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The Effect of Wetland Size and Surrounding Land Use on Wetland Quality Along an Urbanization Gradient in the Rocky River Watershed

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THE EFFECT OF WETLAND SIZE AND SURROUNDING LAND USE ON WETLAND QUALITY ALONG AN URBANIZATION GRADIENT IN THE ROCKY RIVER WATERSHED

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THE EFFECT OF WETLAND SIZE AND SURROUNDING LAND USE

ON WETLAND QUALITY ALONG AN URBANIZATION

GRADIENT IN THE ROCKY RIVER WATERSHED

MARILYN S. GUNSCH

ABSTRACT

An intensive floristic evaluation of 17 Cleveland Metroparks (CMP) wetlands in the Rocky River Watershed (RRW) was undertaken to determine whether wetland size or anthropogenic disturbance in the surrounding landscape is a better predictor of wetland quality in this protected parkland. Wetland study sites were selected in three reservations, Hinckley, Mill Stream Run, and Rocky River. My research adds valuable information to the CMP wetland database and will contribute to its wetland management policies.

Wetland quality was determined using the following floristic indices: species richness, % non-native species, % wetland species, mean coefficient of conservatism (C of C), floristic quality assessment index (FQAI), and an FQAI weighted with the wetland indicator status (FQAI-WIS). Wetland perimeter and area were calculated from shape files created by a 12-channel global positioning system (GPS) receiver and data logger. The extent of anthropogenic disturbance was measured within 100 m, 250 m, 500 m, and 1000 m buffers surrounding the wetlands using a landscape development intensity (LDI) index. This LDI index was based on 1) the percentage of each land use and land cover (LULC) category found in the buffer zones and 2) LDI coefficients for each LULC category that reflect the amount of energy associated with human activities.

Linear regressions ($p = 0.05$) were run to evaluate the relationship between the predictor variables (perimeter, area, perimeter/area ratio, and LDI) and the response

variables (floristic indices). Results showed a significant positive correlation between % wetland species and perimeter. However, when the site with the largest perimeter was removed from the data set, this correlation no longer existed. Results also showed a significant negative correlation between 1) mean coefficient of conservatism and 250 m LDI, 2) FQAI and 250 m LDI, 3) FQAI and 500 m LDI, and 4) FQAI-WIS and 250 m LDI. While these regressions were significant, the R^2 range from 0.27 to 0.31 indicated weak correlations.

Because the regressions between floristic wetland quality and LDI of 250 m and 500 m showed a weak fit, this study should be extended to include more wetlands in CMP and wetlands outside CMP in the RRW to determine if landscape disturbance in the 250 m and 500 m buffers are the most useful predictors of wetland quality in this region. In addition, other types of disturbance surrounding the study sites likely affect wetland quality and should be investigated. Impervious and compacted surfaces such as roads, bike paths, hiking trails, and bridle paths are common in CMP and many are close to or adjacent to the wetland sites within the 100 m buffer. These surfaces are often under the forest canopy and therefore not included in calculating the LDI index, but may play a role in determining wetland quality. Past land use, including agriculture and sandstone quarries, and present-day browsing by a large population of white-tailed deer may also influence current wetland quality.

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ABBREVIATIONS

ANOVA	Analysis of Variance
dbh	diameter breast high
C of C	Coefficient of Conservatism
CMP	Cleveland Metroparks
CRW	Cuyahoga River Watershed
CSWCD	Cuyahoga Soil and Water Conservation District
FAC	Facultative
FACU	Facultative Upland
FACW	Facultative Wetland
FQAI	Floristic Quality Assessment Index
FQAI-WIS	FQAI (weighted with) Wetland Indicator Status
HGM	Hydrogeomorphic
HKWL	Hinckley Reservation Wetland
HR	Hinckley Reservation
LDI	Landscape Development Intensity
LULC	Land Use and Land Cover
MSR	Mill Stream Run Reservation
MSWL	Mill Stream Run Reservation Wetland
NOACA	Northeast Ohio Areawide Coordinating Agency
OBL	Obligate
ODNR	Ohio Department of Natural Resources

ABBREVIATIONS (continued)

ODOD .... Ohio Department of Development

OEPA .... Ohio Environmental Protection Agency

ORAM .... Ohio Rapid Assessment Method

RRR .... Rocky River Reservation

RRW .... Rocky River Watershed

RRWL .... Rocky River Reservation Wetland

UN .... United Nations

UPL .... Upland

USCB .... United States Census Bureau

USDA .... United States Department of Agriculture

USEPA .... United States Environmental Protection Agency

WIS .... Wetland Indicator Status

CHAPTER I

INTRODUCTION

Overview

A wetland is an ecosystem distinguished by water that either covers or saturates the ground in the root zone for at least part of the year, low oxygen to anoxic soils, and flood-tolerant (hydrophytic) vegetation adapted to these water and soil conditions. Some wetlands are permanently flooded (marshes and swamps), some are only seasonally flooded (riparian wetlands), and some have saturated soils but standing water is rarely present (prairie potholes and vernal pools). Inundation or saturation for two weeks during the growing season is long enough to classify an area as a wetland if certain vegetation is present. For example, vernal pools are inundated during the spring season, but are dry during the rest of the year (Mitsch and Gosselink 2000a).

Hydrology is the most important wetland component since soil conditions and the presence of vegetation adapted to saturated soil are direct results of the presence of water. The amount of precipitation and evaporation determine a wetland's water level, water flow, frequency, and duration of flooding. Wetland soils are hydric soils that become anaerobic (without oxygen) because they are saturated or flooded during the growing season or throughout the year. In order to survive in saturated soils, plants must be adapted to anaerobic conditions in the root zone. Some of the structural adaptations seen in these hydrophytic plants include air spaces in roots and stems for diffusion of oxygen, roots growing above the anaerobic zone, and buttressed tree trunks.

Wetlands play vital ecological roles in a region's landscape. They act as sponges when they prevent and/or ameliorate flooding, protect shorelines, and help to recharge groundwater. They also serve as a region's kidneys when they receive, process, and clean water that is polluted by waste and sediment from natural and human input. Because of their high productivity, they provide many nutrients and unique habitats for nesting and migrating waterfowl and nurseries for fish. When a wetland is converted to a different type of wetland or reduced from a large area to several smaller areas, its efficiency is reduced. When a wetland is degraded or destroyed, its valuable functions are lost from the environment.

Human valuation of wetlands has varied among the world's cultures and within cultures over time (Coles and Coles 1989). When wetlands are seen as impediments to economic development, they are often converted to agricultural land and urbanized areas (Dugan 1993). Urban wetlands, in particular, are very susceptible to degradation since the activities associated with human populations drastically alter the landscape (Ehrenfeld 2000). Therefore, studies that focus on urban wetlands often attempt to determine the relationship between the quality of the wetland and the degree of anthropogenic disturbance, e. g. Ervin *et al.* (2006) and Wardrop *et al.* (2007).

As people began to understand that the degradation and destruction of wetlands nullify the wetlands' natural functions, thereby placing at risk their property and health, laws were enacted and conservation groups formed to help protect these valuable resources. Federal, state, and local laws and regulations, public support, and data from wetland studies assist land managers as they integrate the social, economic, and ecological values of wetlands into management practices and policies.

Wetland Valuation

The value placed on any resource, including wetlands, is conditional upon the services the resource provides to people (Mitsch and Gosselink 2000b). When Costanza *et al.* (1997) quantitatively analyzed types of ecosystems using 17 different goods and services including water supply and regulation, soil formation, habitat, and food production, they showed that wetlands are extremely valuable resources. According to their analysis, wetlands rank higher in value than lakes and rivers, forests, and grasslands, among others.

In addition to quantitative analyses, wetland value can be qualitatively assessed by determining the types of goods and services available at various ecological levels and by the wetland's hydrogeomorphic (HGM) classification (Mitsch and Gosselink 2000b). At the plant and animal population level, wetlands provide goods such as food and timber. At the ecosystem and biosphere levels, they provide increasingly more complex services such as flood mitigation and biogeochemical cycling. The goods and services wetlands provide also vary based on HGM category. For example, a major service of isolated and riparian wetlands is flood control while coastal and in-stream wetlands provide important fish habitat (Mitsch and Gosselink 2000b).

Some cultures have prospered by wisely using the goods and services that healthy wetlands provide (Coles and Coles 1989, Mitsch and Gosselink 2000a, Schuyt 2005). Other cultures have destroyed wetlands and the associated goods and services by converting these wetlands into agricultural land and urban areas (Dugan 1993, Dahl and Allord 1999, Pauchard *et al.* 2006).

Wetland Protection

Drawing upon an increased understanding of wetland functions and the recognition of the ecological, economic, and societal value of wetlands, government agencies, private organizations, and concerned citizens have worked together to conserve wetlands and to enact and enforce legislation that protects them from degradation and destruction. In the United States, the Clean Water Act (CWA) of 1972 provides for the "restoration and maintenance of chemical, physical and biological integrity of the Nation's waters." In 1977, this act was amended to specifically include wetlands by requiring permits (§404) to dredge and fill these wetlands (United States Environmental Protection Agency – USEPA 2006). Recent federal interpretation of the CWA has excluded isolated wetlands (wetlands that have no surface water connection to navigable waters) from its regulatory provisions (Kusler 2004).

Ohio protects its wetlands, including isolated wetlands, under 33 C.F.R. 323.2, Ohio Administrative Code 3745-1-02(B) (Mack 2007). The extent of regulatory protection afforded an Ohio wetland increases as wetland quality increases. Category 1 wetlands provide low quality habitat and only marginal hydrologic functions, e.g. flood control. Category 2 wetlands provide a moderate quality habitat and hydrologic functions or have the potential to be restored to a moderately-functioning wetland. Category 3 wetlands contain excellent habitat for native, threatened, and/or endangered species, exceptional hydrologic functions and/or are an uncommon wetland type, e.g. bog, fen, or old growth forest (Mack 2001).

Wetland Loss

As much as 50% of wetlands worldwide may have been lost through the centuries due to human activities (Dugan 1993) with much of this loss occurring since 1900 (Barbier 1993). Examples of major wetland losses include a 56% reduction of the Chepe-Carriel Sur freshwater-salt wetland in Chile (Pauchard *et al.* 2006), a 92% reduction of New Zealand's original wetlands (Brinson and Malvarez 2002), and a 94% reduction of the al-Hammar Marsh in Iraq (Lawler 2005).

Two hundred years ago, in what is now the conterminous United States, wetlands totaled approximately 221 million acres (894,355 km^2) (Dahl 1990). By 2004, wetlands accounted for approximately 5.5% of the surface area of the lower 48 states, equivalent to 107.7 million acres (435,846 km^2) (Dahl 2006). According to Dahl (2000), 98% of all the wetlands converted to other uses were freshwater wetlands.

Draining wetlands for agriculture, mining, and logging along with filling in wetlands for roads and residential and commercial development have destroyed 90% of Ohio's wetlands (Noss and Peters 1995). Overall, an estimated original 5,000,000 acres (20,234 km^2) of Ohio wetlands has decreased to 483,000 acres (1,955 km^2) (Sibbing

1995). For example, a large wetland known as the Great Black Swamp that once covered 988,422 acres (4,000 km^2) in northwest Ohio is now almost completely converted into farmland (Mitsch and Gosselink 2000a).

Role of Urbanization in Wetland Loss

Urbanization can be defined as an increase in human population that is associated with an increase in both energy and material consumption along with changes to the natural landscape (McDonnell and Pickett 1990, Faulkner 2004). The human population density in urban areas is greater than or equal to 1,000 people/mi^2 (386 people/km^2) (United States Census Bureau – USCB 1995). During the 20th century, there has been a 10-fold increase in the world's urban populations (Platt 1994). In 1996, approximately 46% of people worldwide lived in urban areas; by 2030, it is estimated that this amount will increase to 61% (United Nations – UN 1997). In the United States, the urban population accounted for approximately 81% of the total population in 2005; in 2030 this amount is estimated to increase to around 87% (UN 2008).

Urbanization with its wide variety of associated human activities is a major component of wetland loss and fragmentation. As much as 58% of total wetland loss may be due to urbanization (Opheim 1997). Data from Anderson and Magleby (1997) illustrate the growing impact of urbanization in wetland destruction in the United States. Between 1954 and 1974, the conversion of wetland to agricultural land accounted for 81% of wetland destruction, while urbanization accounted for only 8%. From 1974 to 1983, agriculture contributed to 53% of wetland loss while urbanization dropped to 3%. However, between 1983 and 1992 agriculture accounted for only 20% of wetland conversion while urbanization was responsible for 57%, a substantial increase over previous years. This change is significant because over long periods of time urbanization impacts the natural environment more than forestry or agriculture. The probability of urbanized areas reverting back to the original landscape is much lower than that of harvested forests or farmed land (Marzluff and Ewing 2001).

