Populus tremuloides</i>	18.1	16.5	6.1	6.9		17.8	29.9	27.4
	26.7	25.4	32.7	8		30.2	18	29.9
	31	23.4	6.6	7.5			51	25.5
	30.5	26.7	24.2	23.9				32.6
			23.4					28.4
			23.2					
			27.4					
			25.3					
Quad:488								
<i>Abies balsamea</i>		12.7	16.1	7				
		7.6	8.5	10.7				
			9	9.5				
			12	14.2				
				7				
				11.2				
<i>Acer saccharum</i>		7.6	11.2	13				
<i>Alnus</i>							10.5	
<i>Betula papyrifera</i>	22.1	21.8	6	30.8		8.6	23.4	25.6
	10							9.5
<i>Picea glauca</i>	25							
<i>Pinus strobus</i>	31.5							
<i>Populus tremuloides</i>	24.3	23.6	6.5	7.5	18.7	19.8	33.3	24.4
	24.5	26.4	25				10.5	26
	24.5						19.5	29.1
	31.2						26	
Quad: 489								
<i>Abies balsamea</i>			6.5	6.1				
			9	7.2				
			9.5	7.9				
			11	9.6				
				12.5				
				12.5				
				14.4				
				15.0				
<i>Alnus</i>			6.1					
			6.2					
			6.3					
			6.5					
			6.5					
			6.6					
			9					
<i>Betula papyrifera</i>	11.8		17	8	8			
			8	17.8				
<i>Populus tremuloides</i>	25.1	26.4	40.9	41		24.9	26.7	26.3
	26	43.9					27.8	44.4
	27.6						28.2	
							44.1	

Vegetation Plot C	living trees				standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
Quad:187								
<i>Abies balsamea</i>		7.1	9.1	5.8				
			10.4	7				
				7.2				
				7.2				
				10.4				
				19.8				
<i>Betula papyrifera</i>	13.7	7.1	6.8	6.8			17.1	
	17.5	17.5	26	25.8				
	20.8	24.6						
	25.1							
<i>Populus balsamifera</i>			19.5					

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Vegetation Plot Data

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Vegetation Plot C	living trees				standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
<i>Populus tremuloides</i>	18.3	18.8						
Quad:374								
<i>Abies balsamea</i>		6.4	6.7	8				
		6.6	7.2	8				
		7.1	7.3	8				
		9.1	8	8.7				
			8.5	8.8				
			10.5	9.3				
				10.6				
				12				
<i>Betula papyrifera</i>	23.3	8.9	20.7	21.2			22.3	27.8
		22.4						
<i>Pinus strobus</i>	37.9	38.1	40.2	40.1				
	38.1	39.6	42.3	44.8				
<i>Picea glauca</i>		7.1	8.7	10				
Quad:375								
<i>Abies balsamea</i>		7.6						
<i>Betula papyrifera</i>	18		6.8	7				
<i>Pinus strobus</i>	23.2	23.4	22.3	23.9	30.9	33	33.2	32.5
	26.1	24.9	26	27.5				
	27	27.4	27.5	27.8				
	33.3	43.2	44.1	45.5				
<i>Populus tremuloides</i>	20.4							
	24.7							
	27.9							
Quad:376								
<i>Abies balsamea</i>		6.4	7.3	6.4				
		7.1	7.3	6.9				
		9.7	8.7	7.5				
		10.7	10.6	7.5				
			12	7.5				
				8.3				
				8.4				
				10.2				
				11.6				
				12.2				
<i>Betula papyrifera</i>	22.2	22.1	22.5	23.5				
	25	25.1	25.3	26				
<i>Pinus strobus</i>	(12.3)	13.2	13.6	14.3				
	(21.3)	23.6	25.9	28.9				
<i>Populus tremuloides</i>	26.3	26.7	27.7	27.4				
	25							
Quad:377								
<i>Abies balsamea</i>		14.2	16.2	7				
	(12.2)	15.7	16.8	15.9				
	(16.6)			18				
<i>Betula papyrifera</i>	(8.4)	8.6	9	9				
	(10.8)	10.9	10.6	11				
	15	15.5	15.9	15.5				
<i>Pinus strobus</i>	40							
<i>Populus tremuloides</i>		4.7	7.8	8.3				
	(42.5)	(43.8)	44.1	44.4				
		7.9						
Quad: 378								
<i>Abies balsamea</i>	7.9	9.9	10.8	6.3				
				6.7				
				12.4				
<i>Betula papyrifera</i>		7.6	7.5					7.5
<i>Pinus strobus</i>	29.3	28.7	29.1	30				
<i>Pinus resinosa</i>	(30.0)	(31.4)	32.4	33.5				
<i>Populus tremuloides</i>	28.9	25.7	26	26				
	28	28.4	29.7	30.2				
	32.7							
	25.9							

APPENDIX:

Vegetation Plot Data

DBH

Vegetation Plot C	living trees				standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
	7.7							
Quad:379 <i>Abies balsamea</i>	8 (12.0) 21.9	6.6 13.2 23.4	7.8 9.7 14.4 24.2	9.4 10.7 16.3 24.5				
<i>Betula papyrifera</i>	(13.0) 14.3 (18.0)	13.5 15 19.1	14 15.4 18.2	14.4 15	19.3			18.3
<i>Pinus strobus</i>	35.2							
<i>Populus tremuloides</i>	21.7 22.1 30.5 35.8	30.7 36.8	32.1 37.7	32.3	19.8			38
Quad:380 <i>Abies balsamea</i>	9.7	10.7	6.4 11.2	8.3 12.4				
<i>Betula papyrifera</i>	18.5							
<i>Pinus strobus</i>	28.7 35.3	28.4	30	29.3	30			
<i>Picea glauca</i>	30.9	(31.5)	32.2	32.6	32.2			
<i>Populus tremuloides</i>	21.8 23 26.4 27.1 29.8	18.3 22.1 26.7 26.9 28.2 30.5	23.2 24.1 28.4 28.7 29.6 31.7	23.6 24.3 28 28.6 30 31.5	19.1			
Quad:381 <i>Abies balsamea</i>	15.5 15			7				
<i>Betula papyrifera</i>	(14.4)	(14.6)	7.2 14.8	7 15				
<i>Pinus strobus</i>	29 31.7 36 43.2	43.7	44.5	45				
<i>Populus tremuloides</i>	23 26.4 33	24.1 26.9	25.9 28.4	26.2 28.7				

Vegetation Plot D	living trees				standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
Quad:492 <i>Abies balsamea</i>		10.4	8.3 13.4	6.5 11.6 16.5				
<i>Betula papyrifera</i>	17.8 18.1 19.4 18.9	(14.0) (18.0)	14.4 18.2		18.7 24.5 24.9	25.4 22.1 25.7	24.1 24.3	14.3
<i>Populus tremuloides</i>				7.0 7.0 7.1 7.9 8.6 30.4 (37.7) 37.1 (40.4)				
		33.3 39.9 39.9 44.2	8.2 11.0 35.5 41.3 42.1 48.0	10.0 11.7 36.4 41.8 43.1 47.6				
Quad:493 <i>Abies balsamea</i>				9.5 10.5				

APPENDIX:

Vegetation Plot Data

DBH

Vegetation Plot D	living trees				standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
<i>Betula papyrifera</i>	7.1 9.6 10.5 10.6 11.2 12.0 13.4 20.1 20.2	10.2 12.4 20.3	8.9 10.8 15.0 15.2 21.2	13.3		10.9 12.7 20.3	12.2 21.1	8.8 14.2 22.1
<i>Pinus strobus</i>	23.0	26.7	(31.0)	35.3				
<i>Populus balsamifera</i>	13.2 39.9 43.5	16.3 40.6 44.2	19.8 43.1 48.2	22.2				
<i>Populus tremuloides</i>	4.9 5.5 5.8 7.9 9.0		7.1	8.1				43.0 47.6
Quad:494 <i>Abies balsamea</i>		9.7	9.1 12.8	12.0 13.5				
<i>Betula papyrifera</i>	15.4 15.9 16.4				16.9 20.4 21.1	15.2 17.0 17.8	15.4 17.1 17.9	16.0 17.7
<i>Populus balsamifera</i>	31.5	32.5	33.5	33.8		18.3 22.4 23.6		
Quad:495 <i>Abies balsamea</i>	9.9 12.6	9.4 (16.1)	14.6 10.3 19.8	6.0 6.5 15.9 21.5				
<i>Betula papyrifera</i>	7.5 11.4 12.5 17.4 17.4 20.8							
<i>Pinus strobus</i>	32.4 36.8							
<i>Picea glauca</i>	9.2							
<i>Populus tremuloides</i>	8.9 13.0 18.5 32.8	10.4 27.4 29.7	10.9 29.6 31.1	11.0 30.2 30.8	20.7			
Quad:496 <i>Abies balsamea</i>		7.6 7.9	6.9 7.7 9.5 11.1	8.0 9.5 14.8 37.9				
<i>Betula papyrifera</i>	14.6 16.0 18.5 22.3 25.5	13.2 22.9 25.4	13.7 23.9	24.9	14.3	14.0 18.5	14.0 25.4	13.6 22.9
<i>Pinus strobus</i>	(12.0) (16.0)	(17.0) (22.0)	22.1 27.0	27.6				
<i>Picea glauca</i>	35.7	36.8	37.3					
<i>Populus tremuloides</i>	40.6 44.9	42.4 46.5	44.0 48.1	45.8				47.6
Quad:497 <i>Abies balsamea</i>	7.5	(8.0)	9.0	8.0 11.5				

APPENDIX:**Vegetation Plot Data****DBH**

Vegetation Plot D	living trees				standing dead trees			
	1986	1992	1999	2004	1986	1992	1999	2004
<i>Betula papyrifera</i>	11.6	(12.0)	7.4 13.4 (13.4) 15.4 (21.5) 22.1	15.7				13.4 22.3
<i>Pinus strobus</i>	25.0	(38.2)	41.9	45.7				
<i>Populus tremuloides</i>	29.0 21.0				23.6	20.3 21.6 29.7	20.2 28.8	28.5
Quad:498								
<i>Abies balsamea</i>	20.3	(23.1)	25.6	26.2				
<i>Pinus strobus</i>	(58.0)	58.2	58.3	60.1				
<i>Populus tremuloides</i>	38.8 30.0	40.9	42.3	43.3				
Quad:499								
<i>Abies balsamea</i>				8.0				
<i>Betula papyrifera</i>			18.3 12.7 8.0				19.5	19.5
<i>Pinus strobus</i>				7.0				
<i>Populus tremuloides</i>				6.7				
	(32.0) (36.0)	34.5 38.4	36.6 40.4	37.1 40.8				

APPENDIX:

Vegetation Plot Data

Shrub Layer

Table A-2. Understory layer in four vegetation sampling plots in Grand Portage National Monument from 1986, 1992, 1999 and 2004. Woody stems between 1.25 and 6 cms were tallied by species within 10-meter square sample quadrats, nine for plots A, B, and C, eight for plot D.

