**Tree Surveying in Mequon Nature Preserve**

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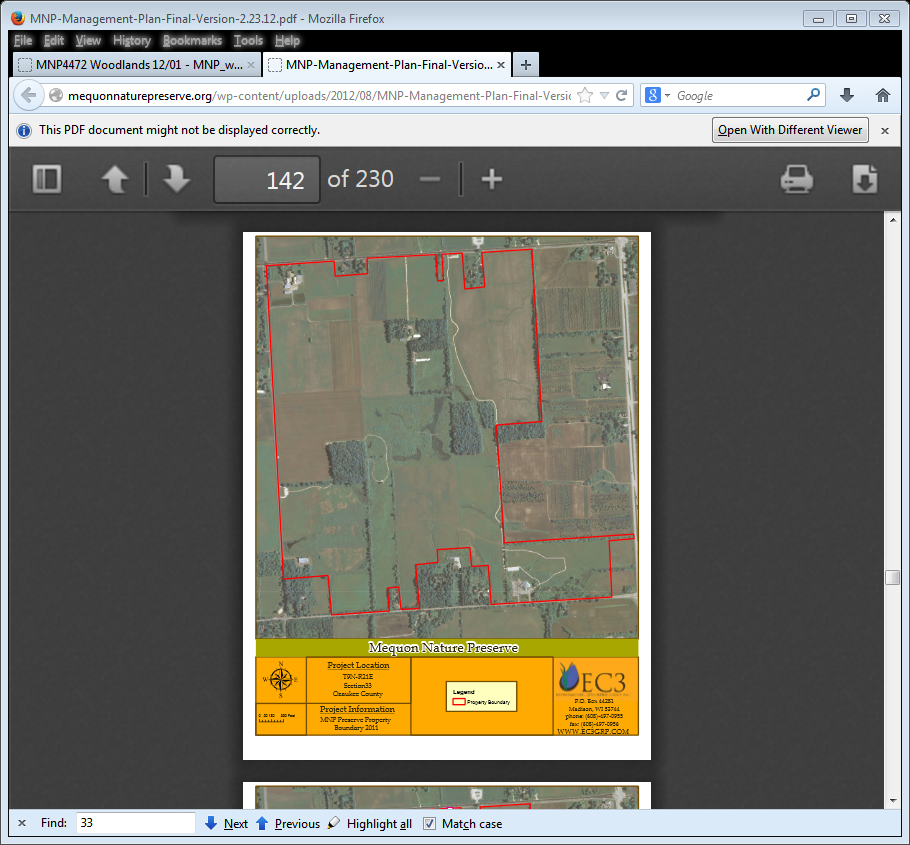
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**Introduction**

The Mequon Nature Preserve was founded in 2000 by the partnership between the City of Mequon, Ozaukee Washington Land Trust, and the Great Milwaukee Foundation (Mequon Nature Preserve 2010). In 1836, after being acquired by the government through a treaty with Native Americans, the land that is now the Mequon Nature Preserve was put up for sale (Mequon Nature Preserve 2010). In 1839, the first section of land was sold for $1.25 per acre. The land was then quickly divided between different farmers (EC3 Environmental Consulting Group, Inc. 2011). Some of the first landowners were Benjamin Betty, Robert Eastman, Patrick Pentony, and Philip Stauss (Mequon Nature Preserve 2010). Since then, the landowners of these farms have changed, but the land continued to be used for farming.

In February of 2003, the first 356 acres for the Mequon Nature Preserve were purchased from Stauss, Batzler, and Fox lots (Mequon Nature Preserve 2010). Then, in April of 2006, the properties of Bacher and the Spirit Life Church were purchased, increasing the size of the Preserve to 438 acres (EC3 Environmental Consulting Group, Inc. 2011). The ultimate expansion goal is to purchase all of section 33 within the city limits (Figure 1). Section 33 is the land bounded by Donges Bay Road on the north, Wauwatosa Road on the east, County Line Road on the south, and Swan Road on the west (Mequon Nature Preserve 2010). In this section of land, the Mequon Nature Preserve plans to restore the deciduous hardwood forests and wetlands to how they existed before European settlement and cultivation (Mequon Nature Preserve 2010).