Urban Wetland Degradation

Kentula *et al.* (2004) suggest that no group of wetlands is subjected to destruction and degradation more than urban wetlands. As an area becomes increasingly urbanized, the activities associated with a dense population place pressures on urban wetlands that are not encountered by rural wetlands. These activities are associated with surrounding high intensity land use, e.g. residential, commercial, and industrial sites, roads, and railroads. Vehicles and other machinery disturb wetland substrates. Hydrologic regimes are modified by ditching, dredging, and filling and habitat alterations occur due to grazing, sedimentation, mowing, selective cutting, debris removal, and clear cutting (Mack 2001, Wardrop *et al.* 2007). Often only narrow buffers of natural undisturbed land separate wetlands from these surrounding activities. Other unique stressors are increased predation on native species by feral animals, inadvertent damage caused by recreational activities, vandalism, and use of the wetland as a dump for a variety of materials including toxic chemicals (Zedler and Leach 1998).

Due to these activities, wetlands present within urban areas are likely to experience many alterations to their hydrology, geomorphology and biology (Zedler and Leach 1998, Ehrenfeld 2000, Houlahan *et al.* 2006) that will impact their ability to perform ecological functions. Levees, dams, and culverts often permanently destroy hydrologic connections between wetlands. This results in the creation of small, isolated urban wetlands that often cannot perform large-scale functions such as flood mitigation (Mitsch and Gosselink 2000b). Instead of reducing flooding, levees built in the upper Mississippi watershed have contributed to a 140% increase (Hey and Philippi 1995). In an urban setting, high levels of organic and inorganic materials flowing both in and out of a wetland are difficult to control (Ehrenfeld 2000), thereby reducing the amount of pollutants a wetland can process. In addition, physical changes in hydrology and geomorphology often lead to biological changes including an increase in the number of non-native species (Magee and Kentula 2005).

Importance of Urban Wetlands

Wetlands in urbanized areas are important from ecological, economic, and societal perspectives. The multiple ecological services that wetlands provide include reducing and/or eliminating flooding, receiving, processing, and cleaning water polluted by waste and sediment from both natural and human sources, and providing nutrients and unique habitats for resident biota and migratory animals (Mitsch and Gosselink 2000a). Based on studies conducted in Scandinavia and the Midwest United States, Mitsch and Gosselink (2000b) suggest that wetlands need to cover approximately 5% of a temperate zone watershed area in order to effectively provide the goods and services associated with ecological functions. Hey and Philippi (1995) estimate that wetlands comprised 9-11% of the watersheds of the Missouri and Upper Mississippi Rivers prior to 19th century settlement. They also estimate that if only half of the drained wetlands in the region had remained undisturbed, the effects of the catastrophic flooding of the Mississippi River in 1993 would have been greatly alleviated.

Urban wetlands also provide economic and societal services that directly benefit humans at a local level. These include filtering the air of pollution generated by vehicles and factories, aiding in noise reduction, and providing sites for recreational activities (Bolund and Hunhammer 1999).

As the number and size of wetlands decline in urban areas, those that remain will need to be carefully managed to protect them from destruction, preserve the ecological functions they provide, and comply with federal, state, and local regulations. Wetland ecology is a relatively new area of study, with very few researchers prior to 1960 (Mitsch and Gosselink 2000a). The USEPA (2002) reported that only 8% of the nation's wetlands have been studied. Newer still is the field of urban ecology (McDonnell and Pickett 1990) and there is a lack of information about urban wetlands due to the small number of studies that focus on them (Faulkner 2004).

It is important to study all types of wetlands to determine if the structure and function of urban wetlands are significantly different from those of rural wetlands (Ehrenfeld 2000, Faulkner 2004). Zedler and Leach (1998) present convincing arguments through three case studies that when research is combined with restoration and recreation all three activities benefit. The data derived from urban wetland research can provide the basis for ecological, economic, social, and regulatory decisions (Grayson *et al.* 1999).

Wetland Evaluation Methods

Wetland ecologists use more than 100 different methods to evaluate wetland condition (Kusler 2006), i.e. the current quality of an ecosystem when compared to a reference site not impacted by human activities. Such reference wetlands sustain their full ecological integrity (Fennessy *et al.* 2007a), their ability ". . . to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region" (Karr and Dudley 1981).

Although there are many different wetland evaluation methods, they can be grouped into three levels based on time commitment and cost (Mack 2006, Fennessy *et al.* 2007a, Hychka *et al.* 2007, Wardrop *et al*. 2007). Level 1 methods do not require a site visit, instead utilizing land use and land cover (LULC) data obtained from maps, digital sources, and geographic information systems (GIS). Level 2 methods involve a site visit and are often called rapid assessment methods because they can usually be completed quickly by using a checklist to examine the factors that impact the wetland. Level 3 methods include an intensive, detailed assessment of a wetland's biotic, chemical, and/or physical condition that necessitates a site visit and sometimes requires additional laboratory analyses and biotic identifications.

Wetland studies often compare a measure of quality to a measure of disturbance. Quality metrics include species richness, i.e. the number of different species present in a wetland (Matthews *et al.* 2005, Houlahan *et al.* 2006), proportion of native and non-native species (Matthews *et al.* 2005), floristic quality indices (FQI) (Lopez and Fennessy 2002, Matthews *et al.* 2005, Ervin *et al.* 2006, Miller and Wardrop 2006, Nichols *et al.*

2006, Hychka *et al.* 2007, Wardrop *et al.* 2007), and indices of biotic integrity (IBI) (Mack 2004, Mack 2007). Disturbance metrics include LULC in zones surrounding the wetland (Houlahan *et al.* 2006, Nichols *et al.* 2006, Hychka *et al* 2007, Wardrop *et al.* 2007) and wetland isolation (Matthews *et al.* 2005). Several recent indices developed for multiple ecosystem stressors include the Disturbance Index (DI) (Lopez and Fennessy 2002, Ervin *et al.* 2006), Landscape Development Index (LDI) (Brown and Vivas 2005, Mack 2006), Anthropogenic Activity Index (AAI) (Ervin *et al.* 2006), and various rapid assessment methods (Mack 2001, Miller and Wardrop 2006, Wardrop *et al*. 2007).

Effect of Wetland Size and Surrounding Landscape on Wetland Quality

Houlahan *et al.* (2006) investigated the relationship between plant species richness (the number of species in a community), wetland size, and adjacent land use. They concluded that wetland size was the best predictor of total plant species richness but that there was also a strong correlation between adjacent land use and total plant species richness. The land use data included forest cover and hydrology as well as environmental components of urbanization such as road density. They studied marshes, shrub swamps, forest swamps, bogs, and fens along an urban to rural agricultural land use gradient in an area surrounding Ottawa, Canada. However, Houlahan *et al.* (2006) acknowledged that their results may not apply to nonagricultural regions.

In a study of wetlands in southern Illinois, Matthews *et al.* (2005) investigated the influence of area and isolation (distance between wetlands) on wetland quality. Historic land use in this part of Illinois included logging, agriculture, coal mining, and urban development. Wetland quality was measured using both the mean coefficient of conservatism (C of C) (ranking of plant habitat preference) and an FQI. They concluded that when all wetland types were included in the analysis, both increasing FQI scores and mean C of Cs were correlated with increasing wetland area and decreasing isolation.

Regional data show an expansion of urbanization in the Cleveland metropolitan area. The only recent investigation of the effect of urbanization on wetlands in this area is a study of the Cuyahoga River Watershed (CRW) (Fennessy *et al*. 2007b). It is the first detailed study of Ohio wetlands since the National Wetland Inventory was completed over 20 years ago. Detailed information about wetlands is still lacking for most of the region including the Rocky River Watershed (RRW), located immediately west of the CRW. Many of these RRW wetlands are also located in Cleveland Metroparks (CMP), providing protected study sites that bridge the gap between strictly urban and rural wetlands.

Due to this lack of information about wetlands in the RRW and CMP, I researched the relationship between 1) the quality of these wetlands and wetland size (perimeter, area, and perimeter/area ratio) and 2) wetland quality and surrounding landscape disturbance in four buffer zones. My study was set up to test the following hypothesis: Wetland size is a more accurate predictor of wetland quality than surrounding land use along an urbanization gradient in publicly-owned protected wetlands.

This study provides information to 1) assess the influence of size and surrounding landscape on the quality of wetlands located in the RRW, 2) compare the quality of these protected wetlands to wetlands in nearby regions, and 3) assist CMP natural resources personnel as they evaluate their wetland management policies.

CHAPTER II

MATERIALS AND METHODS

Study Sites

Rationale for Site Selection

The study sites are a subset of wetlands identified by the Cleveland Metroparks (CMP) 2006 wetland inventory and assessment. The study wetlands were selected because they represent a range in size and variation in surrounding land use. Wetland sizes were available from the CMP 2006 wetland inventory and assessment (M. Durkalec, personal communication, April 15, 2008). Estimated % impervious surface, used as a proxy for landscape disturbance in areas surrounding the wetlands since roads and other paved surfaces are associated with human activities, was provided by ArcMap version 9.2, an application of ArcGIS (Environmental Systems Research Institute – ESRI 2002). I limited my research to sites in the Rocky River Watershed (RRW) and CMP because, except for Lake Abram and the Strongsville Wetland Area, there have been no intensive wetland evaluations in this area (Northeast Ohio Areawide Coordinating Agency – NOACA 2006).

Location

The 17 wetlands in this study are located between 41.21300° N and 41.45155° N latitude and 81.70592° W and 81.86942° W longitude, northeast Ohio, USA (Figure 1, Appendix A) in the RRW (Figure 2). This watershed is in the Erie - Ontario Drift and Lake Plains (EOLP) ecoregion (Ohio Environmental Protection Agency – OEPA 2001, Fennessy *et al*. 2007b). The hydrologic and geologic characteristics found in the EOLP are evidence of the numerous glaciations of the past, which ended approximately 9,000 – 12,000 years ago. Glacial action formed the unconsolidated materials (till) that lie on top of the bedrock, which is composed of shale, siltstone, sandstone, and conglomerates. The predominant soils in the RRW have a high clay content that inhibits water infiltration and flow (NOACA 2006). The RRW, which includes Rocky River and its tributaries, drains 293.8 mi^2 (188,032 acres) (NOACA 2006). The river and its tributaries flow through Summit, Lorain, Medina, and Cuyahoga Counties and ultimately drain into Lake Erie (Figure 2).