Vegetation Plot A										
Species	Sample date	190	191	192	193	194	195	196	197	198
<i>Abies balsamea</i>	1986		3	9	4	10			13	9
	1992		2	5	3	7	2		7	15
	1999	6	4	7	5	4	9	10	4	17
	2004	8	6	8	6	3	6	11	5	17
<i>Acer spicatum</i>	1986		6	16		3	8	10	38	11
	1992	3	3	8	1	3	23	8	5	3
	1999	8	7	13	2	4	23	15	10	18
	2004	15	7	19	2	3	36	17	11	5
<i>Alnus</i>	1986		4		19	29	7	26	102	42
	1992	6	13		2	26	7	29	9	53
	1999	8		40	15	18	20	64	48	27
	2004	13		10	9	3	12	41	26	19
<i>Amelanchier</i>	1986		3	1	1	2	3	6	4	1
	1992	1								
	1999	1		1					1	
	2004	1				4	1		1	
<i>Betula papyrifera</i>	1986				3					
	1992					2				
	1999			1	1				2	
	2004				1		3		1	1
<i>Cornus stolonifera</i>	1986		2	3	22	20	3		6	3
<i>Corylus cornuta</i>	1986	5	8	3	3	23	2	23	3	3
	1992			9	24		2	9		5
	1999		4							
	2004		2		3	5	9	1	1	
<i>Fraxinus sp.</i>	1992				1					
	1999				1					
<i>Picea glauca</i>	1986		1		2				1	
	1992				3					
	1999				1					
	2004				2	2		1		
<i>Populus balsamea</i>	1986						3			
<i>Populus tremuloides</i>	1986					1			8	61
	1992					1		4		53
	1999			1		1	5		6	17
	2004					1	4		3	8
<i>Rosa</i>	1986					1				
<i>Salix</i>	1986			1	4				2	
	1992				1					
	1999			1	1					
<i>Sambucus</i>	1986				1					
<i>Sorbus</i>	1986		1							

Vegetation Plot B										
Species	Sample date	480	481	482	483	484	485	487	488	489
<i>Abies balsamea</i>	1986		17	17	4	13	2	21	22	5
	1992	15	22	8	7	4	27	12	20	7
	1999	18	39	9	5	12	44	23	24	9
	2004	22	27	10	8	7	39	27	22	2
<i>Acer saccharum</i>	1999								1	
<i>Acer spicatum</i>	1986	18	5	5	4	4	4	13		5
	1992	10	12	6	6	4	16	12	11	4
	1999	27	16	6	9	12	30	19	24	13
	2004	31	13	17	12	13	29	6	24	20
<i>Alnus</i>	1986	7	3	30	19	48	19	49	42	118
	1992	7	7	31	18	30	16	49	25	72
	1999	1	8	14	19	42	4	28	17	77

APPENDIX:

Vegetation Plot Data

Shrub Layer

Vegetation Plot B Species	Sample date	480	481	482	483	484	485	487	488	489
	2004		1	32	12	29	2	30	14	41
<i>Amelanchier</i>	1986		7		2			6		3
	1992		2				1		1	
	1999		4	25		1		7	2	
	2004					1			2	
<i>Betula papyrifera</i>	1986				2			11		
	1992		1							
	1999				1			3		3
	2004	1			1	1		3	3	3
<i>Cornus stolonifera</i>	1986	1	24	3		20	3	10		
	1992					2	5			
	1999					2	1	2		
	2004					1	1			
<i>Corylus cornuta</i>	1986	27	9	3	11	2	1	25	48	48
	1992	4	8		6					3
	1999	4		5	3	1	10	5	4	23
	2004							2		40
<i>Lonicera sp.</i>	1986		5			6				2
<i>Picea glauca</i>	1986		1	1		2	3			
	1992		1	2		2	11			
	1999				1	2	3		3	
	2004			3	1	2	4			
<i>Pinus strobus</i>	1986									1
<i>Populus balsamea</i>	1992									2
	1999									3
<i>Populus tremuloides</i>	1986						1	17	13	6
	1992							13	4	
	1999					3		10	9	2
	2004					3		7	1	1
<i>Prunus sp.</i>	1986					2				
	1992					1				
<i>Sorbus</i>	1986			1					24	
	1992									4
	1999									2
	2004									2

Vegetation Plot C Species	Sample Date	187	374	375	376	377	378	379	380	381
<i>Abies balsamea</i>	1986	22	10	18	13		3	1	4	5
	1992	19	2	9	18	10	2		5	6
	1999	21	3	11	14	13	2	1	5	7
	2004	19	5	12	15	8		1	6	7
<i>Acer spicatum</i>	1986			5			0			
	1992		10	5	12	2	6			
	1999			8		5	7			1
	2004		8	7		8	6			1
<i>Alnus</i>	1986	34	86	45	19	10				51
	1992	10	39	56	7	54	80			22
	1999	11	40	31	4	57	62	24	51	24
	2004			9		4	27	5	3	3
<i>Amelanchier</i>	1986	4								
	1999	1		2			1			1
<i>Betula papyrifera</i>	1986	4	2							
	1992	1								
	1999		3	1				2		
	2004			1				1		
<i>Cornus stolonifera</i>	1986	2	9	15	41					8
	1992	5						2		9
	1999		4		3			2		8
<i>Corylus cornuta</i>	1986	5	2	2		4	45	17	25	
	1992							34	31	
	1999			11				4		4
	2004			1						
<i>Lonicera</i>	1986					3				
<i>Picea glauca</i>	1992		3							

