St. Olaf College

Local Ecology Research Papers

Effects of Trail Edge on Species Richness and Floristic Composition in Norway Woods

Ramona J. Butz
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Effects of Trail Edge on Species Richness and Floristic Composition in Norway Woods

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ABSTRACT

Two 50 m transects were conducted to determine whether trail edge affected species density and floristic composition at the edge as compared to the interior of a small forest in southeastern Minnesota. Each transect contained eight points, at 0, 5, 10, 15, 20, 30, 40, and 50 meters from the edge of the trail. At each point, a 1 x 1 m plot was used to measure herbaceous and seedling species, a 2 x 3 m plot was used to measure sapling species, and a 5 x 20 m plot was used to measure mature trees. 5 herbaceous/seedling, 7 sapling, and 4 mature tree species were recorded for a total of 141 plants. Total density for seedlings, saplings, and mature trees were 812.5/ha, 10104.2/ha, and 206.3/ha respectively. Sugar maple (*Acer saccharum*) is the dominant species saplings species with a density 6145.8/ha, and has an importance percentage among mature tree species of 67.7%. Shannon and Simpson Diversity Indexes gave values of 1.22 and 0.57 respectively, indicating relatively low species diversity. The significance of edge effect results (ANOVA) varies with the classification of "interior" and "exterior" forest. When 0-40 m constitutes exterior, or edge, and 50+ m constitutes interior, there is a significant difference in overall seedling density and sugar maple seedling density with the higher densities occurring on the interior of the forest. By grouping the eight points into four groups (0-5 m, 10-15 m, 20-30 m, and 40-50 m), a significantly higher density of both overall mature trees and mature sugar maple occur in group 3 as compared to group 1. Sugar maple saplings, however, show a significantly lower density in group 4 as compared to group 2. These differences may be due to microclimate conditions and the relatively small size of Norway Valley.

INTRODUCTION

As human populations continue to expand, fragmented areas increasingly dominate the landscape. This fragmentation is caused by a variety of anthropogenic activities, such as agriculture, urban sprawl, silviculture, management for game animals, road-building, and residential and commercial development (Alverson et al. 1994). Although some species have become ubiquitous in the presence of edge, other species dependent on habitats without human disturbance are struggling. As non-developed areas become smaller, the threat to species biodiversity in these

patches increases, leading to possible local, regional, or worldwide extinction.

Fragmentation can be defined as a change in landscape structure that typically, but not universally, includes smaller patch sizes, smaller patch perimeter lengths, greater distances between patches, more edge habitat, and less interior habitat (Reed et al. 1996). The main element of descriptive biogeography, as explained by Wilcox (1980), is the species-area curve - the larger the patch, the more species it contains. The exposed edge of a forest receives increased penetration of sunlight and wind, along with variations in other microclimate data, such as relative humidity and temperature. Many of these abiotic edge effects influence forest stands within 50 meters of their boundaries with adjacent, open habitats, but others, such as wind-throw, wind fetch, and acid rain, can operate at a much greater distance (Alverson et al. 1994). Changes in the dynamics of wind and water alter rates at which seeds, spores, insects, and bacteria are transported into and out of forest stands, just as changes in the abundance of these mobile biological entities in the surrounding matrix of vegetation will greatly influence the numbers of species introduced into remnant stands (Bradshaw 1992).

The exact influence of edge effects are debatable at best. Vaillancourt (1995) found that edge effects were evident approximately 50 m or more into the surrounding forest habitat, whereas Chen et al. (1992) showed that edge effects in conifer forests in the Pacific Northwest were evident up to 137 m into the surrounding old-growth Douglas fir forests. The size of patches, or fragments, are therefore also directly connected to the influences of edge effects. Regularly shaped forest

fragments less than 9.0 ha are dominated by edge patterns and processes (Young et al. 1994).

Influences of roads and trails in fragmentation

Reed et al., in a study from 1996, found that landscape structure measurements in Medicine Bow-Routt National Forest in southeastern Wyoming demonstrated a clear pattern of fragmentation, or patchiness, of the landscape by roads. They found that roads increase the area of edge, and thus edge effects, as well. Such trends indicate a significant reduction in the amount of interior forest habitat available to requisite interior species and could ultimately lead to the isolation of subpopulations within patches or small areas of the landscape (Saunders et al. 1991).

While trails are, on average, much smaller than roads, they too have the potential of increasing the fragmentation and edge area of a forest or grassland. The effects of trails on natural areas have been studied with regard to recreational trampling and successive loss of vegetation cover, loss of plant species, and soil compaction (Cole 1985), but they have not been adequately analyzed with regard to their possible role in forest fragmentation through increased edge. Further study can provide a basis for the planning and layout of new hiking/walking trails and evaluation of currently used trails.

The objectives of this study are to (1) compare the floristic composition of patches of Norway Woods adjacent to trails with those in the interior; and (2) determine the impacts of trail edge on seedling, sapling, and mature tree species of this area.

METHODS

Study Area

Norway Valley is a small forested area located on the campus of St. Olaf College in southeastern Minnesota located in Sections 35 and 36 of Greenvale Township in Rice County (Figure 1). It is a Maple-Basswood forest of approximately 5 hectares, bordered to the north and much of the west by paved roads. The southern edge of the runs parallel with Highway. A mowed lawn and another paved road border the western edge, and another mowed area separates Norway Woods from a hardwood restoration plot (planted in 1994) along the eastern edge. The interior of the forest contains a relatively large clearing with two cylindrical water tanks that increase the amount of forest edge. A trail runs just inside the perimeter around the west, south, and east areas of the valley. It varies approximately between one and two meters in width and is composed alternatingly of dirt, woodchips, finely ground gravel, and rocky gravel. This trail is used for recreational walking and running as well as for a portion of the St. Olaf Cross Country Invitational trail.

The Valley is located in the Big Woods ecosystem of this part of Minnesota and is characterized by annual precipitation of 29-31 inches, a growing season of 145-150 days, and loamy soils. The woods do not exist in aerial photographs of the college from the late 1800's which suggests that the current wooded area is less than 100 years old.