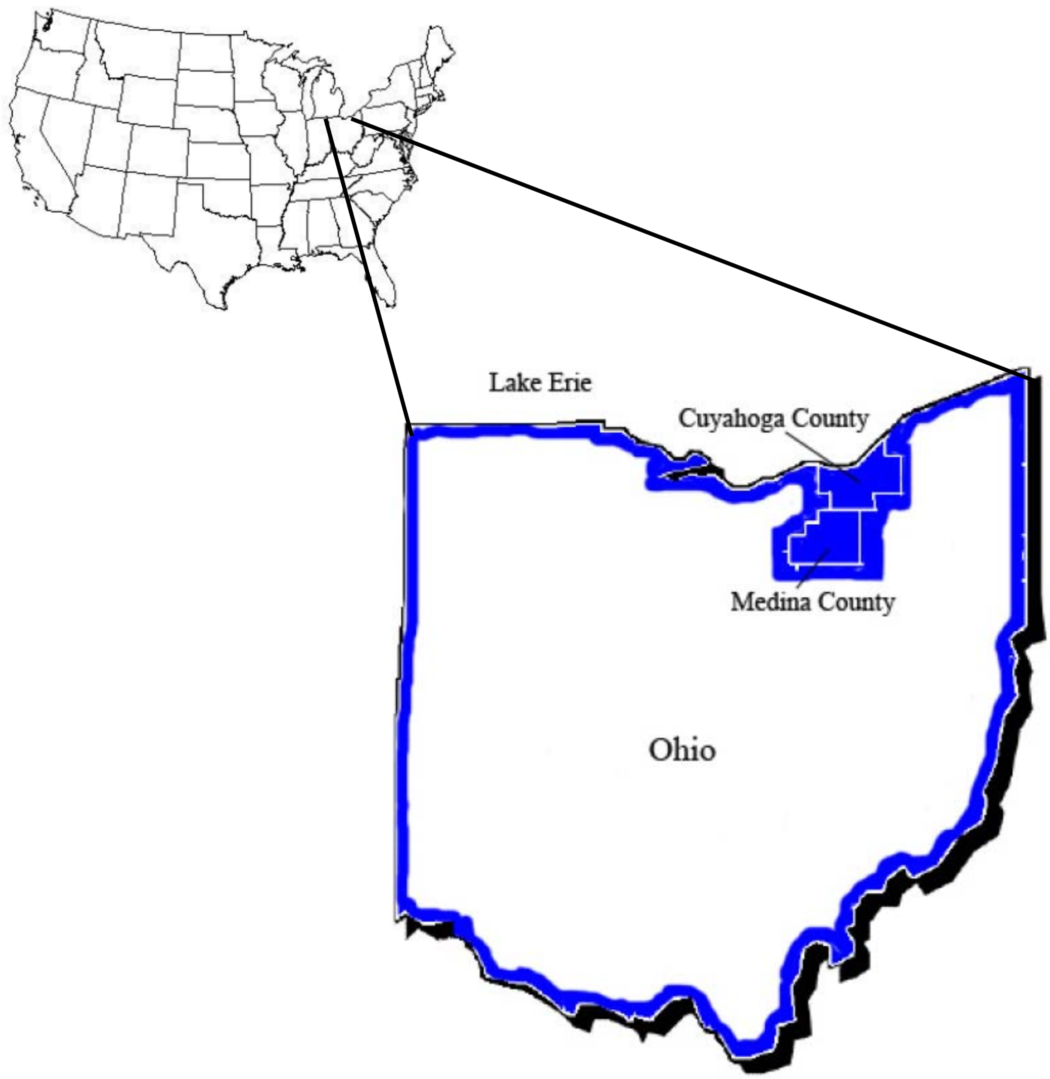

Figure 1. Location of study region: Cuyahoga and Medina Counties, Ohio, USA

Figure 2. The three main subwatersheds of the Rocky River. Study sites are located in the East Branch and Mainstem subwatersheds.
Source: Modified from http://www.myrockyriver.org/maps.htm

Major land uses in the RRW are deciduous forests, agricultural lands, and urban areas (OEPA 2001). Wetlands cover approximately 1.85% of the watershed. Ninety percent of these are forest and shrub wetlands with emergent wetlands accounting for the remaining 10% (NOACA 2006). This watershed is home to over 250,000 people and includes part or all of 16 villages and cities (Cuyahoga Soil and Water Conservation District and WVIZ 2006).

The wetland sites in this study are located in two of the three main subwatersheds of the Rocky River, the East Branch and Mainstem (Figure 2). The East Branch stream is

34.5 miles (55.5 km) long. From its source in North Royalton to Baldwin Lake in Berea, it exhibits characteristics of a natural stream with access to its floodplain, a minimal amount of bank erosion, and high quality riparian zones. Downstream from Baldwin Lake, urbanization impacts affect stream quality (NOACA 2006).

The mainstem stream is 11.8 miles (19.0 km) long, beginning at the confluence of the East and West Branches and emptying into Lake Erie. Its channel and riparian zones are almost entirely within the Cleveland Metroparks (CMP) boundaries. Having only minimal modifications to its bank, flood waters can easily spill onto the floodplain. Urbanization just outside of CMP affects this part of the river (NOACA 2006).

In addition to their location in the RRW, all study sites lie within the boundaries of CMP (Figure 3). Four of Ohio's eight wetland hydrogeomorphic classes (depression, impoundment, riverine, slope, fringing, coastal, bog, and mitigation) (Mack 2004) are represented in this study: fourteen wetlands are classified as depressions, one as riverine, one as a slope, and one as fringing.

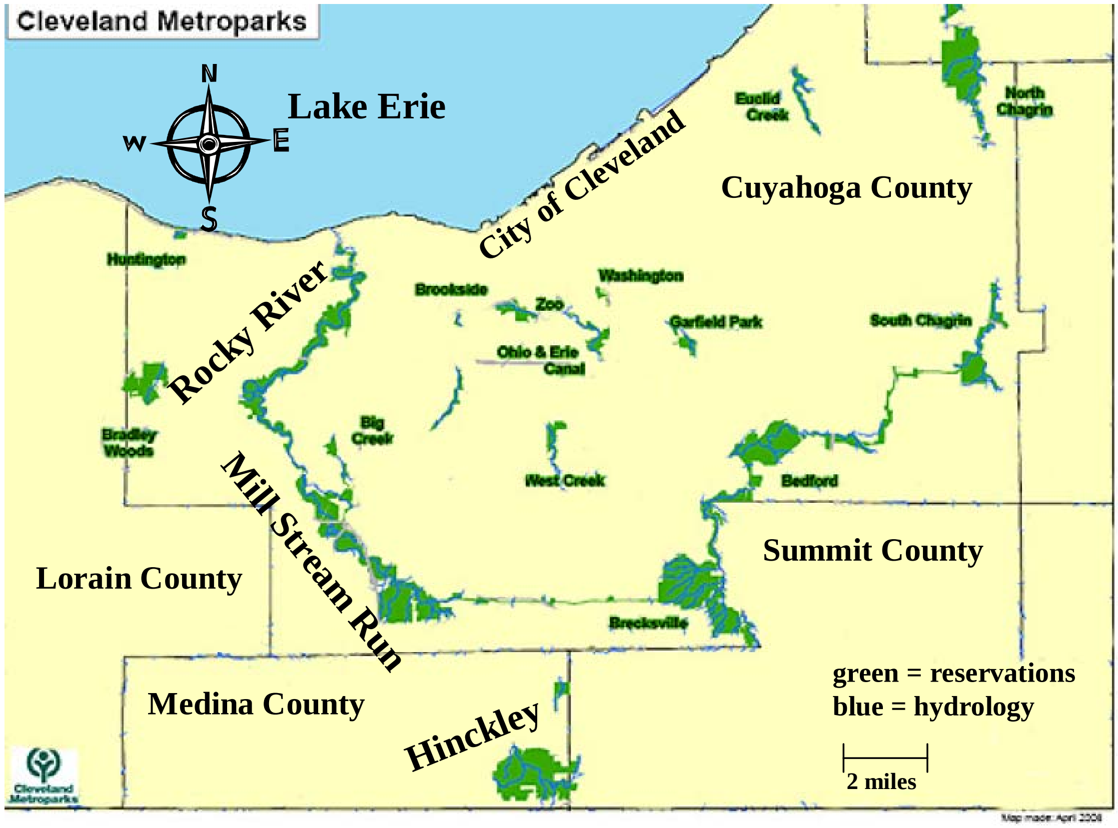

Figure 3. Reservations of Cleveland Metroparks. Study sites are located in Rocky River, Mill Stream Run, and Hinckley Reservations, Cuyahoga and Medina Counties, northeast Ohio.
Source: Modified from Cleveland Metroparks map, 2008

Three of the study wetlands are in Medina County (Hinckley Reservation - HR) while the remaining 14 are in Cuyahoga County (Mill Stream Run Reservation – MSR and Rocky River Reservation - RRR) (Figures 3 and 4). The population density of Medina County is 401.7 people/mi^2 (155.1 people/km^2) (Ohio Department of Development – ODOD 2006). Cuyahoga County is the most densely populated county in Ohio with 2,867.6 people/mi^2 (1,107.2 people/km^2) (ODOD 2006).

Hinckley Reservation is roughly rectangular in shape with a total area of 2,772 acres (11.22 km^2) (Figure 4A). Mill Stream Run and Rocky River Reservations are long and narrow with some wider areas in MSR (Figure 4B-C). The total area for MSR is 3,200 acres (12.95 km^2) while the total area for RRR is 2,575 acres (10.42 km^2).

The identification label for each wetland site in this study is the same as the CMP 2006 wetland inventory and assessment code. It includes the abbreviations for the reservation (HK = Hinckley; MS = Mill Stream Run; RR = Rocky River) and wetland (WL) along with a three digit number. Site HKWL008, located to the west of HKWL006, is listed first in all tables and graphs. The remaining sites are ordered from south to north in the Rocky River valley.