APPENDIX:

Vegetation Plot Data

Shrub Layer

Vegetation Plot C Species	Sample Date	187	374	375	376	377	378	379	380	381
	1999		1							
<i>Pinus strobus</i>	1986	6			2					
	1992	5						1		
	1999	4			1			1		
	2004	2								
<i>Populus tremuloides</i>	1986	3	5	1	1					1
	1999		2							
	2004		2	2			1	1		1
<i>Prunus virginiana</i>	1986									2
<i>Salix sp.</i>	2004									2
<i>Thuja occidentalis</i>	2004							1		

Vegetation Plot D Species	Sample Date	492	493	494	495	496	497	498	499
<i>Abies balsamea</i>	1986	4	8	6		52	14	3	
	1992	3	9	11	5	6	4		2
	1999	4	8	8	7	9	10	1	5
	2004	5	8	9	7	10	11		7
<i>Acer spicatum</i>	1986	24	29	44	2				
	1992	16	21	12			8		
	1999	21	35	28			9	1	
	2004	30	48	44		1	1	2	1
<i>Alnus</i>	1986	56	24	48	42	10	160	62	
	1992		43	48		13	65	16	41
	1999	43	36	21	16	17	64	12	72
	2004	4	12	28	3	2	21	3	13
<i>Amelanchier</i>	1986		2	1	2	1	1		
	1999		1				1	1	1
	2004		1			2			6
<i>Betula papyrifera</i>	1986		8		5	2	3	6	
	1992							4	
	1999								1
	2004								5
<i>Cornus stolonifera</i>	1986			12	7	1	18	41	
	1992			10	15	2	12	12	5
	1999					5	3		1
	2004					2			
<i>Corylus cornuta</i>	1986	35		8	14	71	1		3
	1992	32		8		17	5		
	1999	2	1	4	6	28	1		4
	2004	18	4	11	1	4	2		2
<i>Lonicera</i>	1986					2			
	1999								1
<i>Picea glauca</i>	1986			1				1	
<i>Pinus strobus</i>	1986	3		4	1				
	1992	2			3	1			2
	1999	1			3	1			2
	2004	1			4	1			1
<i>Populus balsamea</i>	1986							25	
	1992		5	4					3
	1999			3					
	2004		1	2					
<i>Populus tremuloides</i>	1986	11		1		12	6	10	
	1992				48	1	3		
	1999	4	3	1	1	13	5		7
	2004	5	1	1	4	7	9	15	7
<i>Prunus sp.</i>	1986								
	1992		1			2			
	2004								1
<i>Salix sp.</i>	1992				3				
	1999				2				1
	2004				2				
<i>Viburnum</i>	1986			3					
	1999								1

APPENDIX:

Vegetation Plot Data

Herbaceous Layer

Table A-3. Herbaceous cover from four vegetation plots in Grand Portage National Monument. Percent canopy cover was estimated by species in one meter subquadrats nested in the NE and NW corners of nine sample quadrats for plots A, B, and C, eight quadrats for plot D in 1986, 1992, 1999 and 2004. Surface cover by litter and large diameter down woody material was also estimated.

Vegetation Plot A		190		191		192		193		194		195		196		197		198	
Species	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<i>Abies balsamea</i>	1986		5									1	0.5	0.5	15	1	3		
	1992		2										80	100		5	25		
	1999		2	8		10							2	3		65	40		
	2004		5	15		20				20				10		1			
<i>Acer spicatum</i>	1992	35				80		30								5	20		
	1999	5	3	80	2	5		25		2		2				3			
	2004	5	15	25		5		15	20	5		5	5	5		5	10	10	
<i>Actaea rubra</i>	1986												0.5						
	1992											65				2		2	
	1999													15					
	2004													10		15			
<i>Agrostis alba</i>	1986													1		10	10	15	
	1999				2			5		15				20			30		
<i>Alnus</i>	1992	10	5	50		50				20	60			5	20	80	70		
	1999				7										80		75	50	
<i>Amelanchier</i>	1986									2		2							5
	1992	15								5						20			
<i>Anemone canadense</i>	1992			25							15		50						
<i>Anemone quinquefolia</i>	1992	5		3	15			1		1								1	
	1999				7														
	2004					5				10							5		
<i>Aralia nudicaulus</i>	1986	30	5	35		10		5	50	15	15	7	15		7	1	10		1
	1992	2	10	40	80	15	85	50	25	40	25	5	10	10	50		10	2	15
	1999	20	30		55	10	55	70	75	30	70	30	75	35	65	40	12	10	15
	2004	30	25	5	20	20	25	75	65	35	15	75	15	20	75	30	15	15	20
<i>Aster macrophyllus</i>	1986	10	10	60				25	45	50	15	30	50	50	40	30	50		
	1992	40	40	75	25	25	90	25	45	70	50	35	50	70	70	60	70	25	25
	1999	25	80	60	60	35	80	95	55	80	90	10	25	60	90	60	20	25	15
	2004	40	60	35	95	20	95	90	40	75	60	60	15	15	95	35	10	20	15
<i>Aster sp.</i>	1986					1		0.5	0.5		5		0.5					2	
<i>Calamagrostis canadensis</i>	2004							20		20	80							15	
<i>Carex sp.</i>	2004			10										5					
<i>Cinnamon fern</i>	1992									2									
<i>Clintonia borealis</i>	1986	1	5		5	3	5							10		2		4	
	1992	10			5	5										5			
	1999		20	15						8				15		5	20		
	2004			15		20	30			5				25	20		20		
<i>Coptis groenlandica</i>	1986															0.5		0.5	
	1992							2	2			15				1			
<i>Cornus canadensis</i>	1986		1															5	
	1992		2		2													5	
	1999		20	15														15	
	2004		15	20										5				5	
<i>Cornus stolonifera</i>	1986		5					25				5		15		40		5	
	1992			5				10										20	
<i>Corylus cornuta</i>	1992							35	1										
	1999				5														
	2004																	30	
<i>Diervillea lonicera</i>	1992											30							
	1999									25	8	20							
	2004									20		20	10						
DOWN woody	2004		25			20	15			20	5	25	5			30		35	25
<i>Dryopteris spinulosa</i>	1986							2			5								
<i>Equisetum sp.</i>	1986												0.5						
	2004																	35	
<i>Fragaria virginiana</i>	1986			1		1		20		25		1		1	5			5	1
	1992							10	2	5	5	15							