Field Procedure

To determine floristic composition and species densities, data sets were derived from a minimum of two randomly selected 50 meter transects running from the trail edge into the interior area of the woods in October of 1999. At 0, 5, 10, 15, 20, 30, 40, and 50 meters along the

transect, I surveyed herbaceous and seedling growth using 1 m^2 plots (0.71 x 1.41 m), tree saplings (defined here as > 0.5 m tall and < 13 cm DBH) using 10 m^2 (2 x 5 m) plots, and mature trees (> 13 cm DBH) using 100 m^2 (5 x 20 m) plots.

Statistical Tests

Analysis of variance (ANOVA) tests were used to compare (1) density of seedlings, saplings, and mature trees at various distances from the trail edge, (2) density of sugar maple seedling, sapling, and mature trees at various distances from the trail edge, and (3) diameter of mature trees at various distances from the trail edge. Simpson and Shannon Diversity Indexes were also used to determine the species diversity of the study site. All figures and tables were created using StatView 5.0 and a P-value of <0.05 was used to determine significance.

Materials

Materials to be used will include: quadrat frames, meter sticks, flags, diameter tapes, long metric tapes, and herbaceous and tree identification manuals.

RESULTS

The total number of organisms recorded in both transects was 141 and fell into 9 different species categories. Total seedling density was 812.5/ha, sapling density, 10104.2/ha, and mature tree density, 206.3/ha. A density breakdown by species for all three groups, including importance values for mature trees, is given in Tables 1 and 2. Sugar maple was the dominant species for each category, except in the seedling/herbaceous

category, where it shared the number one spot with the wood nettle. Shannon and Simpson Diversity Indexes yielded values of 1.22 and 0.57 respectively.

Various groupings of distances from the trail edge led to varying statistical results. These are summarized according to life forms:

Herbaceous/Seedlings

In Figure 2, densities are compared using the original eight plots (0 m, 5 m, 10 m, 15 m, 20 m, 30 m, 40 m, and 50 m). Significant differences in seedling density were between 5 m and 50 m, 30 m and 50 m, and 40 m and 50 m, with P-values of 0.0368 for all three. No significant differences existed for sugar maple seedlings within this category (Figure 3).

Combining plots into pairs to make four groups (0-5 m, 10-15 m, 20-30m, and 40-50 m) yielded no significant differences in seedling density for either overall seedlings or sugar maple seedlings (Figures 4-5).

A significant difference in seedling density was apparent only when the first 40 m were considered exterior, or edge, and the remaining 10 m, interior (Figures 6-7). Overall seedling density and seedling sugar maple density were significantly higher in the interior (P-values of 0.0104 and 0.0450 respectively).

Saplings

When using the original eight plots, significant differences existed between 5 m, and 20 m (P-value = 0.0439), 30 m (P-value = 0.0395), and 40 m (P-value = 0.0358) (Figure 8). Sugar maple saplings showed a significant difference in density only between 10 m and 40 m (P-value = 0.0333) (Figure 9).

Combining plots into pairs to make four groups (0-5 m, 10-15 m, 20-30m, and 40-50 m) yielded no significant differences in sapling density for either overall saplings or sugar maple saplings (Figures 10-11).

Grouping 0-20 m into the category of exterior and 30-50 m into interior yielded no significant difference in overall sapling density, but did yield a significantly higher density of sugar maple saplings in the exterior plot (P-value = 0.0359) (Figures 12). This density difference remained true when the exterior/interior distances were shifted to 0-30 m and 40-50 m respectively (P-value 0.0259) (Figure 13).

Mature Trees

Comparing densities in the original eight plots results in no significant differences in overall mature tree densities and a significant difference only between 0 m and 15 m for mature sugar maples (P-value = 0.0273) (Figures 14-15).

Combining plots into pairs to make four groups (0-5 m, 10-15 m, 20-30m, and 40-50 m) yielded a significant difference in mature tree density between Groups 1 and 3 for overall mature trees (P-value = 0.0136) and for sugar maple saplings (P-value = 0.0477) (Figures 16-17).

No other significant differences in density of mature trees were found in varying interior/exterior comparisons.

Diameter of mature trees

There is a significant difference in overall mean diameters of mature trees in the eight plots (P-value = 0.0443) (Figure 18). There are also significant differences between 0 m and 5 m (P-value = 0.0040), 0 m and 10 m (P-value = 0.0113), 0 m and 15 m (P-value = 0.0018), 0 m and 20 m

(P-value = 0.0050), 0 m and 30 m (P-value = 0.0094), 0 m and 40 m (P-value = 0.0078), and 15 m and 50 m (P-value = 0.0211).

Significant differences also existed between species and diameter of mature trees (P-value = 0.0289) (Figure 19). The average northern red oak diameter was significantly larger than that of the sugar maple (P-value = 0.0061), basswood (P-value = 0.0205), and hackberry (P-value = 0.0039).

DISCUSSION

Although seedlings showed a marked significant difference in density with relation to interior/exterior categorization, the delineation for saplings and mature trees was not as clear.

Herbaceous/Seedlings

Seedlings and herbaceous species showed significant differences with respect to trail edge effects, but only under exterior/interior distinctions of 0-40 m and 50+ m. There were a greater number of seedlings 50 meters from the edge of the trail. Yet the general trend seen in Figure 4 does not follow the expected trend of increasingly greater numbers of seedlings or herbaceous plants as one moves from the edge to the interior. This may be due to high density patches of elderberry saplings between 15 and 45 meters on both transect lines choking out seedling growth. There were also five deadfalls between the two transects that covered approximately 10 square meters of seedling and saplings plots and allowed for no growth in those areas.

Due to the late sampling period, most of the herbaceous growth was already dead. In 16 m^2, only 13 plants in 5 different species were found. This was surprising to me, considering that sugar maples, especially, are prolific seed producers and areas with maple dominance usually form a dense understory of seedlings and saplings (Woods 1984). The high density of sugar maple saplings in comparison to seedlings may suggest a decrease in importance of the sugar maple in the future canopy. However, the small sample size may misrepresent overall seedling densities within the forest.