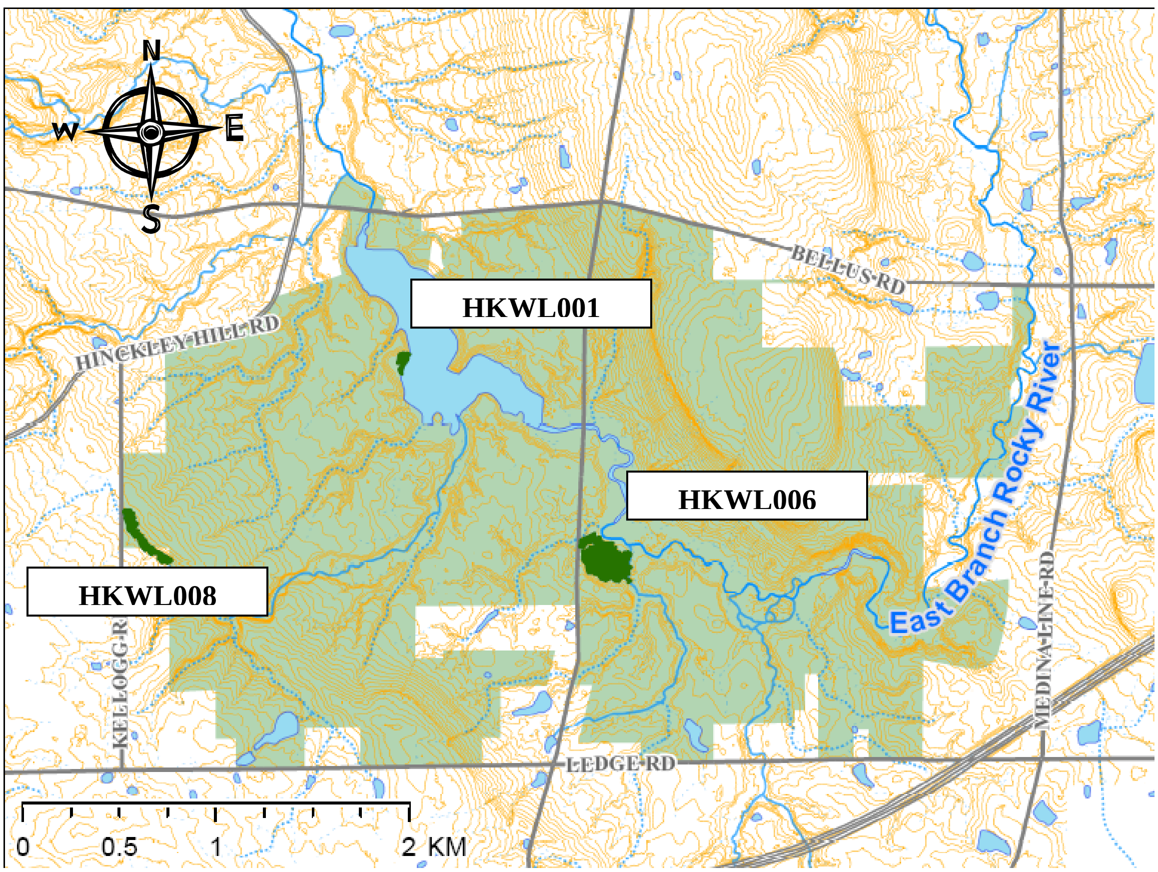

Figure 4A. Hinckley Reservation

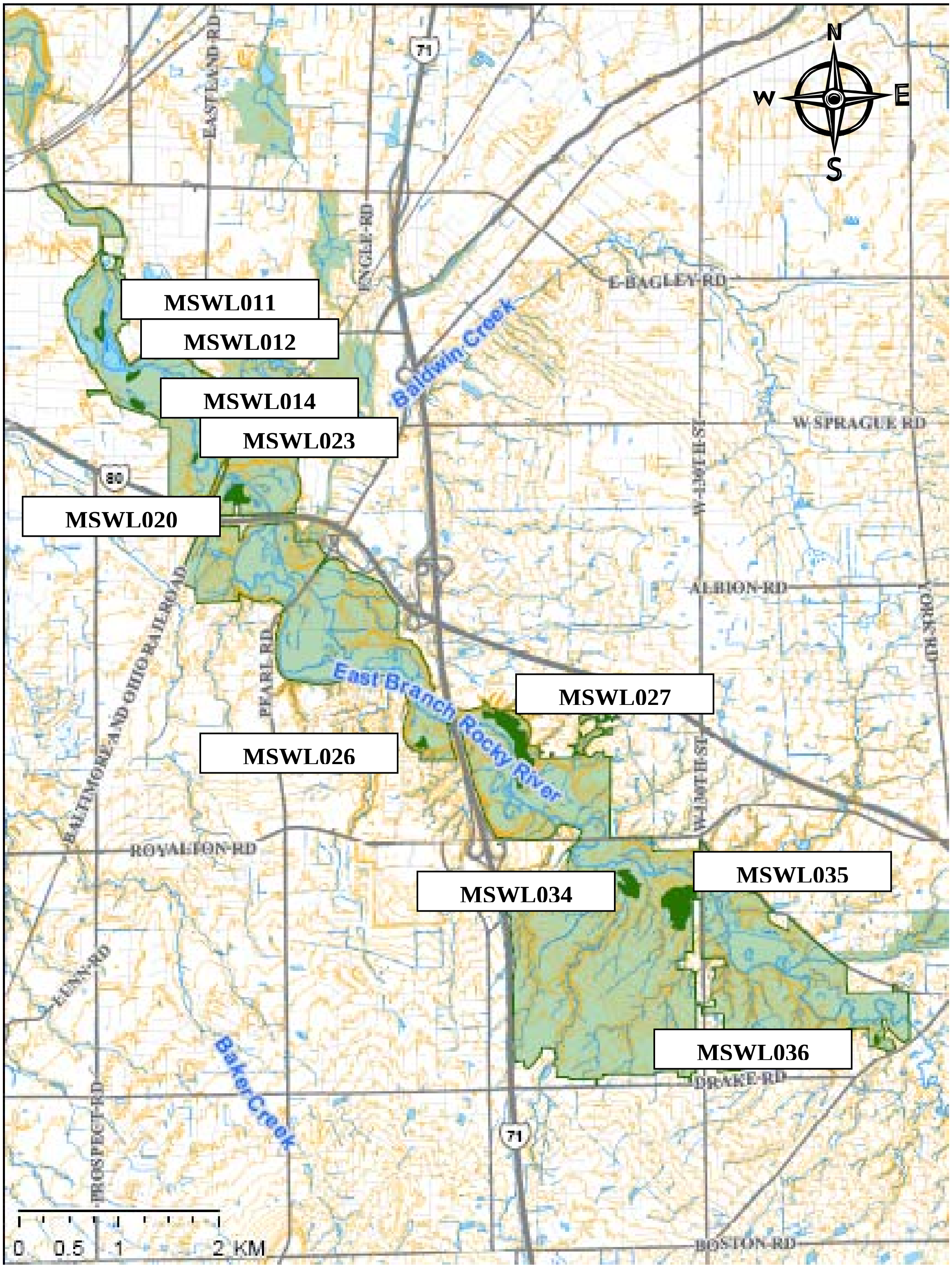

Figure 4B. Mill Stream Run Reservation

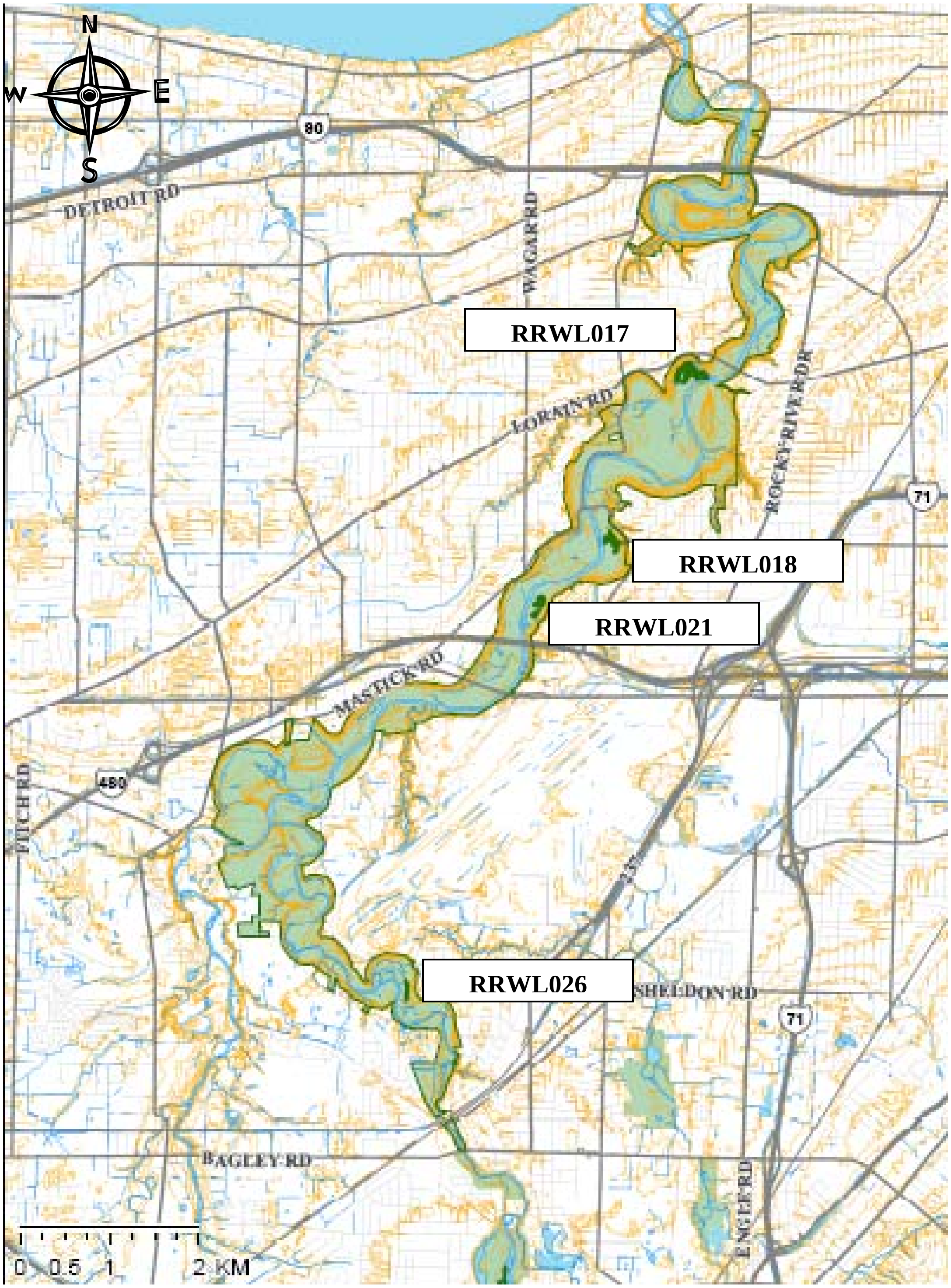

Figure 4C. Rocky River Reservation

Figure 4. Location of study sites in (A) Hinckley Reservation, (B) Mill Stream Run Reservation, and (C) Rocky River Reservation

Description of Floristic Survey

Sampling Period

To calculate the floristic quality indices used in this study, a detailed plant survey was necessary. The best time to conduct a wetland plant survey is between June 15 and September 15 with an extension into October when necessary (Mack 2004). The primary plant survey began on June 26, 2007 and ended on August 15, 2007. In addition, each site was revisited either on September 16, September 23, or October 6 to gather additional specimens of asters, goldenrods, smartweeds, and other late-flowering plants for the identification of immature specimens collected during the June-August surveys.

Plot Layout

Each study site was located using a Garmin GPS 60, programmed with its latitude and longitude from the CMP 2006 wetland inventory and assessment. When a site was reached, it was traversed to locate a representative area for the sampling plot. The plot for most of the sites was 20 meters (m) wide by 50 m long (0.1 hectare), divided into 10 m x 10 m modules (Figure 5) (Peet *et al.* 1998, Mack 2004). After the plot location was determined, the following procedure was used to mark its boundaries and modules. First, the center line of the plot was measured with a 50 m tape measure and marked with stake flags at 0 m, 10 m, 20 m, 30 m, 40 m, and 50 m. The orientation of the center line was due north-south, due east-west, northeast-southwest, or northwest-southeast (Appendix B). Second, a distance of 10 meters was measured outward in both directions from the center end points (0 m and 50 m) perpendicular to the center line and these corners were marked with stake flags. Third, the 50 m tape was extended between the corner flags parallel to the center line and a stake flag was set at 10 m, 20 m, 30 m, and 40 m on each side of the plot. A total of 18 flags outlined the plot and individual modules. Fourth, flagging tape was stretched between the flags across the plot at 10 m, 20 m, and 30 m to set off the intensive modules (2, 3, 8, and 9). Fifth, an 18 inch rebar stake was inserted in the ground and its global positioning system (GPS) location was entered in the Garmin to provide the reference point for plot location (Appendices A and B). This reference point is essential for resurveying if a long-term study develops from this current research.

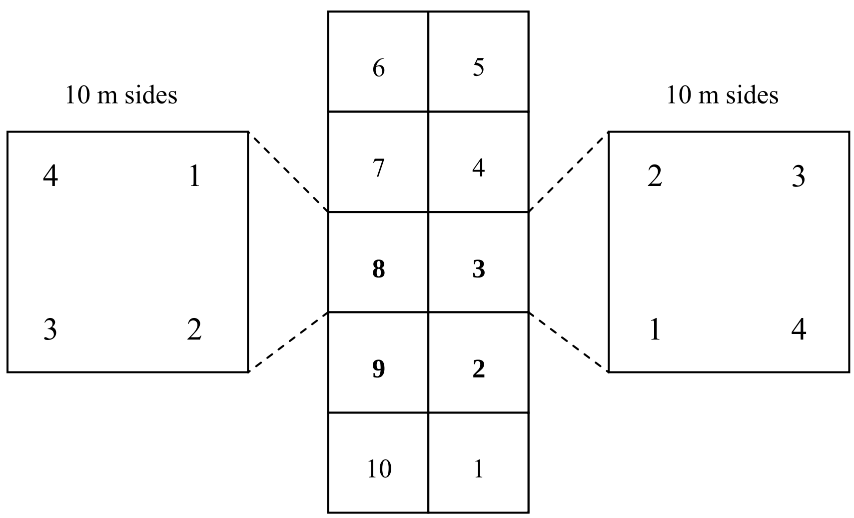

Figure 5. Total plot layout showing the individual modules (center) with the intensive modules in bold type (2, 3, 8, and 9) and the corner numbers of representative modules identified (sides). The corner numbers are labeled clockwise as one moves through the plot starting with module 1 and ending with module 10.

When necessary, modifications to the standard 20 m x 50 m plot design are acceptable (Peet *et al*. 1998). Modifications were made for site RRWL017 and site HKWL001 (Appendix B). The site plot for RRWL017 was divided into two smaller subplots to adequately include site variability. One of these subplots was 20 m by 20 m with modules numbered 1A, 2A, 9A, and 10A (intensive modules were 2A and 9A). The other subplot was 20 m by 30 m with modules numbered 1B, 2B, 3B, 8B, 9B, and 10B (intensive modules were 2B and 9B). Site HKWL001 included only five modules (1, 2, 8, 9, and 10) because it is a narrow fringing wetland bordered by Hinckley Lake and slopes leading to trails. The intensive plots were 1, 2, 9, and 10.

Sampling Technique

The flora of each wetland was sampled using a focused plot sampling technique adapted from Peet *et al.* (1998) and Mack (2004). This sampling technique was used to provide an organized procedure for carefully surveying each plot, ensuring that few species would be overlooked. I separated the plants into four categories (sedge/rush, grass, herbaceous plant, shrub/tree) to facilitate data entry, organization of pressed specimens, and identification of unknown specimens. I also estimated the % areal cover (using cover classes as described in Mack 2004) of understory plants and shrubs and diameter breast high (dbh) data for trees. Though not necessary for this study, they are necessary to calculate the vegetative index of biotic integrity (VIBI) and could be useful in future studies.

In each intensive module, all non-woody plants (excluding mosses) were identified and their % covers were estimated in successively larger areas: 0.1 m^2 (level 4), 1 m^2 (level 3), 10 m^2 (level 2), and 100 m^2 (level 1) (Figure 6). A 0.1 m^2 frame made of polyvinyl chloride (PVC) pipe was positioned at corner 2 of an intensive module. Each species was identified or collected for future identification and its % areal cover was estimated. These data were recorded on field forms (Appendix C). After the 0.1 m^2

quadrat was sampled, a 1 m^2 frame, also made of PVC pipe, was positioned at the same corner; species that had not been seen in level 4 were recorded along with their % cover in the total 1 m^2. Next, a 10 m^2 area (3.16 m sides and 4.47 m diagonal) was measured using a meter tape and marked with corner stake flags. Species that had not been previously seen in levels 3 and 4 were recorded and % cover was recorded for the 10 m^2 area. This same procedure was used for corner 4. After both corners 2 and 4 were sampled in this manner, species identification and % cover were recorded for the remaining area of the intensive module (level 1).