APPENDIX:

Vegetation Plot Data

Herbaceous Layer

Vegetation Plot A Species	Year	190		191		192		193		194		195		196		197		198	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	1999					10		15		3	10								
	2004							15		15		10							
<i>Galium</i> sp.	1986							2				0.5		1		5			
	1992	1						8											
	2004							5											
<i>Habenaria</i> sp.	1986									1									
	1992			3															
<i>Lathyrus leucanthus</i>	1986									2									
	2004													15					
LITTER	1986	100	100	100	100	100	100	95	100	100	100	100	100	100	97	98	100	70	70
	1992	100		100	100	100		100	100	100		90	50	60	60	70	25	90	80
	1999	80	98	97	100	100	100	85	100	98	100	80	85	70	15	90	95	95	
	2004	100	75	95	95	100	80	85	100	100	80	80	80	90	100	70	95	70	75
<i>Lonicera</i> sp.	1986					0.5													0.5
	1999													10					
	2004													20					
<i>Maianthemum canadensis</i>	1986													0.5	1	0.5		0.5	1
	1999		5			15	2							20	40	7	5		
	2004			10		5	5					2		5	30	15	15		10
<i>Mitella nuda</i>	1986							0.5		0.5	7								
	1999							60	55	30		10							
	2004							35	60		15	15						25	
<i>Monotropa uniflora</i>	1992							1											
<i>Picea glauca</i>	2004			20															
<i>Picea mariana</i>	1986																	0.5	
<i>Populus tremuloides</i>	1986											1						1	
	1992		2													50			50
	1999	2	15			25													
	2004																	5	
<i>Prenanthes alba</i>	1986							10	2	7	5	10	5					1	2
	1992																	1	5
	1999							2	17	5	18								
	2004								20	35	15								
<i>Prunus</i> sp.	1999	2																	
<i>Pteridium aquilinum</i>	1986					0.5		5		15									
	1992					15		10								10			
	1999					20													
	2004							25											
<i>Pyrola elliptica</i>	1986	5			1	1										0.5		3	3
	2004	40	30		15	30	5									5			
<i>Pyrola</i> sp.	1999	20	10			15	8					25							
<i>Rosa</i> sp.	1992									5									
	1999		15							30				10				30	
	2004		15							25		10		5					
<i>Rubus occidentalis</i>	1999							15											
<i>Rubus parvifolia</i>	1986		10			15				5		10		10		2	10		
	1992					10	20												
	1999					25										10			
	2004					25								20					
<i>Rubus pubescens</i>	2004							20	15		25	10	15						40
<i>Rubus</i> sp.	1986	5		5	5							3	2						0.5
	1992					1						15							
	1999	25		50	8	15	20	30	40	25	20	5	20					30	
	2004		30		35	35	10												
Sedges	1992											45							
	1999		7		7			3						15	5			15	
<i>Sorbus</i> sp.	1986																		1
	1992							1											
<i>Streptopus roseus</i>	1986							2								20			
	1992			10		3										8	20		
	1999					7										7			
	2004													5	20		20		
Unknown	1992		2																
	1999													20					
<i>Vicia americana</i>	1992													5					

APPENDIX:

Vegetation Plot Data

Herbaceous Layer

Vegetation Plot A		190		191		192		193		194		195		196		197		198	
Species	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	1999													20					
<i>Viola</i> sp.	1992	1	15	1	10	1								2					