**Figure 1:** Section 33 of the Mequon Nature Preserve in Ozaukee County, Wisconsin (Mequon Nature Preserve 2010).

The Mequon Nature Preserve currently consists of over 438 acres of woodlands, grasslands, ponds, and farmland, with over five miles of trails, an observation tower, and an education center (Mequon Nature Preserve 2010). Donations from the Paddock Fund at the Great Milwaukee Foundation, funding from the city of Mequon, and two Stewardship grants from the Wisconsin Department of Natural Resources allowed for the restoration of the area to be possible (EC3 Environmental Consulting Group, Inc. 2011). Through these donations and future grants, Mequon Nature Preserve hopes to achieve their goal and use this land as an educational and recreational resource (Mequon Nature Preserve 2010).

Among the most common native tree species at the Mequon Nature Preserve are green ash, aspen, and oak trees. Green ash (*Fraxinus pennsylvanica)* are native to the central and eastern regions of the United States. Green ash struggle amongst shade competition but are mildly drought tolerant plants (S.D. Department of Agriculture 2013). A major problem associated with ash trees is the emerald ash borer (*Agrilus planipennis).* Since being discovered in North America in 2002, this invasive species from Asia has killed millions of ash trees (Duan et al. 2013). Emerald ash borer larvae crawl through and eat the wood of ash trees, creating tunnels that weaken the tree. The larvae prevent the upper portion of the tree from receiving nutrients and water due the tunnels interfering with the xylem and phloem, which will eventually kill the tree (WDNR 2013). Aspen is the most harvested group of trees in Wisconsin due to its use as a paper crop. According to the Wisconsin Department of Natural Resources, aspen trees have a removal to growth rate of 117%, meaning more trees are harvested than planted (WDNR 2012). Aspen also generally have short life spans since they are susceptible to a host of diseases and pests (ODNR 2013). Oak is also native to the central region of the United States, but after European settlement and farming, many of these trees vanished. Oaks are mesic plants and are maintained through burning (Abrams 2003). If there is not enough controlled burning, then other plants or trees can take over.

The Mequon Nature Preserve’s mission is “to be a guiding example of restoration by returning an urban/suburban area to pre-settlement conditions and establishing an environmental education conservancy and natural habitat that inspires exploration and cultivates stewardship, encouraging visitors to get off the path” (Mequon Nature Preserve 2010). As previously mentioned, the reasoning behind this is that the area was a temperate forest before the city of Mequon was settled and used for farming. It has been estimated that humans have transformed nearly 40% of the earth's surface to agricultural areas (Wade et al. 2007). According to Wade, Gurr, and Wratten, farming practices can affect "air quality, biological diversity, climate, soil condition and the quality and quantity of water" (2007). By restoring unused portions of farmland to their natural state, not only will the immediate area be ecologically improved, but the overall sustainability of agriculture can be enhanced (Wade et al. 2007). This process of reforestation at the Mequon Nature Preserve is estimated to take a little over 100 years to complete (Mequon Nature Preserve 2010). With data collection on tree saplings, the Preserve will be able to see if their goal is on pace. If it is not, the study allows for an opportunity to see what else they can do to get back on track. The observations made within the restoration units will help the Mequon Nature Preserve to provide quantitative measurements for educational purposes and future grant applications.

**Methods**

Tree surveying took place in September through November of 2013 at the Mequon Nature Preserve in Ozaukee County, Wisconsin. In a modified protocol from Dobkin and Rich, transects were established in each of three designated restoration units (1998) (Figure 2). The number of transect lines recorded was based on the area of each unit, which was determined by measuring the side lengths of each unit with measuring tape. A transect line was determined by laying a measuring tape from the starting point on one border of a unit to the far border of the same unit. Transect lines within a unit were spaced equidistant from each other as well as the parallel borders of the unit. Surveyors worked in groups of three to five, with one surveyor walking down the center of the transect line and surveyors 1.5 m to the left and right of the centered surveyor. A distance of 1.5 m from the center line was maintained by holding a 3 m string between the far surveyors, with the middle surveyor holding the middle of the string just above the transect line. The number and species of each tree within 1.5 m of the centered surveyor were recorded. The “Woodlands” chapter of Mequon Nature Preserve’s *Field Guide* directed the identification of each tree species by using characteristics that included leaf shape, size of teeth, and branching patterns (Mequon Nature Preserve 2010). The number and identification of all trees along the transect lines were recorded in a surveyor’s notebook which were used to calculate the average species density and the Shannon-Wiener diversity index in each unit (Blue Valley Wilderness Science Center 2013).