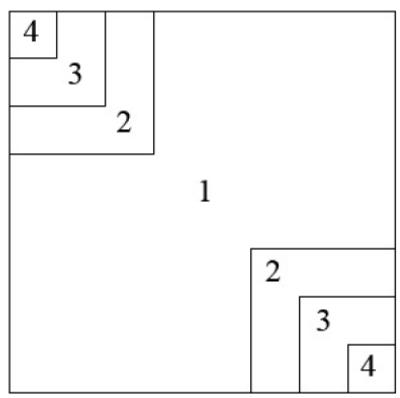

Figure 6. An intensive module showing the four sampling levels. Level 4 is 0.1 m^2; level 3 is 1 m^2; level 2 is 10 m^2; and level 1 is the remainder of the module area that is not already included in the other three levels of both corners (not drawn to scale).

After all the intensive modules were sampled, the remaining six modules (1, 4, 5, 6, 7, and 10) were surveyed. For these six modules, all the species were identified but % cover was not recorded. Each shrub species in the entire plot was identified and its % cover in each module was estimated. Each tree in the entire plot was identified and its dbh was measured. Shrub and tree identifications, % cover, and dbh were all recorded on field forms (Appendix C).

During the survey, 837 specimens that could not be positively identified in the field were collected. Each specimen (entire plant, leaf, and/or fruit) and its identification tag with the site number and specimen number were placed into a plastic bag. In addition, photos were sometimes taken to aid in identification. The plastic bags were refrigerated as soon as possible after leaving the site. All species that were not field identified were either identified while still fresh or after being preserved in a plant press. Fresh plants were also pressed following identification. Taxa were identified using Gleason & Cronquist (2003), Holmgren (1998), Braun (1967), Braun (1961), and the USDA Plant database (2008a). All of the pressed specimens are the property of Cleveland Metroparks and are stored at the Cleveland Museum of Natural History Herbarium.

Indicators of Wetland Quality

The quality of an ecosystem is in part determined by its species diversity (the number of different species found in the ecosystem). Quality ecosystems generally have high diversity. Because plants provide excellent clues about the soil and hydrologic conditions that are present in the landscape (e. g. skunk cabbage indicates the presence of groundwater), floristic indices have often been used as indicators of wetland quality. In this study, wetland quality was determined using the following floristic quality indices: species richness, % non-native species, % wetland species, mean coefficient of conservatism (C of C), floristic quality assessment index (FQAI), and FQAI-WIS, which is a weighted index that incorporates the wetland indicator status.

Species Richness and Native/Non-native Classification

Species richness is calculated by counting the total number of species growing in a site (Andreas *et al.* 2004). The number of native and non-native plants in a site is also determined by tabulation. The native/non-native status is available from the United States Department of Agriculture (USDA) National Resources Conservation Services National Plant List (USDA 2008a).

Wetland Indicator Status (WIS)

The classification system for a species' affinity to water is called its wetland indicator status (WIS). This system places a species in a particular category based on the probability of finding it in a wetland when random plots within the species range are sampled (Table 1). The status is further defined by adding a positive (+) or negative (-) sign to the facultative wetland (FACW), facultative (FAC), and facultative upland (FACU) categories to indicate if the probability is higher (+) or lower (-) in the specified range. A species can be obligate (OBL) even when a wetland is only seasonally or semi-permanently flooded. FACU species may include cosmopolitan plants or ecotypes that are adapted to wetlands (USDA 2008b). The wetland indicator status is also available from the USDA National Resources Conservation Services National Plant List (USDA 2008a).

Table 1. Description of each wetland indicator status (WIS) (adapted from USDA 2008b)

WIS	Probability (%) of finding the species in a wetland under normal conditions	Location
OBL obligate	> 99	Almost always in wetlands
FACW facultative wetland	67-99	Usually in wetlands
FAC facultative	34-66	In both wetlands and uplands
FACU facultative upland	1-33	Occasionally in wetlands but usually in drier uplands
UPL upland	< 1	Almost never in wetlands and almost always in drier uplands

Coefficient of Conservatism (C of C)

Each species is assigned a C of C value from 0-10 based on its ecological tolerance (Table 2). Species with a lower C of C are adapted to a broad range of habitats (generalist species) while species with a higher C of C require more specific habitat conditions (conservative species). The C of C values that were used in this study were developed specifically for Ohio plants (Andreas, 2004).

Table 2. Habitat conditions for coefficients of conservatism (C of C) (adapted from Andreas *et al.* 2004)

Coefficient of Conservatism (C of C)	**Ecological Tolerance – Habitat Conditions**
0	Broad range: assigned to invasive species as well as to native species that thrive in disturbed areas
1-2	Broad range: assigned to native species that are widespread and do not exhibit preference for a specific habitat
3-5	Intermediate range: assigned to native species that generally grow in a stable community but can exist where there is some disturbance
6-8	Intermediate range: assigned to native species that typically grow in a stable and non-disturbed community
9-10	Narrow range: assigned to native species that require very specific habitat conditions

Floristic Quality Assessment Index (FQAI)

The floristic quality assessment index (FQAI) was first developed by Swink and Wilhelm (1979, 1994). Recently, regional adaptations have been developed for Illinois, Michigan, Missouri, Ohio, and Wisconsin with coefficients of conservatism specific to each state (Miller and Wardrop 2006).

The FQAI is a weighted average of species richness (Andreas *et al.* 2004). This study used the following equation to calculate FQAI:

Equation 1 $$FQAI = \sum (CC_i)/\sqrt{(N_{native})}$$

where FQAI = score that includes only native species, CC_i = coefficient of conservatism for each species i, N_{native} = the total number of native plant species identified in the study site. Only plants that could be identified at least to the taxonomic level of species were included in the calculation of the site FQAI.

Weighted Floristic Quality Assessment Index (FQAI-WIS)

A previous study (Ervin *et al.* 2006) assigned values to each WIS category in place of the C of Cs to calculate a floristic index when regional C of Cs were not available. Since C of Cs were available for Ohio, I further explored the data by replacing the C of C in the FQAI equation with a weighted C of C (WCC) that incorporated the wetland indicator status. The WCC was calculated by multiplying the C of C by the following factors: 5 for OBL species, 4 for FACW+, FACW, and FACW- species, 3 for FAC+, FAC, and FAC- species, 2 for FACU+, FACU, and FACU- species, and 1 for UPL species. These weighted C of Cs were used in the following equation:

Equation 2 $$\text{FQAI-WIS} = \sum (WCC_i)/\sqrt{(N_{native})}$$

Wetland Perimeter, Area, and Perimeter/Area Ratio

The wetland perimeter was determined during the CMP 2006 wetland inventory and assessment using the following method. The perimeter of a wetland was walked off and recorded by a Trimble Navigation Pathfinder Pro XR, a 12-channel GPS receiver and data logger that uses Asset Surveyor software. The information from the Trimble data logger was transferred to a computer using GPS Pathfinder 2.8. The index of GPS data for the date and time of each surveyed wetland was retrieved from the Lexington/Bluegrass Community Base Station (LBCBS 2006) to correct the perimeter points. The perimeter points produced a polygon of each wetland from which the area was calculated and the perimeter and area values were used to calculate a perimeter/area ratio.

Land Use and Land Cover (LULC) and Landscape Development Intensity (LDI) Index

Human activities related to the production and transportation of the nonrenewable resources in a particular land use and land cover (LULC) category are a reflection of human disturbance, expressed as solar energy joules/ha yr^{-1} (Brown and Vivas 2005). The normalized natural log of this value is the landscape development index (LDI) coefficient.

Land use and land cover (LULC) categories and their LDI coefficients have been developed for Florida (Brown and Vivas 2005) and Minnesota (Brandt-Williams and Campbell 2006). The Florida system uses 26 different LULC categories while the Minnesota system uses only eight more generalized LULC categories. Frohn (2005) identified 11 LULC categories in Ohio (Table 3). The LDI coefficients that were developed for Minnesota have been used with the Ohio LULC categories based on similarities in the climates and land uses of these two states (Fennessy *et al.* 2007b). A combination of Minnesota LDI coefficients and Ohio LULC categories were used in this study to calculate LDI. The LDI coefficient for natural areas, whether forests, wetlands, or open water, is 0.00, which assumes no substantial human impact on these ecosystems. The other LULC categories reflect increasingly higher coefficients with greater human impact. Mature trees in long-established residential areas create a canopy similar to that of a deciduous forest. However, the presence of house and garage rooftops, yards, and roads in these areas creates a unique remote sensing spectral image that distinguishes this canopy from forest cover and thus includes them in the residential LULC category (J. A Bishop, personal communication, July 17, 2008).

Table 3. Ohio land use and land cover (LULC) categories, their descriptions, and landscape development intensity (LDI) coefficients (adapted from Frohn 2005 and J. J. Mack, personal communication, June 25, 2008)

LULC category	**Description**	**LDI Coefficient**
Deciduous forest	Land where trees that shed their leaves are the dominant species (≥ 75%); foliage drops with the change to cooler weather in autumn	0.00
Evergreen forest	Land where trees that do not shed their leaves are the dominant species (≥ 75%)	0.00
Woody wetlands	Areas where trees and shrubs that are adapted to hydrophytic conditions are the dominant species	0.00
Herbaceous wetlands	Areas where Perennial soft-stemmed plants that are adapted to hydrophytic conditions are the dominant species	0.00
Open water	Areas that are covered with water in at least 25% of the area	0.00
Pasture/Hay	Land planted with crops used for grazing by farm animals or used for growing hay and seed crops	1.08
Cropland	Land used to grow a variety of crops such as tobacco and corn	3.247
Urban/ Recreational Grasses	Plants, usually grasses, grown to control erosion or for recreational and beautification purposes	3.566
Residential	Areas with a range of urban/suburban housing developments from densely populated to more sparsely populated	4.04
Commercial/Industrial/ Transportation	Land is dedicated to railroads, roads, and high intensity development other than residential	4.65
Bare/Mined land	Land not covered by any vegetation or development; quarries and open pit mines	4.65

To quantify the extent of human disturbance, an area-weighted LDI was calculated using the formula:

$$\text{Equation 3} \qquad LDI_{total} = \sum (\%LU_i \ \text{x} \ LDI_i)$$

where LDI_{total} = the LDI index, $\%LU_i$ = the percent of the total buffer area that is a particular land use *i,* and LDI_i = the landscape development intensity coefficient for land use *i* (Brown and Vivas 2005, Mack 2006, Fennessy *et al.* 2007b).

Two types of information were used to calculate the LDI index of land that surrounds the study wetlands: 1) a current LULC map of Ohio (Frohn 2005) and 2) polygons of the wetland area. ArcView 3.3 (ESRI 2002), a computer software program with the Patch Analyst extension and geographic information systems (GIS) procedures, produced varying buffer widths around each polygon, extended outward from the wetland perimeter. The program then used the LULC map information to calculate the % of each LULC category found within each buffer width (Bishop and Lehning 2007).

Various buffer widths have been used in wetland studies depending on the regional landscape (Table 4). Smaller buffer widths (100 m and 250 m) give an indication of localized impacts to a wetland while the larger buffer widths (500 m and 1000 m) show impacts at a larger landscape scale (Kettlewell *et al.* 2008). This wetland study includes an analysis of the LDI index at 100 m, 250 m, 500 m, and 1000 m buffer widths.

Table 4. Buffer widths used in various wetland studies

Buffer Widths (m)	Region	Study
300, 1000	Cuyahoga River Watershed in northeast Ohio	Ketterwell *et al.* 2008
100, 250, 500, 1000, 2000, 4000	Cuyahoga River Watershed in northeast Ohio	Fennessy *et al.* 2007
250, 1000	Upper Juniata Watershed in south-central Pennsylvania	Hychka *et al.* 2007
1000	Upper Juniata Watershed in south-central Pennsylvania	Wardrop *et al.* 2007
1000	Ohio	Mack 2006
1000	Central Pennsylvania	Miller and Wardrop 2006
100	Florida	Brown and Vivas 2005

Statistical Analysis

Microsoft Office Excel 2003 was used to perform basic descriptive calculations (sums and percentages) and calculate floristic and LDI indices. SAS 9.1 for Windows (2002-2003), a statistical software program, was used to run the Kruskal-Wallis test, analysis of variance (ANOVA), tests for normality, the Tukey's multiple comparison procedure, and linear regressions. Quantile-quantile (qq) plots and boxplots were used to visually assess normality. The tests for normality were Shapiro-Wilk, Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling. Because of the small sample size for each reservation (n = 3 for HR, n = 10 for MSR, and n = 4 for RRR), the Kruskal-Wallis test was used to determine statistical differences between reservations.