Vegetation Plot B		480		481		482		483		484		485		487		488		489	
Species	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<i>Abies balsamea</i>	1986		10		10		8		0.5		5			1	5				
	1992	20	5		5	15		10	20	80		25	30	5		60		15	
	1999	2	30	20					35	10			20						
	2004	1				1			25					1		5	30		
<i>Acer saccharum</i>	1992															50			
<i>Acer spicatum</i>	1986									20				1					
	1992				20		80		100	100	5	20	3			40		5	
	1999	2	10	2	5		40	30	5	2	30	2		10	5		15		
	2004	10					30	30	15	5	35	5	10	5	15	10	5	5	5
<i>Actea rubra</i>	1992															5			
<i>Agrostis alba</i>	1992																		100
	1999		10															15	
<i>Alnus</i>	1986									10									
	1992	50	10		15	100		2		10		2		7	5	25		10	
	1999							30						20					
	2004			15	20									20					
<i>Amelanchier</i>	1999							25											
	2004							20	35										
<i>Anemone canadense</i>	1992	5																	
<i>Anemone canadensis</i>	1999							5						8					
<i>Anemone quinquefolia</i>	1992	10	5					5	1		1	1						5	
	1999			15															
	2004			20				15	5	5				5	15				
<i>Aralia nudicaulus</i>	1986					2				3	25	1	8	8	5	5	5		
	1992			50		20	5	50	30	25	15	20	20	7	15	20	20	1	
	1999	25			30	10		25	25	25	50	25	50	50	25	20	40	25	
	2004	20	45	15	25	30	50	25	25	20	30	65	25	35	30	25	25	10	
<i>Aster macrophyllus</i>	1986	10		20	8	10	30	5	8	20	85	90	90	90	30	50	45	40	85
	1992	35		20	60	25	15	15	25	40	50	90	70	95	85	80	80	70	40
	1999			60	40	20	15	15	30	30	50	80	40	55	20	15	80	65	15
	2004	60		55	15	15	25	30		35	75	45	20	15	20	15	45	20	
<i>Aster</i> sp.	1986					2													
<i>Betula papyrifera</i>	2004							15				5							
<i>Calamagrostis canadensis</i>	2004	10	15																
<i>Carex</i> sp.	2004													10					
<i>Clintonia borealis</i>	1986	2				15		10	5	0.5						1			
	1992					20	15		10					10		1		1	
	1999											20						15	
	2004	5		10	20	10		1				30						20	
<i>Coptis groenlandica</i>	1986			1	1			0.5											
	1992			1					2										
	1999			20	20	20													
<i>Cornus canadensis</i>	1986	15								0.5		0.5							
	1992	5				1				5		1							
	1999	50				3				20				5					
	2004	25				5				10									
<i>Cornus stolonifera</i>	1986	5				5								5					
	1992		10									50		50					
	1999											20							
<i>Corylus cornuta</i>	1986			15				1											
	1992							60								50	20		
	1999	70													15				
	2004	15		40											10				
<i>Diervillea lonicera</i>	1992			20				5											
	1999			27	60			10								15			
	2004			5	25			25											
Down woody	2004				20	10	20	25	5	20	20	25		30	25	10	15	50	50
<i>Dryopteris spinulosa</i>	2004		10																
<i>Equisetum</i> sp.	2004	10																	

APPENDIX:

Vegetation Plot Data

Herbaceous Layer

Vegetation Plot B		480		481		482		483		484		485		487		488		489	
Species	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<i>Fragaria virginiana</i>	1986	5	2									5	4			0.2			
	1999		12										15						
	2004		20										5					5	
<i>Galium</i> sp.	1986									2		0.2	1	4				2	
	1992											3		5				5	
	2004							5											
Labiaceae	1992		5																
<i>Lathyrus ochroleucus</i>	2004													5					
<i>Lily</i> sp.	1992							1	1	10									
<i>Linnaea borealis</i>	1986													15					
LITTER	1986	40	2			20	15	90	90	40	30	90	85	70	50	70	40	25	50
	1992	100	90	100	100	80	50	100	80	75	50	100	70	100	90	100	100		
	1999	100	100	100	80	100	95	70	85	80	70	50	80	95	70	100	40	60	80
	2004	95	50		85	90	60	70	90	80	80	70	100	60	70	80	80	40	40
<i>Lonicera</i> sp.	1986			10	10	15													
	2004																15		
Lycopodiaceae	1992		90	16	80	35	10												
	1999			60	80	75	3												
	2004					15	20												
<i>Maianthemum canadensis</i>	1986		1																
	1992													5					
	1999	25		15		10	5	5	5	7	10		10	5	5	7	10		
	2004	10		5	10	5		5		10	5		10	5		20	5	5	
<i>Mentha</i> sp.	2004		5																
<i>Mitella nuda</i>	1999									15									
Moss	2004		50																
<i>Petasites frigidus</i>	1999									3									
<i>Picea glauca</i>	1986					8									1				
	1992					20													
<i>Picea mariana</i>	1999									15									
<i>Pinus strobus</i>	1992														2				
<i>Populus tremuloides</i>	1986	2																	
	1992														2				
	1999													5	5		10	10	
<i>Prenanthes alba</i>	1986	5																	
<i>Pteridium aquilinum</i>	1986																	15	
	1992																15	65	
	1999																5		
	2004																30		
<i>Pyrola elliptica</i>	1986	5	2		5	5		3				1			4				
	2004													5					
<i>Pyrola</i> sp.	1999			5		5				5				7					
	2004					5				10									
<i>Ranunculus</i> sp.	1999							5											
<i>Rosa</i> sp.	1986	1			5														
	1992																		
	1999			5															
	2004			10															10
<i>Rubus parvifolia</i>	1986					3	25	5						1	8	2		5	
	1992							5								20			
	1999														10	20			
	2004															20			
<i>Rubus pubescens</i>	2004	55	25	10				25	5			15							
<i>Rubus</i> sp.	1986	10				2		0.5		0.5		5	5						1
	1999	35	10	15				20	5	5		5	10						
Sedges	1999	20	60																
<i>Streptopus roseus</i>	1986																3		
	1992			15	5	25	20												15
	1999			20	7	25								25			15	10	
	2004			35	10	15	10	15	5					5			25		5
<i>Trientalis borealis</i>	1992									2									
	2004							5		15						5			
Unknown	1992	10								1								1.5	
<i>Viola</i> sp.	1992	5				3		3				1	1			1			

APPENDIX:

Vegetation Plot Data

Herbaceous Layer

Vegetation Plot C		187		374		375		376		377		378		379		380		381	
Species	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<i>Abies balsamea</i>	1986		1			5												15	
	1992			80		35		70						100		70		2	
	1999									10		20		10				20	
	2004	1				1		1		5		10		20		45		15	
<i>Acer spicatum</i>	1992					1	8			25								20	
	1999					10	5					5	5			10			
	2004					5	5	1						5		5		15	
<i>Actaea rubra</i>	1992					2													
<i>Agrostis alba</i>	1986		5	20															
	1992			0.2		8													
	1999		12			35		30	30	25	25	15				35		5	
<i>Alnus</i>	1992	15		2				90		2	10	10				5		20	
	2004																	10	
<i>Amelanchier</i>	1992																		5
<i>Anemone quinquefolia</i>	1992							2	5	1	35			5					
	2004	10		10				10				2				5			
<i>Aralia nudicaulus</i>	1986			5	30	25		30				10	20	20	40	40	15	20	30
	1992	15		8	20	20	10	25	45	5	20		10	5	80	25	25		
	1999	30	25	25	20	35	80	35	15	25	35		30	75	50	40	30	30	15
	2004	25	15	25	20	20	85	20	80	25	20		35	15	35	25	15		10
<i>Aster macrophyllus</i>	1986	50	30	30	50	30	5	5	40	30	30	10	20	60	30	10	10	40	30
	1992	45	50	55	25	10	35	5	45	40	50	30	40	65	30	20	25	55	8
	1999	100	95	85	90	50	85	50	15	85	65	85	60	85	30	60	60	50	25
	2004	30	100	95	100	40	90	5	80	95	75	85	40	40	5	30	40	50	30
<i>Aster sp.</i>	1992	4																	
	2004	5																	
<i>Betula papyrifera</i>	2004													5					
<i>Calamagrostis canadensis</i>	2004	20	10							10									
<i>Carex</i>	1986							1		1	1								
	2004	15				25				15	25								
<i>Coptis groenlandica</i>	1992													2		2			
<i>Cornus canadensis</i>	1986					1										0.5			
	1992													2					
	1999													10		10			
	2004													5	5	15			
<i>Cornus rugosa</i>	2004															15		40	
<i>Cornus stolonifera</i>	1986					25										25			
	1992	5		3				35	15	7						25		20	
	1999		20	5				35								80		90	
<i>Corylus cornuta</i>	1986			1												5			
	1999	20																	
	2004	15																	
<i>Diervillea lonicera</i>	1992			5				45		45				5					
	1999									20									
	2004									5				5					
Down woody	2004	15				20	10	10		15	10	50	75			15	15		
<i>Fragaria virginiana</i>	1986	10	1	1		1		1		1	1			1		2			
	1992	5	2	2		1												20	
	1999	10	10	5				20		20		5				5		5	
	2004			5				15		10									
<i>Galium sp.</i>	1986											1						0.5	
	1992	1				1						8		1	1			1	
	1999											20			10				
	2004											15							
<i>Lily sp.</i>	1992	1		0.1								0.3	0.1						
<i>Linnaea borealis</i>	1986		0.5							1								1	
	1992	1		1													4	1	
	1999		10											5			10		
	2004															15			
LITTER	1986	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	1992	90	90	90	90	90	90	90	85	90	100	90	90	90	90	100	95	45	90
	1999	85	95	100	85	85	95	90	85	95	80	95	75	85	900	100	95	70	80
	2004	100	100	100	90	95	100	95	100	100	75	100	75	20	85	100	100	80	75
<i>Lonicera sp.</i>	1986									20	1								
	1999			15				55						15					

APPENDIX:

Vegetation Plot Data

Herbaceous Layer

Vegetation Plot C		187		374		375		376		377		378		379		380		381	
Species	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	2004							5											
<i>Maianthemum canadensis</i>	1986							1				0.5		0.5					
	1992													2		1			
	1999	5				8	25			15		25		5					
	2004					5	15					5		5					
<i>Mitella nuda</i>	1999													10		20			
<i>Moneses uniflora</i>	1999															12			
<i>Picea glauca</i>	1986		15																
	1992							1										1	
<i>Populus balsamifera</i>	1999									8									
<i>Populus tremuloides</i>	1992					1													
	1999					10						5							
	2004											15	15					10	
<i>Prenanthes alba</i>	1999	5												5					
<i>Pteridium aquilinum</i>	1986											2	20						
	1992											25	5			25		2	
	1999											30				45	70		
	2004											5	20	25					
<i>Pyrola</i> sp.	1992											1							
	1999																	30	
	2004																	5	
<i>Rosa</i> sp.	1986	1						0.5											
	1992	5	2	5				10		5	5	15	15	10				7	
	1999	15	5	10						25	25	40		30				35	
	2004	15		30						5	10	35		15				15	
<i>Rubus parvifolia</i>	1986			1	20			40	30	40	10			10		10			
	1992	3	3	10	15	5	1	45	35	35				5	10				
	1999	40	15	40	75		40	40	40	75				50	30				
	2004	60	25	25	50	15	20	20	50		60			35	40	15			
<i>Rubus pubescens</i>	2004							15		60				15	25	25	40	5	
<i>Rubus</i> sp.	1986					1													
	1999							25		60				20	10	20	35		
<i>Sanicula marilandica</i>	1986											1							
	1999			5				5											
Sedges	1992							5	5	20	1							2	
<i>Streptopus roseus</i>	2004				1														
<i>Thuja occidentalis</i>	1986															10			
	1992													20					
	2004													45					
<i>Vicia americana</i>	1986	1	1	5															
	1992		3	3															
	1999	10		25										25					

