MATERIALS AND METHODS

QUALITATIVE ASSESSMENT

Historical Data

A composite list of vascular plant species was compiled from many available sources of information. The natural features inventory conducted by the Kalamazoo Nature Center (KNC) (Adams et al. 2002) formed the foundation of the list. In addition, three WMU student papers (Benson et al. 1978, Scott 1976, Hohn 1992) were referenced and a complete search of the Kalamazoo County collections in WMU's Hanes Herbarium and a partial search of Michigan State University's Kellogg Biological Station Herbarium were made. Herbarium specimens not annotated by the Michigan Flora Project were checked by the T. Bassett. Reports of aquatic plants were also taken from a historical (Engeman 1976) and recent (Keiser and Associates 2008) water quality study of both Asylum Lake and Little Asylum Lake.

Floristic Surveys

Meander surveys were conducted in each of the survey areas throughout the year. Each survey area was completely covered at last once in each season with more frequent visits to high quality habitat. A list of collections at WMU was compared to the compiled species list for the Preserve, and those species not collected were sought out. Unknown plants and plants without voucher specimens were collected and pressed and will be deposited in WMU's Hanes Herbarium. Management areas as delineated by the Council were utilized as survey areas to facilitate data collection in discrete units. The oldfield in Forest I, and wetlands along the north and south shore of Asylum Lake (Coastal) were used as additional survey areas (Map 2).

GPS Mapping of Uncommon Plant Species and High Quality Natural Community Patches

Locations of locally uncommon plant species were mapped as points with a Trimble GeoXT GPS unit provided by WMU's Landscape Services to facilitate relocation and to aid in determining boundaries of high quality natural community patches. Special attention was placed on mapping locations of conservative plants with a savanna affinity. High quality natural community patches were mapped as polygons based on low densities of invasive species, presence of community indicator species, and presence of structural characteristics (e.g., open-grown overstory oaks in savanna patches, groundwater seepage and sedge-dominance in wet meadow). All GPS data is stored at Landscape Services.

Wolf Trees

In the upper Midwest, the term "wolf tree" is generally reserved for large open-grown oak trees indicative of a sparse to absent overstory canopy. When found in a landscape once dominated by oak savanna, they can provide clues to the historical distribution of oaks and help illuminate the structure of historical savannas and the relative dominance of herbaceous and woody plant species. Wolf trees were defined for this study as oak (*Quercus* spp.) or hickory (*Carya* spp.) with significant branching within ten meters of the ground, a circumference of at least 200 centimeters (DBH > 64 cm), and more or less upright growth pattern (i.e., not leaning toward the light of a trail or wetland). Each wolf tree was further classified as "true" or "false", with the "false" wolf trees exhibiting the general stature of

being open-grown, but not meeting the above requirements. Data on the "false" trees was collected due to the uncertainty in classifying wolf trees.

Floristic Quality Assessment

The floristic quality of each survey area of the Preserve was analyzed with the Floristic Quality Assessment (FQA) developed by the Natural Heritage Program of the MDNR (Herman et al. 2001). Given a list of plant species, it allows the user to calculate the mean coefficient of conservatism (C) and the floristic quality index (FQI) for the flora of the site. The coefficient of conservatism, a number between 0 and 10, "is applied to a plant based upon its fidelity to a pre-settlement landscape, not its rarity or legal status" (Herman et al. 2001), where a 10 indicates a plant found only in undisturbed habitats (e.g., old growth), and a 0 indicates a plant that could be found even in the most disturbed sites (e.g., recently tilled ground).

The FQI is calculated by multiplying the mean C by the square root of the total number of species in question ($FQI=C \times \sqrt{N}$) (Herman et al. 2001). An area with an FQI above 35 is considered floristically important, and most likely ecologically important in the state. An FQI higher than 50 is highly conservative and its preservation is of utmost priority. These communities represent a blueprint of what we only partially understand and cannot recreate, and therefore have the highest conservation value. The accuracy of the FQI requires that a conscientious effort was made to compile a complete list of plant species for an area under study. Also, the FQI is an area-dependent index, such that larger areas tend to support more species, increasing the probability of a higher FQI.