CHAPTER III

RESULTS

Each of the 17 wetland sites contained a unique plant community impacted by various factors within and outside the individual site. No significant differences were found between reservations in the range of wetland quality, size, and surrounding landscape disturbance with the exception of the 1000 m LDI between HR and RRR. Correlations between measures of wetland quality and size and surrounding land use were found for 5 variable combinations: 1) % wetland species and perimeter, 2) mean C of C and 250 m LDI, 3) FQAI and 250 m LDI, 4) FQAI and 500 m LDI, and 5) FQAI-WIS and 250 m LDI.

Indicators of Wetland Integrity

Species Richness

A total of 290 species were identified to species epithet or variety (Appendix D). Some specimens were identifiable only to genus and were included in 25 of the 162 genera. Overall, there were 41 (13%) sedge and rush species, 29 (9%) grass species, 177 (56%) herbaceous species, and 68 (22%) shrub and tree species. The sites with the highest number of species were MSWL034 (63), HKWL008 and RRWL021 (62), and MSWL014 (61). The sites with the lowest number of species were RRWL026 (29), MSWL012 (32), MSWL011 (34), and MSWL027 (38) (Table 5, Figure 7). There was no statistically significant difference between the mean species richness of the reservations ($p = 0.48$).

Table 5. Values for floristic quality indices

Wetland	Species Richness	% Non-native	% Wetland[1]	Mean C of C[2]	FQAI[3]	FQAI-WIS[4]
HKWL008	62	16	56	2.4	20.5	64.9
HKWL006	58	3	64	3.3	25.5	86.3
HKWL001	51	16	82	3.0	23.2	93.6
MSWL036	51	16	43	2.7	21.3	54.6
MSWL035	45	9	71	3.4	23.6	82.3
MSWL034	63	21	67	2.2	19.4	64.1
MSWL027	38	18	87	2.1	14.5	63.9
MSWL026	46	2	65	3.3	23.0	81.1
MSWL020	41	27	59	1.9	14.4	49.1
MSWL023	52	13	63	2.9	22.7	75.7
MSWL014	61	13	69	2.3	19.2	65.0
MSWL012	32	25	47	2.2	14.3	42.7
MSWL011	34	21	82	1.6	10.8	39.1
RRWL026	29	10	59	3.6	20.2	65.3
RRWL021	62	15	60	3.1	26.6	81.2
RRWL018	57	21	68	2.5	21.6	75.7
RRWL017	59	24	76	2.1	18.3	77.4

[1]includes OBL, FACW, and FAC species
[2]coefficient of conservatism
[3]Floristic Quality Assessment Index
[4]FQAI weighted with values associated with wetland indicator status (WIS)

The most common species, found at more than 50% of the sites, were *Carex tribuloides* (FACW+), *Leersia oryzoides* (OBL), *Glycera striata* (OBL), *Lysimachia nummularia* (OBL), *Parthenocissus quinquefolia* (FACU), *Polygonum hydropiperoides* (OBL), *Polygonum virginianum* (FAC), *Toxicodendron radicans* (FAC), *Acer rubrum*

(FAC), *Fraxinus pennsylvanica* (FACW), *Lindera benzoin* (FACW-), *Rosa multiflora* (FACU), and *Ulmus rubra* (FAC). *L. oryzoides* is an aggressive native grass and *R. multiflora* is an invasive shrub.

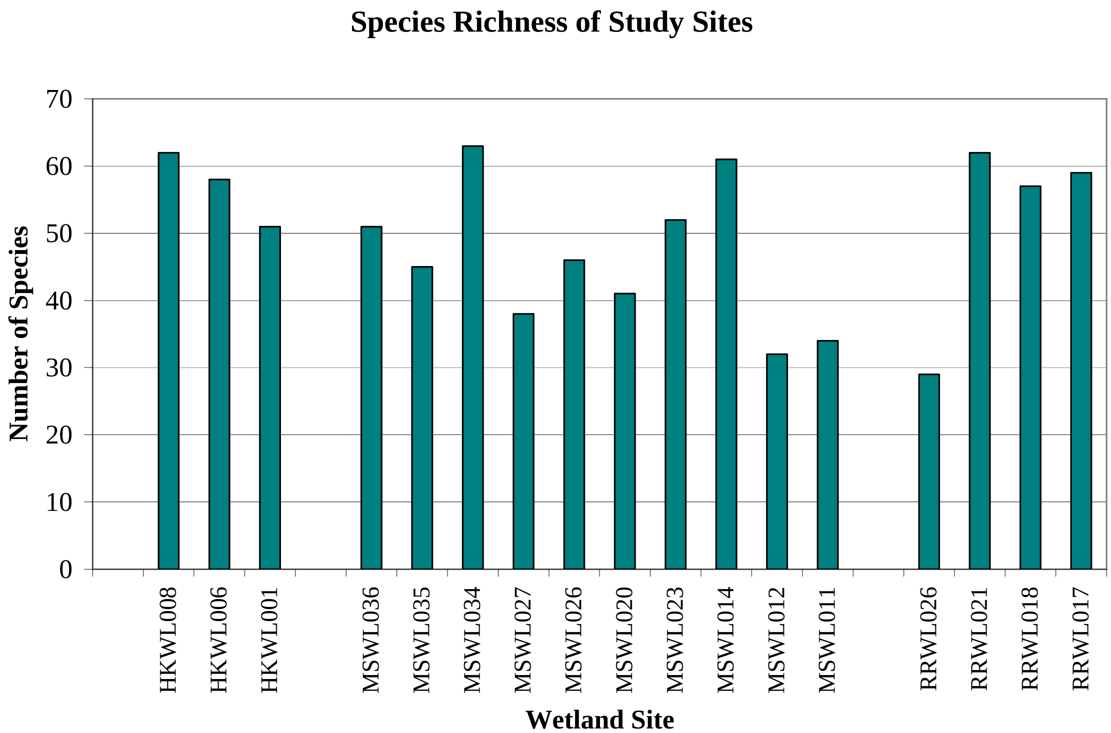

Figure 7. Species richness of each study site

Native and Non-native Species

Of 289 identified species that had a listed coefficient of conservatism (one species of the total 290 did not have a listed C of C), 240 (83%) were native and 49 were non-native (17%). There was no significant difference between the mean % of non-natives of the three reservations (p = 0.67).

The most common native plants as measured by % of total plots were *Parthenocissus quinquefolia* (82%), *Toxicodendron radicans* (76%), *Glycera striata*, *Leersia oryzoides*, and *Polygonum virginianum* (65%), and *Carex tribuloides* (59%). The most common non-native species were *Rosa multiflora* (76%), *Lysimacchia nummularia* (59%), *Solanum dulcamara* (41%), *Alliaria petiolata* (35%), *Ligustrum vulgare* (35%), and *Lythrum salicaria* and *Lonicera morrowii* (29%). Each of the other non-native species was found at less than five of the study sites.

The total percentage of non-native plant species was less than 25% at most study sites. Sites with the lowest % non-native species were MSWL026 (2%) and HKWL006 (3%) and sites with the highest % non-native species were MSWL020 (27%), MSWL012 (25%), and RRWL017 (24%) (Table 5, Figure 8). The % of non-native species increased with increasing landscape disturbance around sites in RRR, but this trend was not evident in HR and MSR.

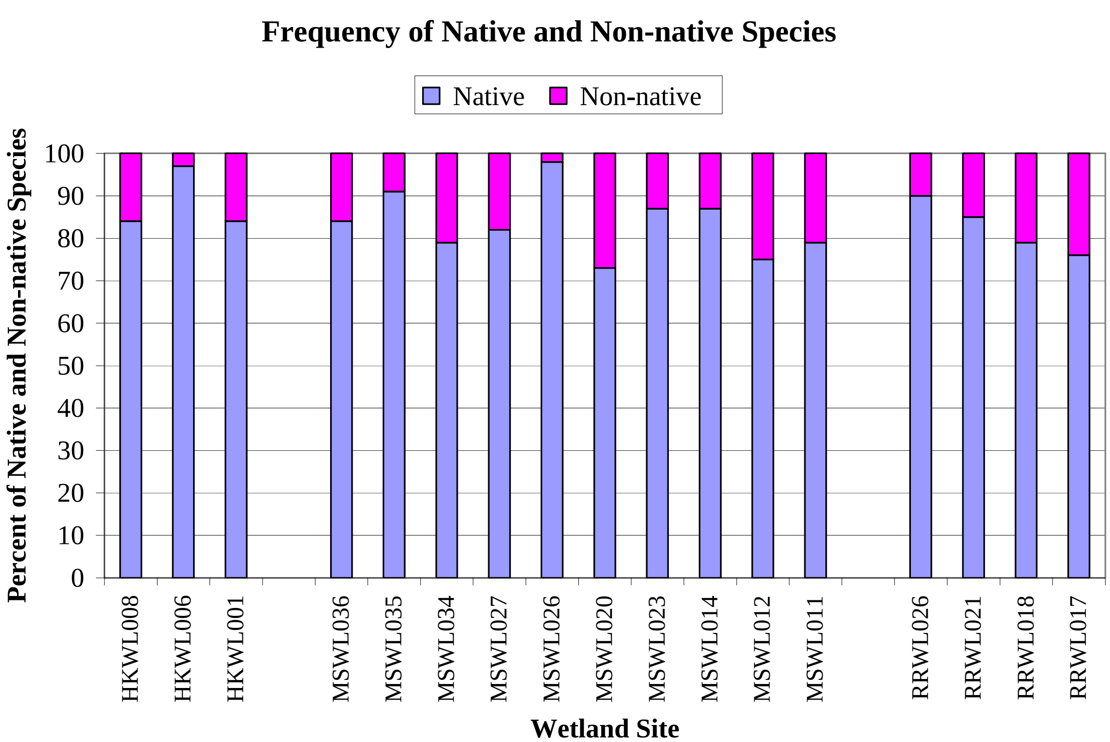

Figure 8. Frequency of native and non-native species at each study site

Wetland Indicator Status (WIS)

Of the 290 identified species, 286 had an assigned WIS (Appendix D). A large number of species (179 = 63%) were OBL, FACW, or FAC. Species in the FACU and UPL categories comprised a smaller number of species (107 = 37%). The plant communities in each of the study site plots included species from all WIS categories, except for MSWL027 which had no UPL species (Figure 9). The three sites with the highest % of wetland plants (OBL, FACW, and FAC) were MSWL027 (87%), a constructed mitigation wetland, HKWL001 (82%), a fringing wetland at the edge of Hinckley Lake, and MSWL011 (82%), the former Baldwin Lake, a filled quarry site that has evolved into a wetland (Table 5, Figure 9) . Sites with the highest % of FACU and UPL species were MSWL036 (57%) and MSWL012 (53%). There was no statistically significant difference between the mean % wetland species of the three reservations (p = 1.00)

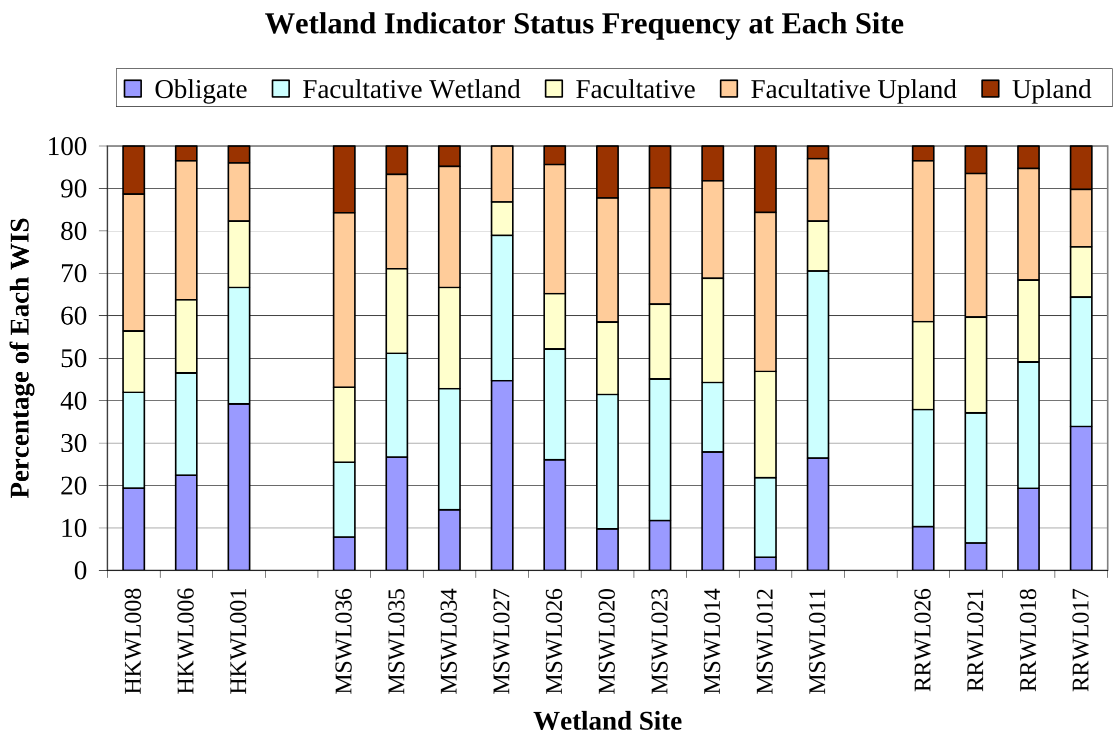

Figure 9. Frequency of wetland indicator status (WIS) categories at each study site

Coefficients of Conservatism (C of C)

The C of C distribution of the 240 native species was skewed toward the lower portion of the range, with 84% of the species assigned a C of C between 0 and 5 and 16% assigned a C of C between 6 and 10 (Figure 10). These results indicate that most of the species in the study wetlands are generalists and/or can exist in moderately disturbed areas (Table 2).