Saplings

Although seedlings densities were significantly higher in the interior of the forest, saplings resulted in the opposite density trends with respect to interior/exterior categorizations. The highest density occurred at 5 m and decreased the further one moved toward the interior. Although the number of total sapling species was similar to that of the seedling/herbaceous group, a much higher total of 95 saplings were recorded. 59 of these were sugar maples and the only other relative majority were 30 elderberry shrubs. Moonseed vine and nightshade vines were also found in several sapling plots, but were not counted in the total species due to their incorrect life form specific to plot size. Again, deadfalls also played a role in sapling distribution at certain distances from the edge.

It is difficult to determine exactly why there are a significantly greater number of saplings close to the edge rather than in the interior of the forest, but the highest numbers of saplings did, however, occur in the areas of lowest mature tree density. Gaps in the canopy created by these

lower densities of mature trees would allow more light to reach these saplings on the forest floor. Contrary to seedling data, the prolific number of sugar maple saplings suggests that these exterior gaps in the canopy will shortly be filled with more sugar maples, continuing the current composition of the forest.

Mature Trees

Mature trees reached their greatest density between 20 and 30 meters from the edge of the trail where saplings experiences their lowest density. Sugar maples were by far the dominant tree in the forest with an overall importance percentage of 67.7% and lots of deadfall suggests some type of relatively recent disturbance. Most of the identifiable downed mature trees were either sugar maple or basswood. There were also several other dead basswood sending up basal sprouts just outside of my plot areas.

The mature tree plots of 5 x 20 meters squared ran within twenty meters or less of the water tower tank clearing. This suggests the possibility of multiple edge effects occurring from various directions on a small plot of trees. Low biodiversity levels may be due in part to the small total area of the forest coupled with multiple edges.

Diameter of mature trees

There was no significant difference in overall mean diameters of mature trees with respect to distance from trail edge. However, there was a significant difference in overall mean diameters of mature trees between species. This is due almost entirely to one single, very large northern red oak, that if removed from the data, negates the significant

difference. Differences in diameter exist because of differences in growth patterns and relative average age and size of trees between species. Sugar maples seedlings and saplings, for example, may exist for long periods of time in a suppressed stage under a closed canopy while waiting for disturbance to create a gap into which they can grow.

The small area of Norway Valley made it impossible to run more than two transects of 50 m without encountering edge from the opposite direction. Several mature tree plots on the second transect also came within 20 -30 m of a grass clearing containing two large, cylindrical water tanks. It is difficult to determine whether the edge effects shown are from the trail itself, from the actual forest edge, or from clearings such as that containing the water tanks. Because the trail in Norway Valley runs very close to the perimeter of the forest, it is not unlikely that effects from the forest edge could reach the transect areas. This is again a matter of the distance that can be considered edge in any given forest. As stated by Young et al. (1994), regularly-shaped areas smaller than 9 ha are dominated by edge patterns and processes. By this definition, the less than 5 ha that comprise Norway Valley are entirely edge habitat.

Specific trends and differences in the data may be due largely in part to the small scale of the study. It would have been ideal, and created better statistical accuracy, to have had a greater sample size with which to work. Other suggestions for future studies would be to find an area larger than 9 ha with trails running directly through interior and conduct the study during peak herbaceous growth season to maximize herbaceous data. Microclimate data recorded at various distances from the trail to test for edge influences in patterns such as wind, temperature, and humidity

would also help to determine areas affected by edge. Trail width and composition should also be taken into consideration.

The results of this preliminary study on the edge effects of trails suggest that further research could be important to the management and design of trail systems both within and outside of our national parks and wilderness areas. The width of the trail and material from which it is made may also play a role in how much, if any, edge effect it creates. Outdoor recreation is projected to increase with increasing population sizes. The magnitude and scale of these edge effects are highly relevant to forest management and intelligent planning efforts. By creating new trails and increasing the usage of current trails, we must be aware of the environmental impacts ranging from recreational trampling to possible fragmentation of natural areas.

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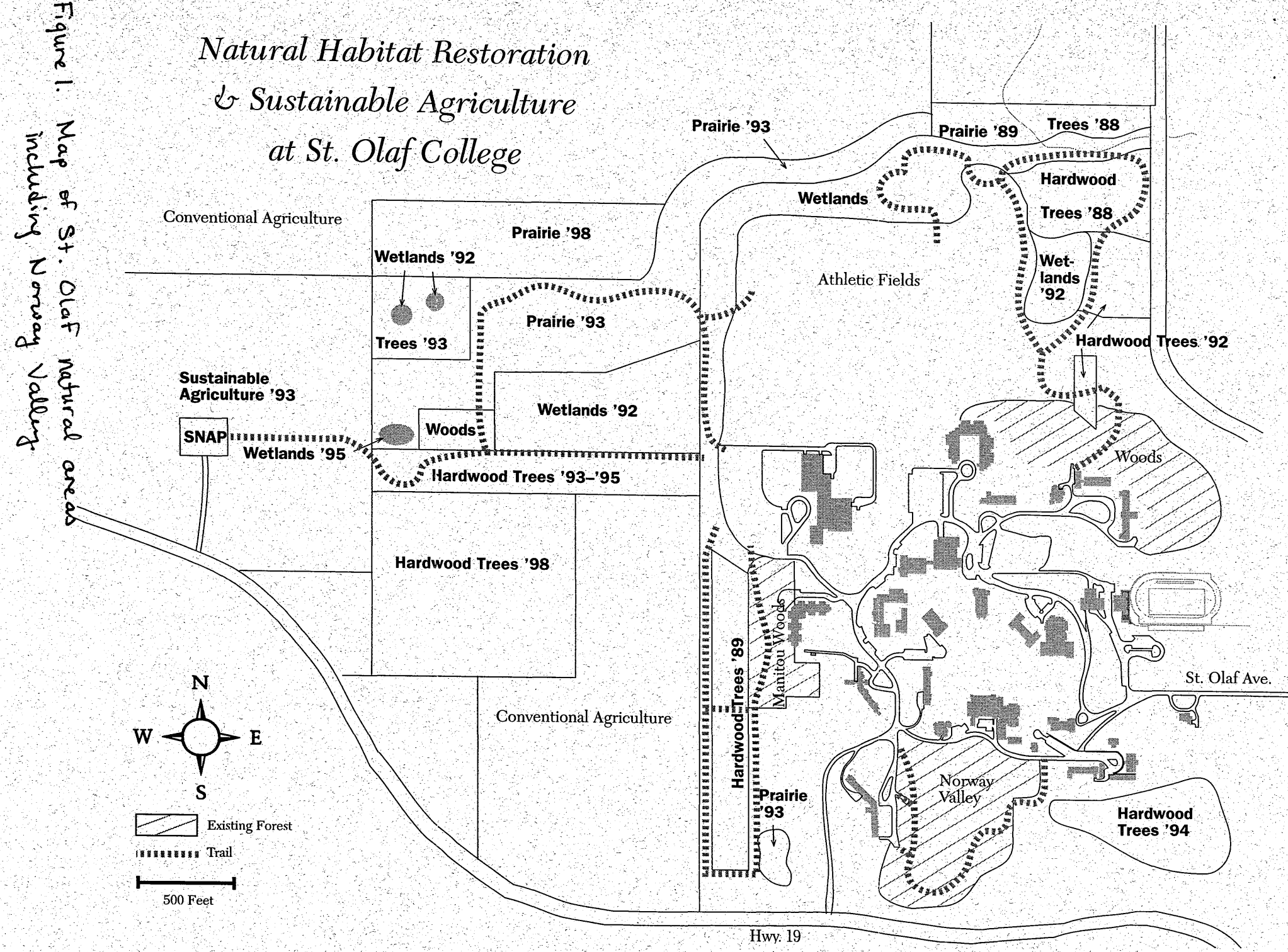