Avian Surveys

Twenty-two surveys were conducted in the morning hours (7- 11 am) between 6 April 2008 and 9 April 2009 to record the bird species present at Asylum Lake Preserve. Two additional visits were made to the prairie in the evening on 31 July 2008 and 6 April 2009 to survey for evening songbirds and two visits were made by Bruce Robertson and Liz Loomis of Kellogg Biological Station for their Great Lakes Bioenergy Research Center study. Surveys were generally conducted once per week during spring migration and about once per 7-10 days during fall migration. Three surveys were conducted during the breeding season to verify breeding pairs and two during the winter to survey for winter residents.

A pre-determined survey route utilized during the KNC study (Adams et al. 2002) was walked over a period of 2-2 ½ hours (Map 3). During each of the surveys an effort was made to tally every bird seen or heard from the route and the habitat compartment in which they were found.

Historical records of bird observations from 1976-2000 were compiled by Adams et al. (2002). Data from the current study were added to this list (Appendix 2).

Photo-monitoring

Thirteen photo-monitoring points were chosen throughout the course of the surveys. They were selected to give a representative sample of all habitats on the property, while keeping the total number of points to a manageable level. With the exception of one point along the northeast shore of Asylum Lake, each point was selected at an existing grid intersection, as permanent markers will eventually be placed at each point (Map 3). Sample sets of photographs were taken at some, but not

all, points during the surveys. Point selection occurred throughout the survey period as familiarity with the Preserve increased, so a full set was not taken.

LONG-TERM VEGETATION MONITORING

The Grid (Plot Selection)

Permanent plots and transects were established in all seven terrestrial survey areas of the property: Forest I and II, Prairie and Savanna I and II, Wet Meadow, and Marsh. A 100 X 100 m grid, anchored on the southwest corner of the property (Map 3), was originated in ArcMap by WMU's Landscape Services staff. The gridpoints, or the points where the lines of the grid intersect, were used as points of origin for randomly selecting plots and transects that fall within designated survey areas. PB8NWH, then, is in the NW quadrant of that point, and the long axis (50m) is horizontal. Emphasis was placed on plots and transects that cross ecotonal boundaries between survey areas. Data was collected primarily to provide baseline data for future monitoring, and also to supply useful data on species composition and community structure.

Forest I & II: Modified-Whittaker Plots

The primary goals in setting up monitoring plots in the Forest I and II units were to assess and track forest structure, monitor oak species (*Quercus* spp.) regeneration, and to monitor effect of management on invasive shrubs.