The areas of the restoration units were calculated in order to survey transect lines proportional to the unit areas. In the calculations, width refers to the distance between the east and west borders of the unit, and length is the distance between the north and south borders. Units 2A and 2B are identical in area, each with widths of 220 m and lengths of 190 m. Since these units are rectangular, multiplying the width by length for the total area results in 41,800 m2 per unit. For these two areas, three transect lines were created, spanning the length (190 m) of each unit. The transect lines for these units were equidistant (55 m) from each other, as well as the north and south borders of the unit. The width of each transect line was 3 m, giving 1,710 m2 of area surveyed along these transect lines in each unit. Dividing the total area of one of these units by the area surveyed results in a factor of 24.4, which will be used to ensure proportionality of the area surveyed in Unit 2.

The total area of Unit 2 was calculated by dividing the unit into geometric shapes and measuring the lengths of each of the sides. The northernmost square (1) has a side length of 60 m, making its area 3,600 m2 (Figure 3). The large, center square (2) has a side length of 120 m, and its area is 14,400 m2. The triangular section is 120 m in both base and length, so its area is 7,200 m2. Therefore, the total area of Unit 2 is 25,200 m2. Dividing this total area by 24.4 (the proportionality factor from Unit 2A and Unit 2B) gives 1,032.8 m2 of area that needed to be surveyed in Unit 2. With the width of the transect lines at 3 m, the combined length of transect lines in Unit 2 should be 344.3 m. Two transect lines were surveyed in this unit, each with a length of 172.1 m and equidistant (40 m) from each other, as well as the east and west borders of the unit.



**Figure 2:** Restoration units for tree surveying. Surveying took place in September through November of 2013 at the Mequon Nature Preserve in Ozaukee County, Wisconsin. Areas surveyed include the Unit 2, Unit 2A, and Unit 2B, as outlined in the map above (Mequon Nature Preserve 2010).

1

2

3

**Figure 3**: Unit 2 of the Mequon Nature Preserve in Ozaukee County, WI drawn for area calculations.

**Results**

A total of 739 trees were identified in restoration units 2, 2A, and 2B at the Mequon Nature Preserve of Ozaukee County, Wisconsin in September through November of 2013 (Tables 1-3). Green ash was shown to have the largest abundance by quite an expansive margin in Unit 2A and Unit 2B (Tables 1-2). In Unit 2, green ash and quaking aspen showed approximately equal dominance (Table 3). The other tree species present had relatively low abundance throughout the various units and could not compete with the large amount of green ash. However, the numbers of trees throughout the restoration units were unevenly dispersed. Green ash showed dominance in all three units, with the most abundant amount in Unit 2A. Big-toothed aspen and quaking aspen were most abundant in Unit 2. The other tree species present showed low abundance in each of the units (Figure 4).

**Table 1**: The total number of trees identified in Restoration Unit 2A of the Mequon Nature Preserve Ozaukee County, Wisconsin in September through November of 2013.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tree Species** | **Transect 1** | **Transect 2** | **Transect3** | **Total in Unit** |
| Green Ash | 138 | 73 | 122 | 333 |
| Quaking Aspen | 5 | 0 | 8 | 13 |
| Red Oak | 0 | 1 | 3 | 4 |
| Swamp White Oak | 0 | 1 | 0 | 2 |
| Maple | 0 | 0 | 2 | 2 |
| **Total Trees** | **143** | **75** | **135** | **353** |

**Table 2**: The total number of trees identified in Restoration Unit 2B of the Mequon Nature Preserve Ozaukee County, Wisconsin in September through November of 2013.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tree Species** | **Transect 1** | **Transect 2** | **Transect 3** | **Total in Unit** |
| Green Ash | 82 | 75 | 49 | 206 |
| Quaking Aspen | 2 | 0 | 0 | 2 |
| Red Oak | 0 | 2 | 5 | 7 |
| White Oak | 1 | 0 | 0 | 1 |
| Swamp White Oak | 0 | 2 | 2 | 4 |
| Maple | 2 | 2 | 1 | 5 |
| **Total Trees** | **87** | **81** | **57** | **225** |

**Table 3**: The total numbers of trees identified in Restoration Unit 2 of the Mequon Nature Preserve of Ozaukee County, Wisconsin in September through November of 2013.

|  |  |  |  |
| --- | --- | --- | --- |
| **Tree Species** | **Transect 1** | **Transect 2** | **Total in Unit** |
| Green Ash | 45 | 26 | 71 |
| Big-Toothed Aspen | 0 | 15 | 15 |
| Quaking Aspen | 66 | 6 | 72 |
| Swamp White Oak | 1 | 0 | 1 |
| Willow | 0 | 1 | 1 |
| Shagbark Hickory | 0 | 1 | 1 |
| **Total Trees** | **112** | **49** | **161** |

**Figure 4**: The various numbers of tree species between units 2, 2A, and 2B in the Mequon Nature Preserve of Ozaukee County, Wisconsin in September through November of 2013.