Figure 1. Map of St. Olaf natural areas including Norway Valley.

Table 1. Stand table of herbaceous, seedling, sapling, and mature tree densities (D/ha)

Species	Herbaceous/ Seedlings	Saplings	Mature Trees
Ash	1250.0	104.2	0
Basswood	0	104.2	31.3
Black Cherry	0	104.2	0
Elderberry	625.0	3125.0	0
Gooseberry	0	104.2	0
Hackberry	1250.0	208.3	25.0
N. Red Oak	0	0	6.3
Sugar Maple	2500.0	6145.8	143.8
Wood Nettles	2500.0	0	0

Table 2. Stand table of mature tree importance value calculations

Species	Relative Density	Relative Frequency	Relative Coverage	Importance Values	Importance Percentages
Basswood	0.152	0.152	0.176	0.430	16.0
Hackberry	0.121	0.121	0.062	0.304	10.1
N. Red Oak	0.030	0.031	0.125	0.186	6.2
Sugar Maple	0.697	0.697	0.638	2.032	67.7

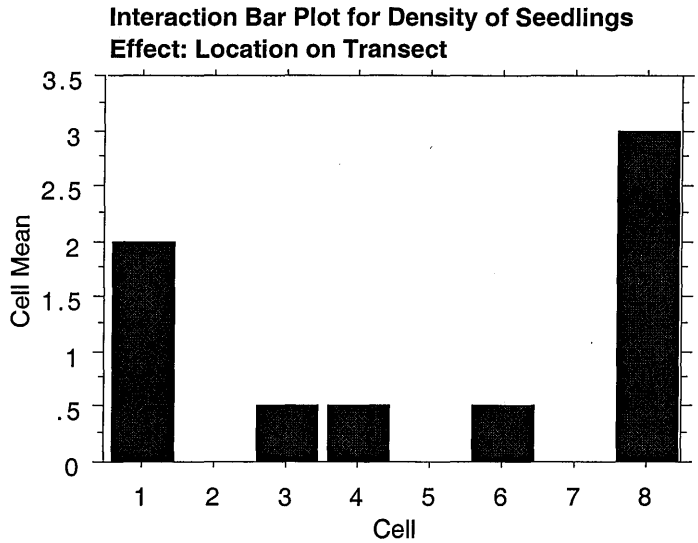

Figure 2. Mean density of all seedling species. Categories are 0 m, 5 m, 10 m, 15 m, 20 m, 30 m, 40m, and 50 m. ANOVA tests showed significant differences between 5 m and 50 m (p=0.038), 30 m and 50 m (p=0.038), and 40 m and 50 m (p=0.038).

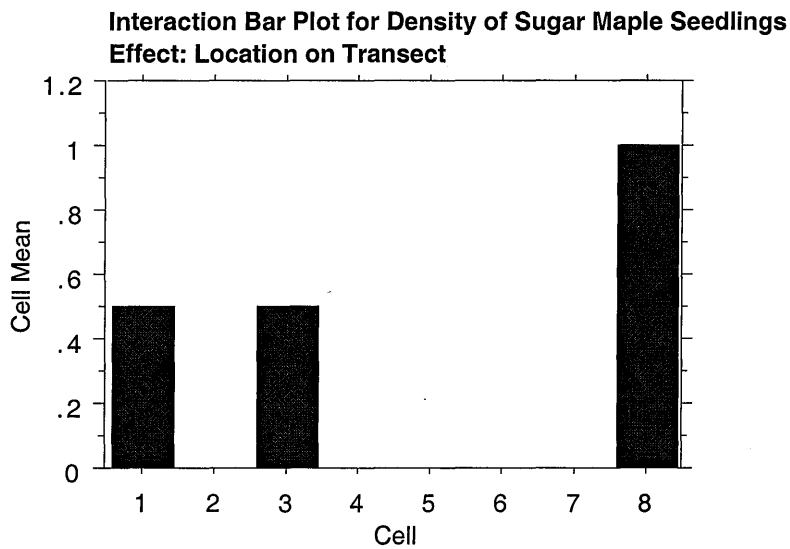

Figure 3. Mean density of sugar maple seedlings. Categories are same as Figure 2. ANOVA tests did not show a significant difference in the densities of sugar maples between the eight plots.