Vegetation Plot D		492		493		494		495		496		497		498		499	
Species	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<i>Abies balsamea</i>	1986	2	2	5		0.2	3	5		10	5						
	1992		20	85			25	5		2	5	25			1		10
	1999				7		20	5	5			30				5	15
	2004	5	40		15	5	60	10		15		20			1		25
<i>Acer spicatum</i>	1986			5			2										
	1992	1		7							1	5		1			3
	1999	5	5							10							
	2004							5	15								
<i>Actaea rubra</i>	1986									2							
	1992											20					
<i>Alnus</i>	1986	20										15					
	1992	7	50		40			1	95	30	8	20	40	20	20		5
	1999		12	5					20								
<i>Amelanchier</i>	1992														3	2	
	1999		10											20			
	2004														20		
<i>Anemone quinquefolia</i>	1992	40	10	0.3		30	20	1	1	10							
	2004						10	5	5			5			15		15
<i>Apocynum androsaemifolium</i>	1999							50	25					25	10		
	2004														10	30	

APPENDIX:

Vegetation Plot Data

Herbaceous Layer

Vegetation Plot D		492		493		494		495		496		497		498		499	
Species	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<i>Aralia nudicaulus</i>	1986	5										2					
	1992	7	2	5				3		7	8	30	15	10	20	25	
	1999	60	25	15	20	5		25		70	45	75	30	25	75	25	
	2004	30		30				20		75	30	50	20	25	90	80	
<i>Aster macrophyllus</i>	1986	25	70	25	80	70	4	20	10	75	40	30	50	15			
	1992	60	40	35	60	50	3	60	20	35	50	60	40	5	50	45	20
	1999	80	30	20	35	65		70	80	35	50	55	20	40	40	70	25
	2004	60	40	20	20	80		10	90	30	60	40	30	40	45	75	15
<i>Aster sp.</i>	1986									10							
<i>Betula papyrifera</i>	1986					2						2					
<i>Botrychium virginianum</i>	2004							15									
<i>Calamagrostis canadensis</i>	1992													2			
	1999			15	40	20		12		30				20	5	10	
	2004					5											
<i>Carex sp.</i>	1992					30	1		1	20						15	
	1999							5		15						10	
	2004					25		10		35							
<i>Coptis groenlandica</i>	1986	2	2				1										
	1992									8							
<i>Cornus rugosa</i>	2004									30							
<i>Cornus stolonifera</i>	1986	15								5							
	1992					2		1		20	5					10	20
	1999					15				20	20						
<i>Corylus cornuta</i>	1986			5	5					20				2			
	1999		5							25		25					
	2004															10	
<i>Diervillea lonicera</i>	1992							5		5	2			7	20		
<i>Fragaria virginiana</i>	1986									15		5				5	5
	1992									7		2				12	10
	1999									20							
<i>Galium sp.</i>	1986	5						1		20				1			
	1992		3							8		3		2	5		2
	1999														15		
	2004													15	15		
<i>Lathyrus ochroleucus</i>	1992									2	7					3	
	2004													5			
LITTER	1986	90	85	60	90		55	40	40	60	60		70	70	30		
	1992	90	90	65	45	90	90	90	65	90	90	80		90	90		
	1999	85	95	70	100	75	100	100	100	65	90	100	90	100	100	85	95
	2004	75		75	100	80	100	75	100	100		75	100	100	95	100	100
<i>Lonicera sp.</i>	1999					5				35							
	2004									40							
<i>Maianthemum canadensis</i>	1992													2			
	1999							20				5		2	5		
	2004							15									
<i>Mertensia paniculata</i>	2004		20														
<i>Mitella nuda</i>	1999									20							
	2004									35							
<i>Osmorhiza sp.</i>	1999															5	
<i>Picea glauca</i>	1992							5									
	1999			7													
<i>Pinus resinosa</i>	2004					25											
<i>Populus balsamifera</i>	1999											10	10	2			
<i>Populus tremuloides</i>	1992									90	8				5	10	
	1999					2	5										
	2004											5					
<i>Potentilla sp.</i>	1992					7											
<i>Prenanthes alba</i>	1986			2													
	1992				0.2		7										
	1999						5									5	
	2004						5										
<i>Prunus sp.</i>	1992											15					
<i>Pteridium aquilinum</i>	1986											40	20	10			
	1992	7								30		10				20	
	1999							35						40		80	

APPENDIX:**Vegetation Plot Data****Herbaceous Layer**

Vegetation Plot D		492		493		494		495		496		497		498		499	
Species	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	2004		50						20		30		50				15
<i>Pyrola</i> sp.	1986	2	3			2			1							3	2
	1992															15	15
	1999		10			2							12			15	15
	2004		15										20			10	
<i>Rosa</i> sp.	1992		10												1	10	
	1999		7						2					25		25	8
	2004													10		10	10
<i>Rubus parvifolia</i>	1986	15		20		5	3	10	2		60	40	10		15		
	1992	1	15		35	10	80					10	15				
	1999		15		95	25	85		50		15		20	25			
	2004	25	40		80	25	80		60		25	25	100				
<i>Rubus</i> sp.	1992															8	55
	1999	40	20	25		35	25			60				5		30	75
	2004	20	20	25		35	15			40				15		30	120
<i>Salix</i> sp.	1992															10	
Unknown	1992									10			1				
<i>Vicia americana</i>	1986										2						
	1992										8						
<i>Viola</i> sp.	1992		5						1								
	1999	10															8