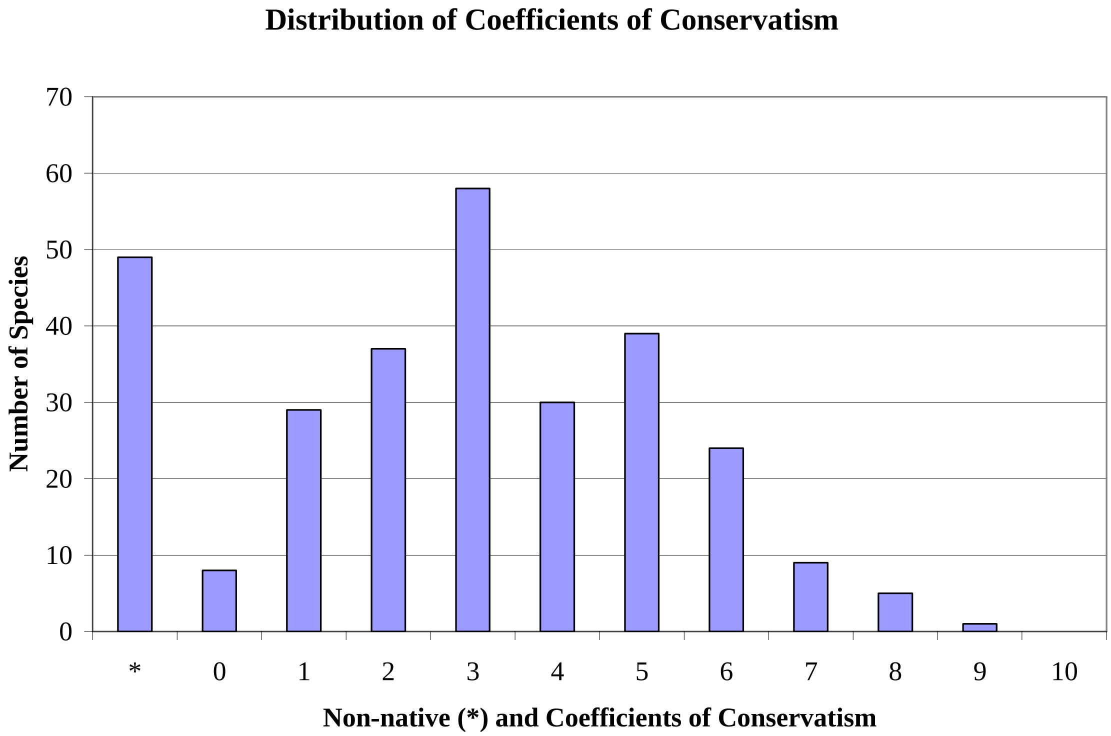

Figure 10. Distribution of the coefficients of conservatism (C of C) for study sites

Wetland MSWL011 had the lowest mean C of C (1.6) of all the study sites (Table 5, Figure 11). In contrast, RRWL026 had the highest mean C of C (3.6) that included a sedge, *Carex tuckermanii* (C of C = 8), and many high quality shrubs and trees such as *Fraxinus profunda* (C of C = 7). The mean C of C decreased with increasing landscape disturbance surrounding sites in RRR, but this trend was not evident in HR and MSR. There was no statistically significant difference between the mean C of C of the three reservations ($p = 0.38$).

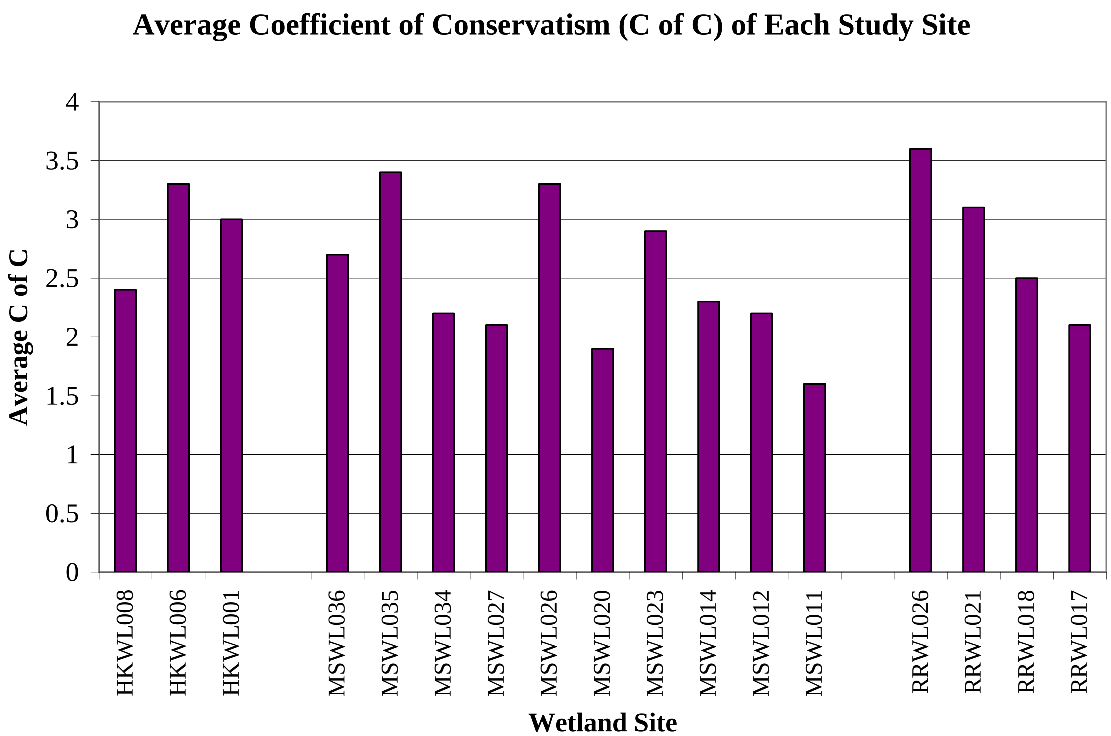

Figure 11. Average coefficient of conservatism (C of C) for each study site

Floristic Quality Assessment Index (FQAI)

The 240 native species were included in the FQAI calculations (Equation 1). The sites with the highest FQAI scores were RRWL021 (26.6) and HKWL006 (25.5) and the site with the lowest FQAI score was MSWL011 (10.8) (Table 5, Figure 12). There was no statistically significant difference between the mean FQAI scores of the reservations ($p = 0.20$).

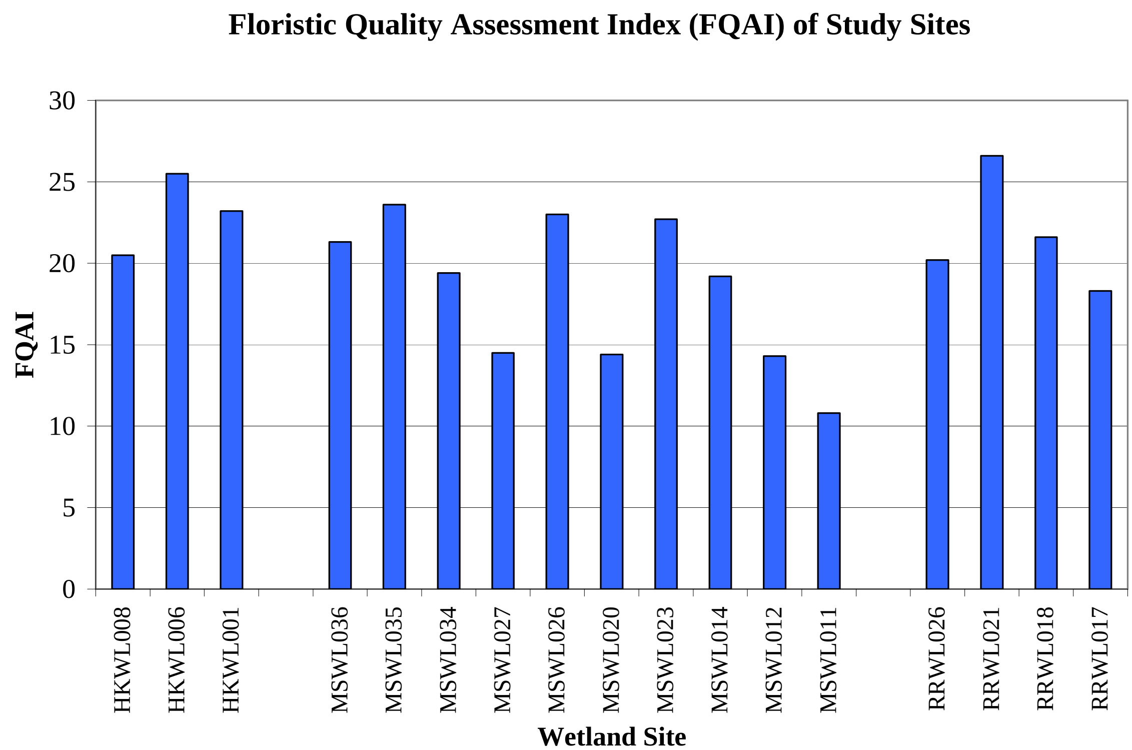

Figure 12. Wetland quality of study sites as measured by the floristic quality assessment index (FQAI)

Weighted Floristic Quality Assessment Index (FQAI-WIS)

The 240 native species used in the FQAI calculations were also included in the FQAI-WIS calculations (Equation 2). The quality ranking of the sites changed somewhat when compared to FQAI (Table 5, Figures 12 and 13). Site HKWL001 had the highest quality when measured using FQAI-WIS while HKWL006 maintained the 2nd highest rank and HKWL011 maintained the lowest rank. There was no statistically significant difference between the mean FQAI-WIS scores of the reservations ($p = 0.08$).