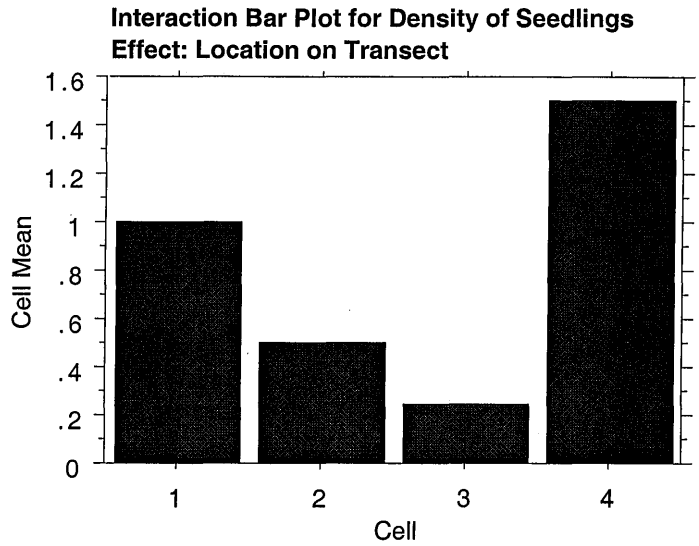

Figure 4. Mean density of all seedling species. Categories are 0-5 m, 10-15 m, 20-30 m, and 40-50 m. ANOVA tests showed no significant differences in seedling densities for the categories shown.

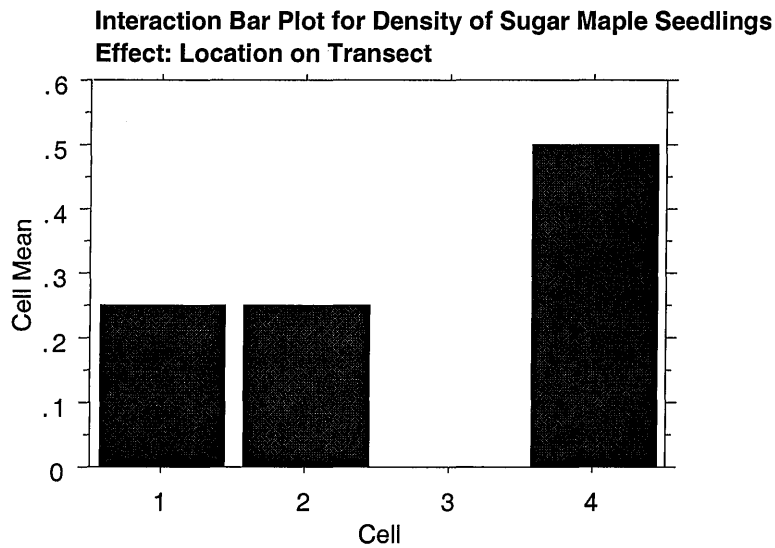

Figure 5. Mean density of sugar maple seedlings. Categories are 0-5 m, 10-15 m, 20-30 m, and 40-50 m. ANOVA tests showed no significant differences in sugar maple seedling densities for the categories shown.

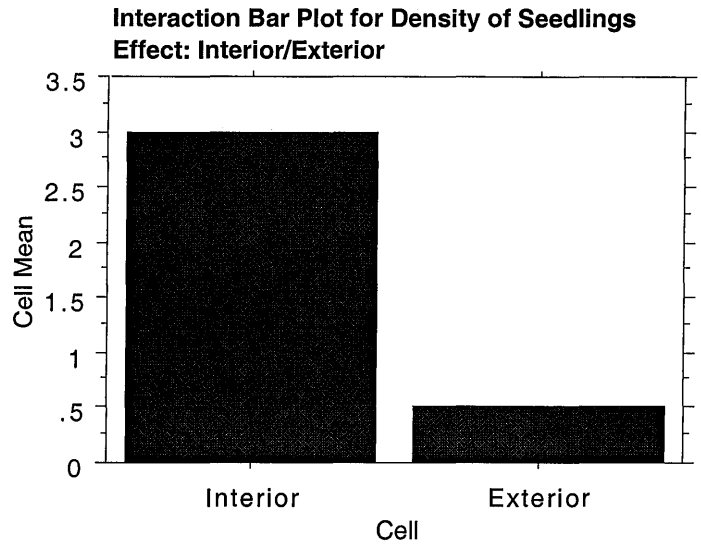

Figure 6. Mean density of all seedling species. Interior is 50+ m and exterior 0-40 m. ANOVA tests showed a significant difference in densities (p=0.0104).

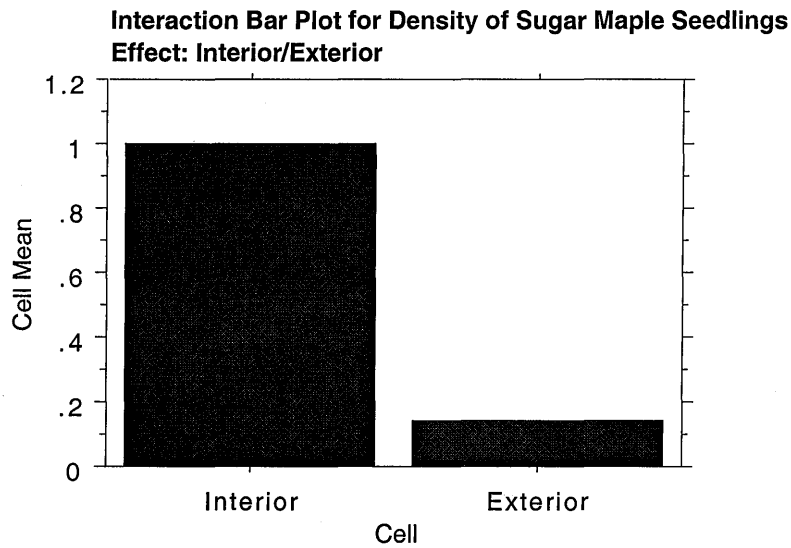

Figure 7. Mean density of sugar maple seedlings. Interior is 50+ m and exterior 0-40 m. ANOVA tests showed a significant difference in densities (p=0.0450).