The density of each species per unit was calculated by taking the total number of individuals of a single species surveyed in a unit and dividing it by the area surveyed along the transects within that unit. From the transect densities, the average density of the species in each restoration unit was determined (Table 4-6). The average densities of the species were then used to find the total number of trees in each unit by multiplying the average density of the species by the total area of the unit. The number of trees per unit and the average density of the restoration unit are evidence of the low diversity of the unit. The highest average density recorded was the green ash in unit 2A with an average density of 0.1947+/- 0.0343 (Table 4). The values determined from the different species in each restoration unit were fairly low (Table 4-6). These values show the need for diversity in each of the restoration units.

**Table 4:** The densities and average densities of the species on the transects in Restoration Unit 2A of the Mequon Nature Preserve Ozaukee County, Wisconsin in September through November of 2013. These values were used to calculate the total number of trees in the restoration unit.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Tree Species in Unit 2A** | **Transect 1**  **Density**  **(Trees/m2)** | **Transect 2 Density**  **(Trees/m2)** | **Transect3**  **Density**  **(Trees/m2)** | **Average Density of Transect Lines**  **(Trees/m2) SE** | **Number of Trees in Unit** |
| Green Ash | 0.2421 | 0.1281 | 0.2140 | 0.1947 +/- 0.0343 | 8138.46 |
| Quaking Aspen | 0.0088 | 0 | 0.0140 | 0.0076 +/- 0.0041 | 317.68 |
| Red Oak | 0 | 0.0018 | 0.0053 | 0.0024 +/- 0.0016 | 100.32 |
| Swamp White Oak | 0 | 0.0018 | 0 | 0.0006 +/- 0.0006 | 25.08 |
| Maple | 0 | 0 | 0.0035 | 0.0012 +/- 0.0012 | 50.16 |
| **Total** | **0.2509** | **0.1317** | **0.2369** | **0.2065 +/- 0.0376** | **8631.70** |

**Table 5**: The densities and average densities of the species on the transects in Restoration Unit 2B of the Mequon Nature Preserve Ozaukee County, Wisconsin in September through November of 2013. These values were used to calculate the total number of trees in the restoration unit.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Tree Species in Unit 2B** | **Transect 1**  **Density**  **(Trees/m2)** | **Transect 2 Density**  **(Trees/m2)** | **Transect3**  **Density**  **(Trees/m2)** | **Average Density of Transect Lines**  **(Trees/m2) SE** | **Number of Trees in Unit** |
| Green Ash | 0.1439 | 0.1316 | 0.0860 | 0.1205 +/- 0.0176 | 5036.90 |
| Quaking Aspen | 0.0035 | 0 | 0 | 0.0012 +/- 0.0012 | 50.16 |
| Red Oak | 0 | 0.0035 | 0.0088 | 0.0041 +/-0.0026 | 171.38 |
| Swamp White Oak | 0 | 0.0035 | 0.0035 | 0.0023 +/-0.0012 | 96.14 |
| Maple | 0.0035 | 0.0035 | 0.0018 | 0.0029 +/-0.0006 | 121.22 |
| White Oak | 0.0018 | 0 | 0 | 0.0006 +/-0.0006 | 25.08 |
| **Total** | **0.1525** | **0.1421** | **0.1001** | **0.1316 +/-0.0160** | **5500.88** |

**Table 6**: The densities and average densities of the species on the transects in Restoration Unit 2 of the Mequon Nature Preserve Ozaukee County, Wisconsin in September through November of 2013. These values were used to calculate the total number of trees in the restoration unit.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tree Species in Unit 2** | **Transect 1**  **Density**  **(Trees/m2)** | **Transect 2 Density**  **(Trees/m2)** | **Average Density of Transect Lines**  **(Trees/m2) SE** | **Number of Trees in Unit** |
| Green Ash | 0.0872 | 0.0504 | 0.0688 +/- 0.0184 | 1733.76 |
| Big-Toothed Aspen | 0 | 0.0291 | 0.0146 +/- 0.0146 | 367.92 |
| Quaking Aspen | 0.1278 | 0.0116 | 0.0697 +/- 0.0581 | 1756.44 |
| Swamp White Oak | 0.0019 | 0 | 0.0010 +/-0.0009 | 25.20 |
| Willow | 0 | 0.0019 | 0.0010 +/-0.0009 | 25.20 |
| Shagbark Hickory | 0 | 0.0019 | 0.0010 +/-0.0009 | 25.20 |
| **Total** | **0.2169** | **0.0949** | **0.1559 +/- 0.0610** | **3933.72** |