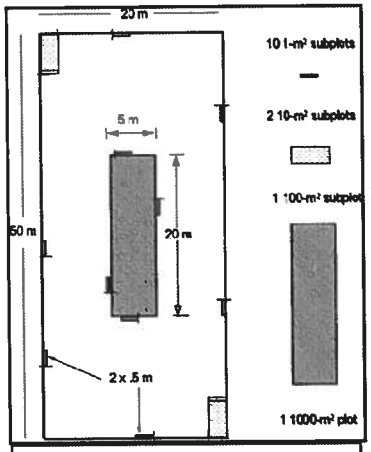

Figure 1. Modified-Whittaker plot

Grid points were randomly generated in ArcMap for the starting corner of 50 by 20 meter Modified-Whittaker nested plots (Stohlgren 1995). Plots were named by the grid for which their starting point is the northwest corner, then the direction to move from the starting point (NE, NW, SE, or SW), and then the orientation of the 50 meter axis of the plot (vertical or horizontal). For example, PD7SWV begins in the northwest corner of grid D7, then is placed to the southwest of that point (which places it within grid D6), and the 50 meter axis is oriented vertically (Map 3). Plot selection was stratified for sufficient separation of plots within each management unit, favored ecotonal transitions between units, and avoided monocultures of horticultural groundcover species such as periwinkle and lily-of-the-valley. Nine modified-Whittaker plots were surveyed in Forest I and II between 13 and 27 May 2008. Nested sub-plots of 1 m^2 (n=10), 10 m^2 (n=2), and 100 m^2 (n=1) were set up within the 1000 m^2 (=0.1ha) plot. DBH of all woody species above 9.9 cm DBH was recorded in the 1000 m^2 plot; number of stems of all woody species 2.5-9.9 cm was recorded in 100 m^2 sub-plots; number of stems of all woody species 1.1-2.4 cm DBH was recorded in 10 m^2 sub-plots; species and percent cover of all woody species less than 1.1 cm DBH and all herbaceous species was recorded in 1 m^2 sub-plots. Snags (dead woody stems) were included in the woody stem counts. Species percent cover was recorded using the following cover classes: 0-1, 1.1-5, 5.1-25, 25.1-50, 50.1-75, 75.1-95, and 95.1-100%. To facilitate assessment of invasive species management, species and percent cover of all invasive species (Table 2) was also recorded in both 10 m^2 and 100 m^2 sub-plots. Soil texture of the A-horizon was also recorded in the corner of each 1000 m^2 and 100 m^2 plot.

Data analysis

Relative Importance Values (RIVs, relative density + relative frequency + relative dominance) were calculated for tree species > 10 cm DBH (McIntosh 1957). These were then sorted into ecological functional groups (oak/hickory species, native maple species, other native species, and adventive species). Number of stems per hectare was calculated for woody plants within each of the three size classes. Canopy trees were analyzed separately from understory trees and shrubs.

Prairie, Savanna I & II: Prairie Transects

The primary goals in setting up transects in the Prairie and Savanna I and II units were to compare native and adventive species, track fire effects, and determine abundance of planted species.

Grid points and associated cardinal direction for 50 meter transects were randomly generated in ArcMap to allow for sufficient separation of transects within each management unit. This resulted in ten transects in Prairie and five for both Savanna I and II (Map 3). Transects were named by the grid for which their starting point is the northwest corner, followed by the cardinal direction of their orientation. For example, TD2S begins in the northwest corner of grid D2 and proceeds south for 50 meters. Sampling occurred between 30 July and 5 August 2008 in Prairie, on 6 August 2008 for Savanna I, and on 7 August 2008 and 3 September 2008 for Savanna II. The later sampling date for Savanna II is assumed to reflect the same general growth period as the others. Species and percent cover (see above cover classes) were recorded in 1.0 X 0.5 m quadrats spaced 5 m apart along transects. Soil was characterized at the bottom left corner of every first, sixth, and tenth quadrat.

Prairie Units

Data collected in Prairie, and Savanna I and II were also analyzed separately with the Floristic Quality Assessment software (Wilhelm and Masters 1999) by seven sub-management units. Prairie was divided into five units as defined by existing burn lanes, and Savanna I and II comprised two additional units (Map 4). Dominants were identified in each unit as species reporting a RIV (relative frequency + relative cover/2) greater than one standard deviation above the mean; common species were identified as species with RIVs above the mean but less than one standard deviation. Percent cover was aggregated into the following physiographic categories: annual and perennial forbs, ferns, perennial grasses and sedges, trees, shrubs and woody vines to identify dominant physiognomies within each unit. Data from Savanna II, an oldfield rather than a planted prairie, was omitted for comparisons but will be useful baseline data after it is restored.

Wet Meadow and Marsh: Wetland Transects

The primary goals in setting up transects in the Wet Meadow and Marsh units were to describe physiographic structure, assess shrub dominance, and describe physiographic dominance.