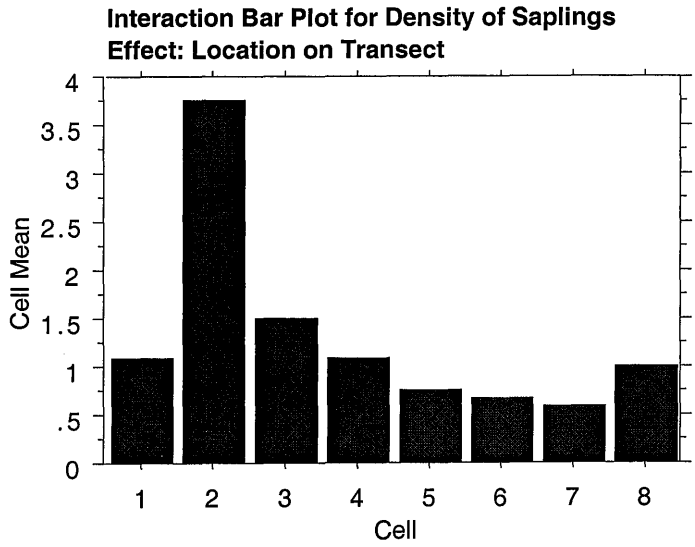

Figure 8. Mean density of all sapling species. Categories are 0 m, 5 m, 10 m, 15 m, 20 m, 30 m, 40m, and 50 m. ANOVA tests showed significant differences between 5 m and 20 m (p=0.0439), 5 m and 30 m (p=0.0395), and 5 m and 40 m (p=0.0358).

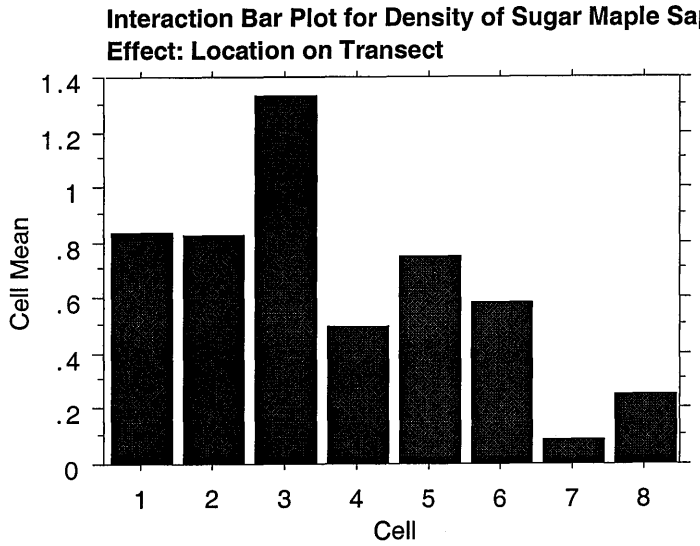

Figure 9. Mean density of sugar maple saplings. Categories are same as Figure 8. ANOVA tests showed a significant differences between 10 m and 40 m (p=0.0333).

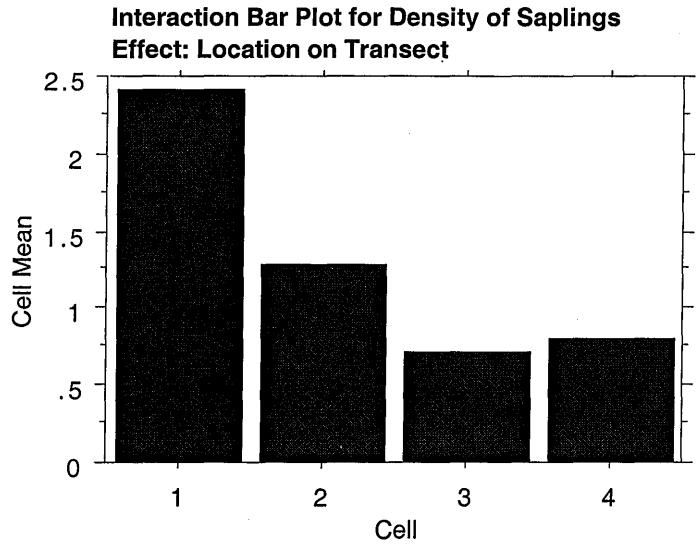

Figure 10. Mean density of all sapling species. Categories are 0-5 m, 10-15 m, 20-30 m, and 40-50 m. ANOVA tests showed no significant differences in sapling densities for the categories shown.

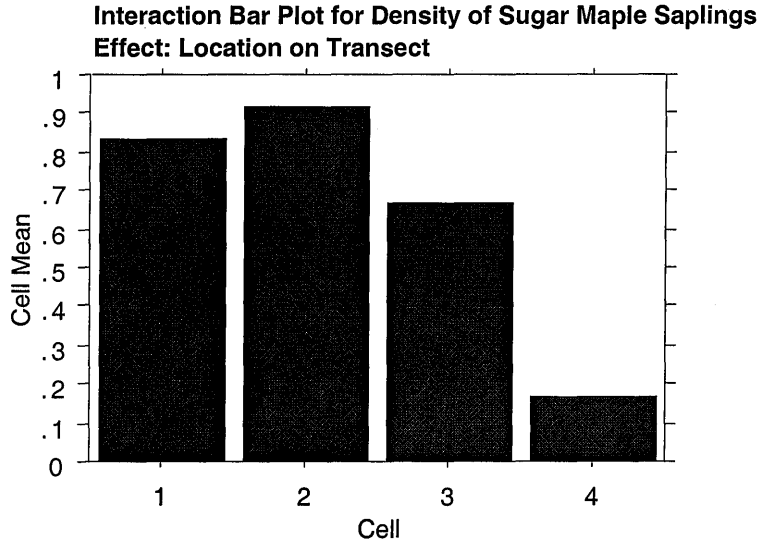

Figure 11. Mean density of sugar maple saplings. Categories are 0-5 m, 10-15 m, 20-30 m, and 40-50 m. ANOVA tests showed no significant differences in sugar maple sapling densities for the categories shown.

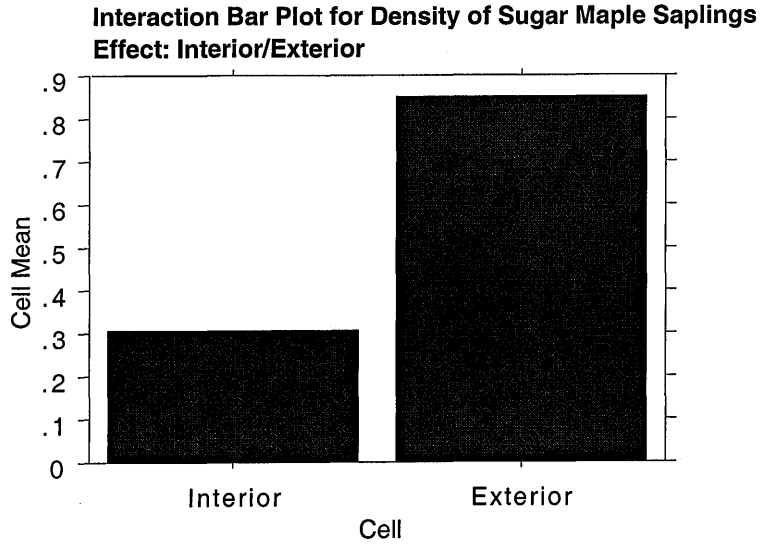

Figure 12. Mean density of sugar maple saplings. Interior is 30-50 m and exterior 0-20 m. ANOVA tests showed a significant difference in densities (p=0.0359).