The Shannon-Wiener diversity index of each restoration unit can be seen in Tables 6-8. This index is calculated by multiplying the negative value of the sum of the proportion of the ith species by the natural logarithm of the proportion of the ith species (Molles 2010). The largest diversity index value was in Unit 2 with a value of 1.035 (Table 8). Unit 2A shows the lowest species diversity of the units surveyed with an index of 0.275 (Table 6). The relatively low values of the Shannon-Wiener diversity index can provide information on the health of the various units.

**Table 6:** The Shannon-Wiener diversity index of Unit 2A of the Mequon Nature

Preserve in September through November of 2013 was 0.275.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Species** | **Number** | **Proportion (Pi)** | **Ln(Pi)** | **Pi ln(Pi)** |
| **Green Ash** | 333 | 0.943 | -0.059 | -0.055 |
| **Quaking Aspen** | 13 | 0.037 | -3.297 | -0.112 |
| **Red Oak** | 4 | 0.011 | -4.510 | -0.050 |
| **Swamp White Oak** | 1 | 0.003 | -5.809 | -0.017 |
| **Maple** | 2 | 0.006 | -5.116 | -0.031 |
| **Total** | 353 | 1.000 | -18.791 | **-0.275** |

**Table 7:** The Shannon-Wiener diversity index of Unit 2B of the Mequon Nature Preserve in September through November of 2013 was 0.408.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Species** | **Number** | **Proportion (Pi)** | **Ln(Pi)** | **Pi ln(Pi)** |
| **Green Ash** | 206 | 0.916 | -0.088 | -0.080 |
| **Quaking Aspen** | 2 | 0.009 | -4.710 | -0.042 |
| **Red Oak** | 7 | 0.031 | -3.474 | -0.108 |
| **White Oak** | 1 | 0.004 | -5.521 | -0.022 |
| **Swamp White Oak** | 4 | 0.018 | -4.017 | -0.072 |
| **Maple** | 5 | 0.022 | -3.817 | -0.084 |
| **Total** | 225 | 1.000 | -21.627 | **-0.408** |

**Table 8:** The Shannon-Wiener diversity index of Unit 2 of the Mequon Nature Preserve in September through November of 2013 is 1.035.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Species** | **Number** | **Proportion (Pi)** | **Ln(Pi)** | **Pi ln(Pi)** |
| **Green Ash** | 71 | 0.441 | -0.819 | -0.361 |
| **Big-Toothed Aspen** | 15 | 0.093 | -2.375 | -0.221 |
| **Quaking Aspen** | 72 | 0.447 | -0.805 | -0.360 |
| **Swamp White Oak** | 1 | 0.006 | -5.116 | -0.031 |
| **Willow** | 1 | 0.006 | -5.116 | -0.031 |
| **Shagbark History** | 1 | 0.006 | -5.116 | -0.031 |
| **Total** | 161 | 1.000 | -19.347 | **-1.035** |

**Discussion**

The objective of the research was to count and identify tree saplings in three restoration units at the Mequon Nature Preserve in order to evaluate the progress of the ongoing forest restoration. The collected data will be used as a starting point for future research to investigate if and how quickly the goal of restoration will be accomplished.

Diversity is essential for an ecosystem's survival in the presence or introduction of environmental disturbances, and it encompasses the total number of species in an ecosystem and their relative abundance. Low diversity indicates that an ecosystem is relatively unhealthy and incapable of supporting multiple species. The Shannon-Wiener diversity index (H’) considers the species richness as well as the species equitability or diversity (Gregory 2013). The minimum value of H’ is 0, which indicates a community of a single species. Larger H’ values show a greater species richness and evenness (Molles 2010). According to Cooper, a Shannon-Wiener diversity index around 4.6 indicates healthy species diversity within an ecosystem (2013).  With green ash as the most frequently observed tree species in the units overall (especially in 2A and 2B), the calculated Shannon-Weiner diversity indices reveal low species diversity within all three units (Table 6-8).  Of the three units, Unit 2 exhibits the greatest species diversity, as indicated by its index number of 1.035 (Table 8). The calculations for the average densities in the different restoration units further provide evidence of the low species diversity (Table 4-6).