Transects were established as above. This resulted in two transects each in Wet Meadow and Marsh (Map 3). Sampling occurred on 3 September 2008 for Wet Meadow and 5 and 8 September 2008 for Marsh. Species and percent cover were recorded as above. Soil was characterized and soil pH was recorded with a pH meter at the bottom left corner of every first, sixth, and tenth quadrat.

Data Analysis

Percent cover was aggregated into the following physiographic categories: annual and perennial forbs, ferns, perennial grasses and sedges, trees, shrubs and woody vines with the Floristic Quality Assessment software (Wilhelm and Masters 1999).

Wetland Comparison
Data collected in Wet Meadow and Marsh were analyzed separately with the Floristic Quality Assessment software (Wilhelm and Masters 1999) as described above under "Prairie Units". Dominant species and physiognomies were identified.

Pooled Data
Data from the smallest plots were analyzed by plot and pooled for comparison across habitat. Statistical analysis was performed using Microsoft Excel 2007, with the statistiXL extension (statistixl.com), and SPSS 10.0. The simplest measure of diversity is simply the number of species detected during the study. This number, however, does not indicate how evenly the numbers of individual plants are distributed among those species.

The Shannon diversity index is the most widely used in biological research (Krebs 1989). It indicates both species richness and evenness of distribution of those species. The Shannon index is calculated by:

$$H' = \sum_{i=1}^{S} \text{abs}((p_i)(\ln p_i)),\ i = 1,2,\ldots,S$$

where S = number of species detected, and p_i is the proportion of all individuals belonging to the *i*th species (Nur et al. 1999). The maximum possible value of the Shannon index, H_{max}, if all species were equally abundant, would be ln(S). Dividing H' by this number gives a measure of the evenness of abundance of the species found, Evenness Index or E.

Cluster Analysis
Cluster analysis was performed on the plots to detect the similarity between plots and survey areas. Plant species presence (using Jaccard distance) and abundance (using the city block metric) were the clustering variables. Nearest neighbor grouping was used in each case. Presence /absence is a binary variable, and Jaccard distance (dissimilarity) between two plots a and b is defined as:

J(a,b) = ((species in a only) + (species in b only)) / ((species in a only) + (species in b only) + (species in a and b))

Abundance is a quantitative variable, and the city block metric (also known as Manhattan distance or taxicab distance) is the sum of the absolute values of the differences in abundances (for those two plots) across all species.

The combined species list from all small plots was sorted into physiognomic groups, separately by native and adventive species, and combined. The percentage of each physiognomic group's contribution to the all native or adventive species, and the whole list, was compared to analogous

percentages for the entire State of Michigan. This gives the ratio P_{ALP}/P_{MI} where P_{ALP} = proportion of contribution to the Preserve flora of a given physiognomic category and P_{MI} = the contribution of that category to Michigan's flora.

INVASIVE PLANT SPECIES MONITORING

GPS Mapping

Invasive plant species were mapped with a Trimble GeoXT GPS unit adapting the North American Weed Management Association standards (NAWMA 2002, Crimmins et al. 2008). A data dictionary was created in GPS Pathfinder to record attributes of the following features: estimated size of population, percent of polygon occupied, and condition of population. Mapping occurred where PDOP was less than seven and the GPS unit was receiving signals from at least four satellites (Crimmins et al. 2008). Although the GeoXT uses WAAS real-time correction and reportedly has sub-meter accuracy (ESRI, Redlands, CA), GPS accuracy was conservatively assumed to be five meters. A unique feature of each species was recorded for each individual species encountered. Patches of an individual species smaller than five meters in diameter were mapped as points, and larger patches as polygons. Cover of individual species was estimated in polygons within the following cover classes: 0-1, 1.1-5, 5.1-25, 25.1-50, 50.1-75, 75.1-95, and 95.1-100%. Area of selected polygons was then multiplied by the midpoint of these cover classes to estimate total area covered. Points were automatically given a cover of 0.5 m^2.