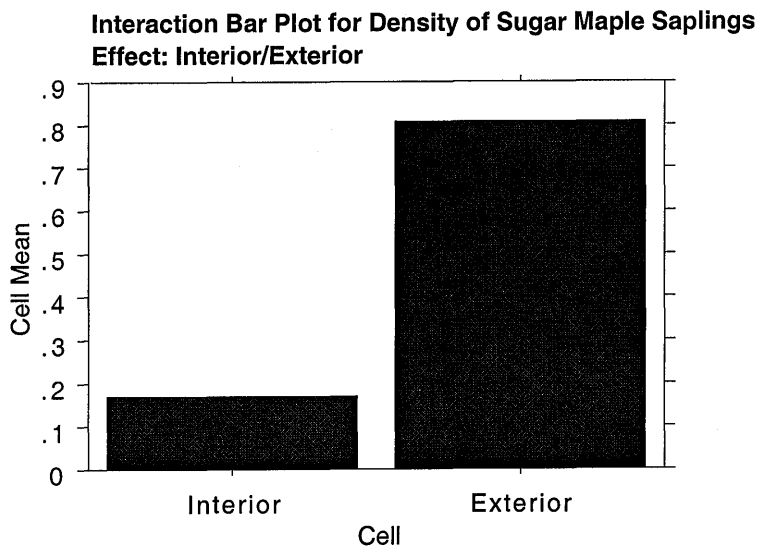

Figure 13. Mean density of sugar maple saplings. Interior is 40-50 m and exterior 0-30 m. ANOVA tests showed a significant difference in densities (p=0.0259).

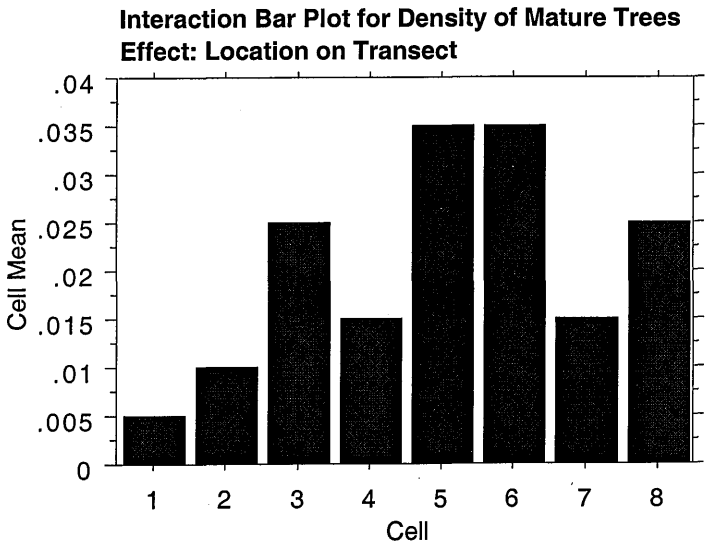

Figure 14. Mean density of all mature tree species. Categories are 0 m, 5 m, 10 m, 15 m, 20 m, 30 m, 40m, and 50 m. ANOVA tests showed no significant differences.

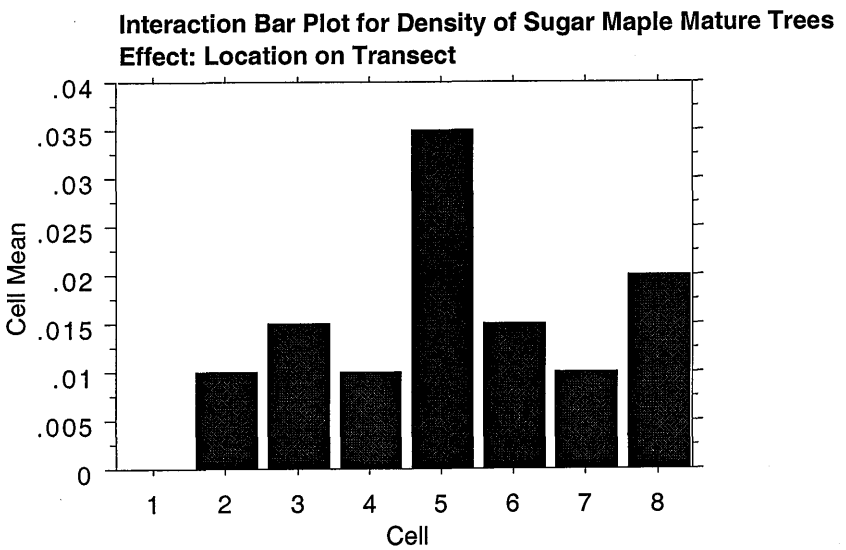

Figure 15. Mean density of sugar maple mature trees. Categories are same as Figure 14. ANOVA tests showed a significant difference between 0 m and 20 m ($p=0.0273$).