There are many possible explanations for the low diversity observed. Soil nutrient composition, such as nitrogen and phosphorus, affects the growth and maintenance of trees. In the nitrogen cycle, nitrogen is available to trees and other plants in the soil as nitrate and ammonium, as it is necessary for tree growth (Kay 2013). Phosphorus is present in the phospholipid bilayers of plants and animals, in the energy transfer molecule ATP, and in nucleic acids (Molles 2010). To increase their phosphorus uptake, plants have developed special strategies, such as fostering symbiotic relationships with mycorrhizae that release inorganic phosphorus from organic matter to allow for the uptake of phosphorus into plants' roots. In return, the plants provide carbohydrates as food for the mycorrhizae. (Filippelli 2002). The agricultural history of the Preserve likely plays a role in the recorded low diversity because the balance of the nutrient content of the soil with the moisture content in abandoned farmland can affect the diversity of plants in an area that is being restored (Robertson et al. 1988). The specific nutrient and soil composition in these areas may be ideal for green ash trees, which were the most prevalent types of trees surveyed.

Methods of seed dispersal could also contribute to the diversity within the units. Green ash trees utilize wind for seed dispersal, allowing the seeds to easily end up in the surveyed prairie areas from the surrounding forests (Kennedy 2013). The second highest average density found in all the units was quaking aspen, which also uses wind for seed dispersal (McDonough 1979). The low number of oak trees observed could be the consequence of a lack of seed dispersal. Oaks produce large acorns and are reliant on animal transportation and storage in the ground (Steele et al. 2001). Since no large trees were in the areas surveyed, animals may not feel safe storing their seeds in an open prairie where they could be easily spotted and captured by predators. Furthermore, red oaks go through a period of dormancy before sprouting. If the red oak acorns were recently planted, they may simply still be in their dormant phase, thus causing their currently low relative density (Steele et al. 2001).

While sampling, the distribution of trees appeared clumped. The random dispersal of seeds by groups of grade school students on field trips to the Mequon Nature Preserve could be the reason for this pattern of distribution, but it could be affected by competition, as well. In a survivorship curve, type III populations may follow patterns of either clumped or random dispersion. With trees being classified as type III populations, seeds are often clumped together in an area. However, with a high mortality rate among young type III individuals, the dispersion could also appear in a randomized pattern (Abedon 2005). It is also important to note that trails intersected the areas surveyed, affecting the overall abundance of trees along the transect lines.

Competition with other plants is also a likely reason for the low diversity in these areas. The restoration units surveyed consisted of dense vegetation that included prairie flowers and grasses. This is significant because prairie grasses have vast and well-developed root systems, which is likely contributing to nutrient and root competition with the young trees (Wilson 1993). Green ash trees are considered to be drought-tolerant trees with developed roots, so this characteristic could possibly allow them to survive in an environment with this type of competition (S. D. Department of Agriculture 2013). The most abundant species recorded (green ash, bigtooth aspen, and quaking aspen) are all considered drought-tolerant, mesic species, as well (Tobiessen and Kana 1974).

Recommendations to improve the species diversity and restore the forest system at the Mequon Nature Preserve are to plant more trees and employ controlled burning in more of the plots. Fires promote the growth of mesic species by decreasing overstory density as well as nonmesic, shade-tolerant species (Parker and Dey 2008). Overall, more data needs to be collected and analyzed to determine how much additional work needs to be done in restoring these units, as this research just skimmed the surface of this continuous project at the Mequon Nature Preserve. No recent tree records of this area are available for comparison since this research is the first tree surveying completed in these areas. With more tree inventories, one option would be for the Preserve to work with the Milwaukee Public Works Forestry Section to move towards establishing a suitable budget for urban forests and recruiting community members to help with its maintenance (Bell and Wheeler 2006). The restoration of the Mequon Nature Preserve is quite a young project, and not enough time has passed for it to fully begin its rehabilitation and exhibit extensive growth. Careful monitoring of the Mequon Nature Preserve will serve to encourage tree species diversity by helping prevent the occurrence and spread of invasive species and allow for an understanding of how the areas of restoration are developing.

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