GPS mapping occurred where an invasive species covered large, but discrete areas and where satellite populations were found. Ubiquitous species such as glossy and common buckthorn (*Rhamnus frangula* and *R. cathartica*) and bush honeysuckle species (*Lonicera maackii, L. morrowii, L. X bella,* and *L. xylosteum,* hereafter *Lonicera* spp.) were avoided in GPS mapping. Garlic mustard (*Alliaria petiolata*), while also ubiquitous, was mapped nearly comprehensively due to its deceptive life history characteristics (quick spread, drastic annual population fluctuations [Blossey et al. 2001]) and because it is already actively managed at the Preserve. A species was identified as invasive by its known ability to expand its population, crowd out native species, and otherwise significantly alter the environment. See Table 2 for a list of invasive species recorded.

Common Name	Scientific Name	Forest	Prairie/Savanna	Wetlands	Old Field
Tree-of-Heaven	*Ailanthus altissima*	X	X		X
Garlic Mustard	*Alliaria petiolata*	X	X	X	X
Japanese Barberry	*Berberis thunbergii*	X		X	
Smooth Brome	*Bromus inermis*	X	X		X
Asiatic Bittersweet	*Celastrus orbiculata*	X			
Spotted Knapweed	*Centaurea maculosa*	X	X		X
Canadia Thistle	*Cirsium arvense*		X	X	X
Lily-of-the-valley	*Convallaria majalis*	X			
Crown-vetch	*Coronilla varia*	X			X
Autumn-olive	*Elaeagnus umbellata*	X	X	X	X
Hairy Willow Herb	*Epilobium hirsutum*			X	
Burning Bush	*Euonymus alata*	X			
Spindle Tree	*Euonymus europaea*	X		X	

Wintercreeper	*Euonymus fortunei*	X			
Day Lily	*Hemerocallis fulva*	X			
Dame's Rocket	*Hesperis matronalis*	X		X	X
Common Privet	*Ligustrum vulgare*	X		X	
Japanese Honeysuckle	*Lonicera japonica*	X			
Amur Honeysuckle	*Lonicera maackii*	X			
Morrow Honeysuckle	*Lonicera morrowii*	X	X	X	X
Belle Honeysuckle	*Lonicera X bella*	X			
European Honeysuckle	*Lonicera xylosteum*	X			
Purple Loosestrife	*Lythrum salicaria*		X	X	
White Sweet Clover	*Melilotus alba*		X		X
Yellow Sweet Clover	*Melilotus officinalis*		X		X
Eurasian Water Milfoil	*Myriophyllum spicatum*			X	
Reed Canary Grass	*Phalaris arundinacea*			X	X
Common Reed	*Phragmites australis*			X	
Curly Pondweed	*Potamogeton crispus*			X	
Common Buckthorn	*Rhamnus cathartica*	X	X	X	X
Glossy Buckthorn	*Rhamnus frangula*	X	X	X	X
Black Locust	*Robinia pseudoacacia*	X	X		X
Multiflora Rose	*Rosa multiflora*	X	X	X	X
Periwinkle	*Vinca minor*	X			

Table 2. Invasive plant species at Asylum Lake Preserve and habitats they occupy.

Forested Grids

The 100 X 100 m grid was employed as mapping units for estimating invasive species cover. Each grid for which at least 1/4 of its area within the boundaries of the Preserve is within Forest I or Forest II (n=55) was comprehensively surveyed. Each species was placed in a cover class (see "GPS Mapping") for each grid. Dominant invasive species were identified as having a relative importance value ([relative frequency + relative cover]/2) greater than one standard deviation above the mean; common species were identified as species with RIVs above the mean but less than one standard deviation. The percent cover of each species was calculated over the 55 grids, at 135.85 acres. Due to the coarseness of this method (Stohlgren et al. ND), this data was compared to invasive species cover data from modified-Whittaker plots.

Northern water snake in Asylum Lake (*left*), grid-point marker (*center*), bur oak (*Quercus macrocarpa*) at edge of Oldfield and Forest I (*right*)