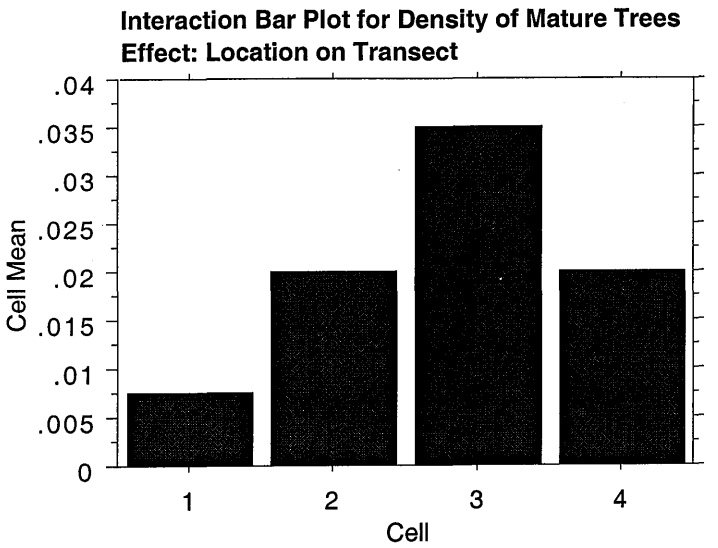

Figure 16. Mean density of all mature tree species. Categories are 0-5 m, 10-15 m, 20-30 m, and 40-50 m. ANOVA tests showed a significant difference between Groups 1 and 3 (p=0.0136).

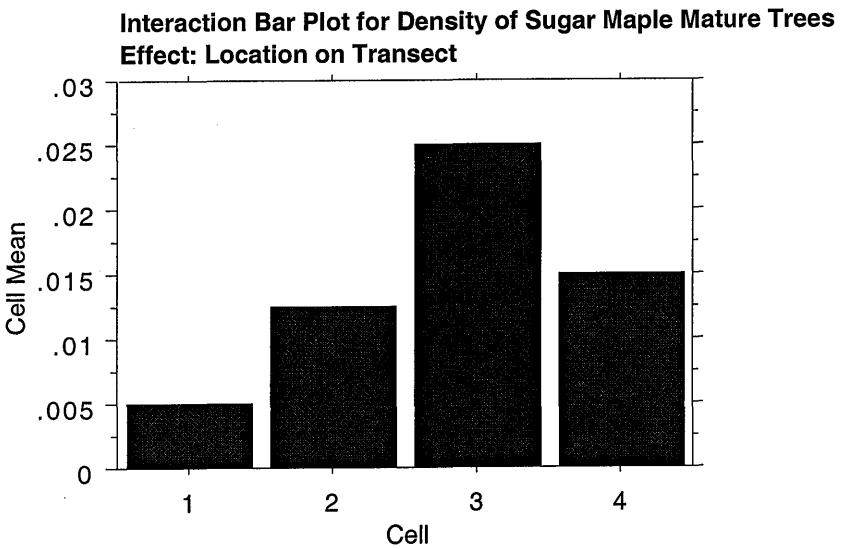

Figure 17. Mean density of sugar maple mature trees. Categories are 0-5 m, 10-15 m, 20-30 m, and 40-50 m. ANOVA tests showed a significant difference between Groups 1 and 3 (p=0.0477).

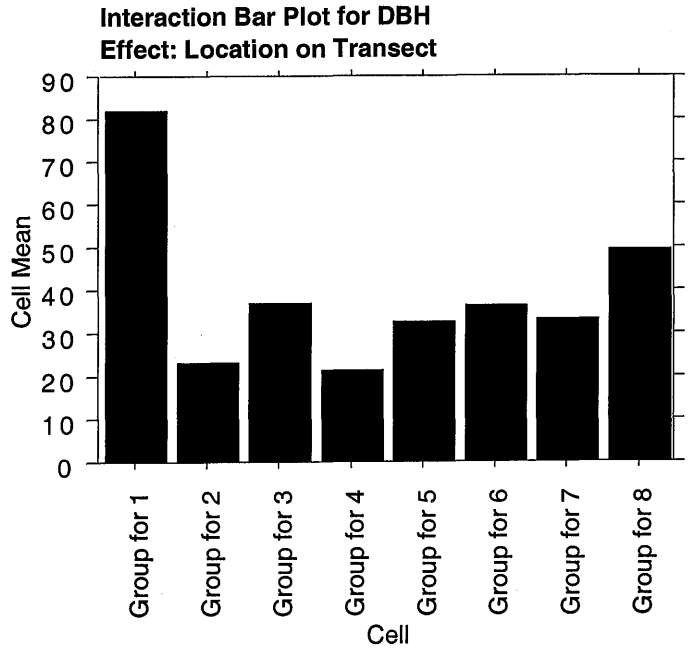

Figure 18. There is a significant difference in overall mean diameters of mature trees in the eight plots (P-value = 0.0443).

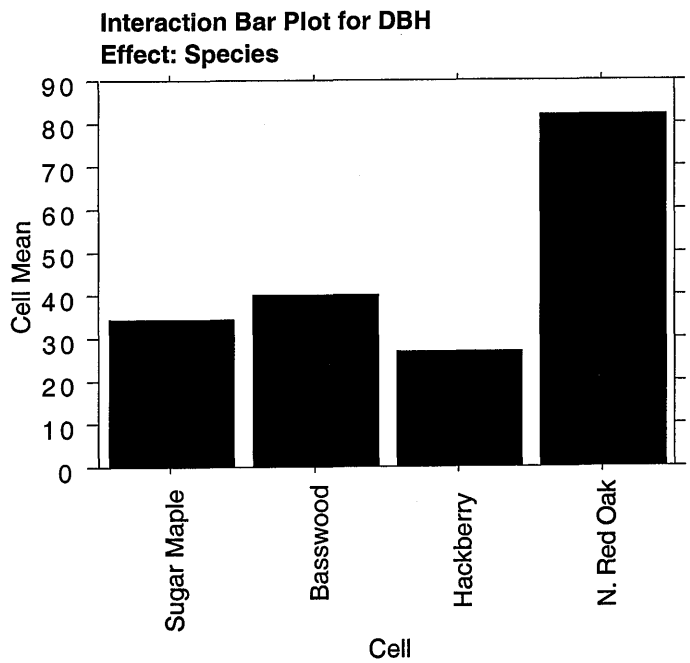

Figure 19. There is a significant difference in overall mean diameters of mature trees between species (P-value = 0.0289).

Appendix A

Common names	Species
Ash	*Fraxinus*
Basswood	*Tilia americana*
Black Cherry	*Prunus serotina*
Elderberry	*Sambucus canandensis*
Gooseberry	*Ribes oxyacanthoides*
Hackberry	*Celtis occidentalis*
Northern Red Oak	*Quercus rubra*
Sugar Maple	*Acer saccharum*
Wood Nettle	*Laportea canadensis*