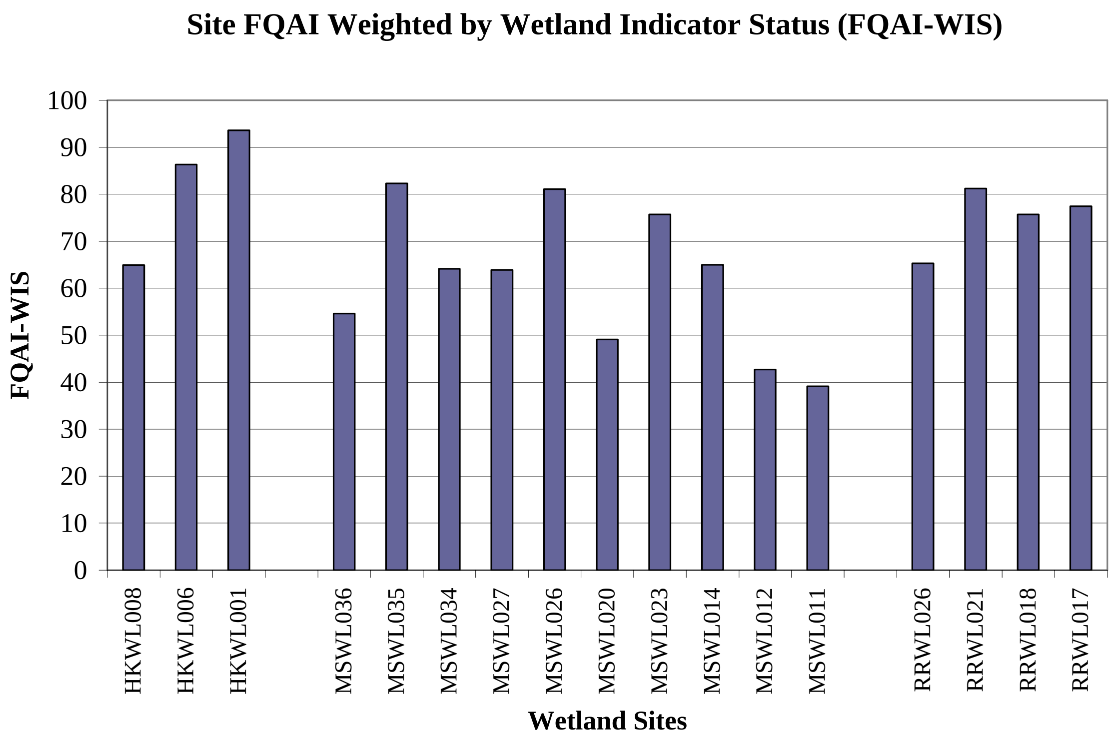

Figure 13. Wetland quality of study sites as measured by the weighted floristic quality assessment index (FQAI-WIS)

Wetland Perimeter, Area, and Perimeter/Area Ratio

Site MSWL023 had the smallest perimeter (240 m) and area (0.19 ha) while site MSWL027 had the largest perimeter (2731 m) and area (9.39 ha) (Table 6). There was a range of perimeter, area, and perimeter/area ratio within each reservation. There was no statistically significant difference between any pair of reservations when comparing mean perimeter ($p = 0.59$), mean area ($p = 0.94$), and mean perimeter/area ratio ($p = 0.73$).

Table 6. Values for predictor variables

Wetland	Perimeter[1] (m)	Area[1] (ha)[2]	Perimeter/ Area	LDI[3]			
				100 m	250 m	500 m	1000 m
HKWL008	1239	1.31	9.46	197.87	167.84	121.50	111.99
HKWL006	1451	4.17	3.48	6.85	23.80	37.68	49.79
HKWL001	364	0.38	9.58	0	5.12	18.25	11.27
MSWL036	246	0.30	8.20	43.27	115.27	82.19	114.06
MSWL035	1550	8.83	1.76	0	0	6.51	50.91
MSWL034	1346	3.24	4.15	0	0	0	24.04
MSWL027	2731	9.39	2.91	55.68	83.15	102.41	120.34
MSWL026	402	0.61	6.59	0	0	56.17	93.55
MSWL020	853	2.73	3.12	0	46.17	40.56	98.91
MSWL023	240	0.19	12.63	0	1.45	47.92	96.74
MSWL014	440	0.80	5.50	15.55	70.62	127.18	167.64
MSWL012	372	0.59	6.31	0	45.73	126.01	189.77
MSWL011	903	0.92	9.82	160.27	175.8	228.74	278.59
RRWL026	588	0.54	10.89	13.17	77.20	135.70	167.98
RRWL021	955	1.48	6.45	0	0	100.47	227.00
RRWL018	987	1.71	5.77	0	42.74	114.94	200.66
RRWL017	1657	3.94	4.21	52.38	156.98	206.46	264.62

[1]from CMP 2006 wetland inventory and assessment
[2]One hectare (ha) is equal to 10,000 m^2, 0.01 km^2, and 2.471 acres
[3]Landscape Development Intensity

Land Use and Land Cover (LULC) and Landscape Development Intensity Index (LDI)

Six of the 11 Ohio LULC categories (Frohn 2005) found in this study – deciduous forest, evergreen forest, open water, residential, commercial, and urban recreational – were in the 1000 m buffer of at least 9 of the wetland sites (Figure 14). Four categories – pasture, cropland, bare/mining, and woody wetland – were within the 1000 m buffer of less than 9 of the sites. Deciduous forest was the most common LULC, found in the 100 m buffer at all 17 sites. The bare/mining LULC appeared in the 1000 m buffer at only one site. One Ohio LULC category, herbaceous wetland, was not found in the landscape surrounding any of the sites.

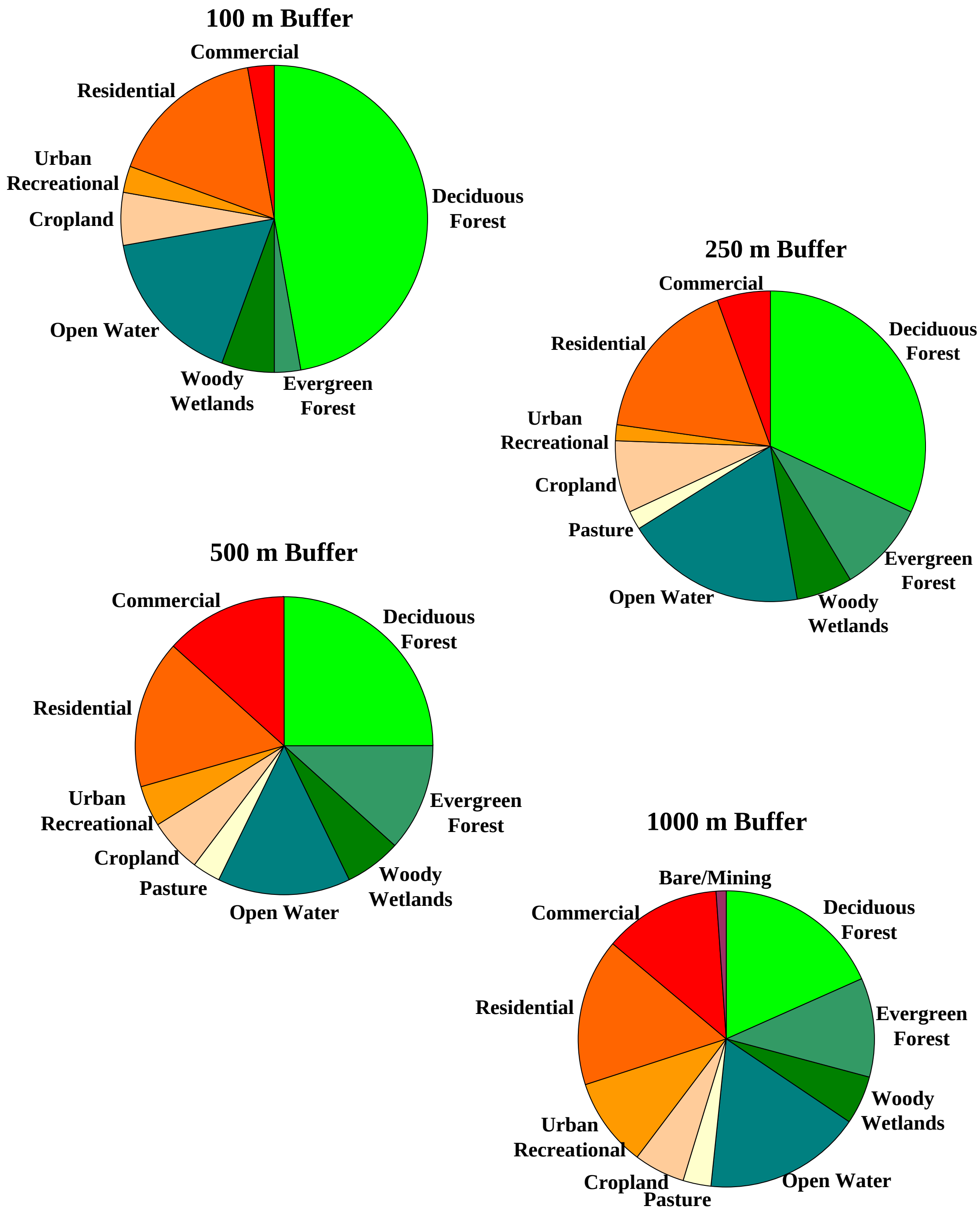

Figure 14. Land use and land cover (LULC) categories at the four buffer widths

In general, the number of LULC categories increased at each site as the buffer width increased. The number of sites that included open water increased from 100 m to 1000 m due to the proximity of Hinckley Lake, Wallace Lake, Baldwin Lake, and the Rocky River. The number of sites with commercial land use increased from one at 100 m to 12 at 1000 m. At 1000 m, only the three Hinckley sites, RRWL026, and RRWL018 had no commercial land use in the surrounding buffers. The number of sites with surrounding cropland increased from two at 100 m to four at 250 m, 500 m, and 1000 m. These four sites included all three in HR and MSWL036 at the far southern end of MSR.

The % of each LULC category in the buffers (Appendix E) determined the relative impact of the LULC on the wetlands and created a unique landscape signature for each site (Appendix F). Around most of the wetlands, the % of deciduous forest remained high throughout all the buffer widths due to the large forest tracts present in the reservations. The % of residential land around most of the MSR and RRR sites increased as the buffer width increased. At 1000 m, only HKWL006 and HKWL001 had no residential land use due to the rural landscape surrounding HR.

The average LDI score of HR sites decreased from 68 at 100 m to 58 at 1000 m primarily due to the decreasing influence of cropland (LDI coefficient = 3.247) around HKWL008, adjacent to Kellogg Road (Figure 4A). Cropland comprised 61% of the 100 m buffer contributing to an LDI index of 198. As the buffer width increased the percentage of cropland and the LDI index steadily decreased to 31% and 112 at 1000 m (Figure 15A).

Cropland was part of the landscape signature for the other two HR sites but at a much lower percentage because they are located away from the edge of the reservation, surrounded by more parkland than HKWL008. Approximately 90% of the 1000 m buffer around HKWL001 and HKWL006 is still in the park while only 50% of the 1000 m buffer around HKWL008 is parkland. The LDI scores for HKWL006, located near State Road that runs through the park, increased steadily from 7 at 100 m to 50 at 1000 m. These scores indicated very little human disturbance in all buffer zones. The LDI scores for HKWL001 increased from 0 at 100 m to 18 at 500 m and then slightly declined to 11 at 1000 m. Even though there are some trails adjacent to HKWL001, the buffers surrounding this site showed the lowest overall disturbance of all study wetlands due to its interior park location adjacent to Hinckley Lake and deciduous forest.

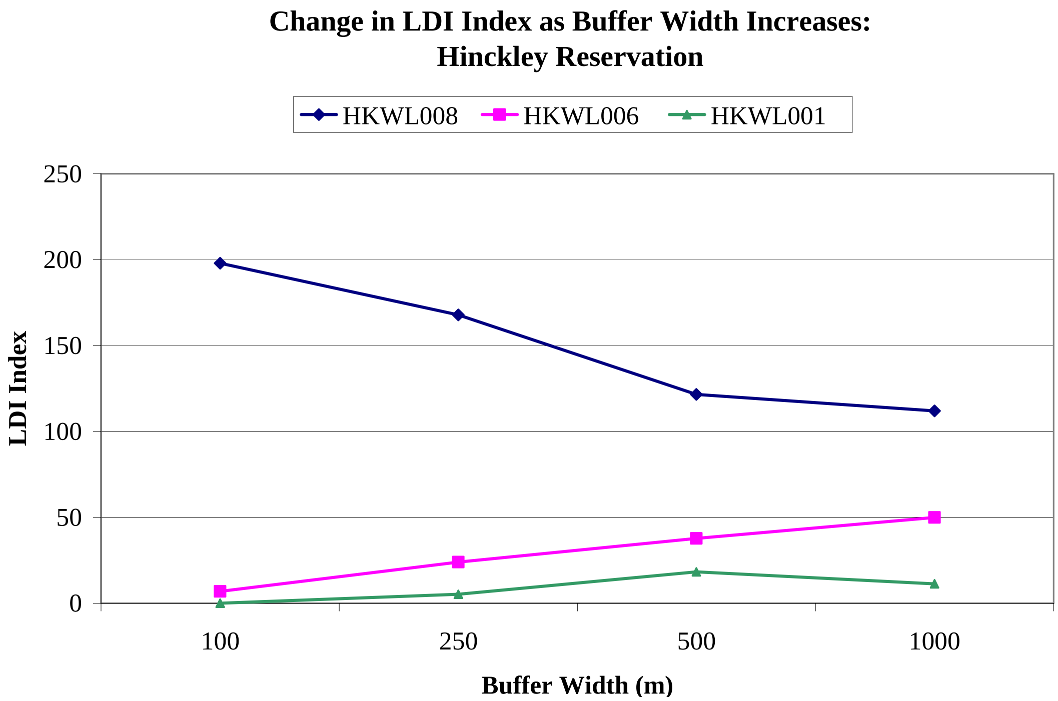

Figure 15A. Hinckley Reservation

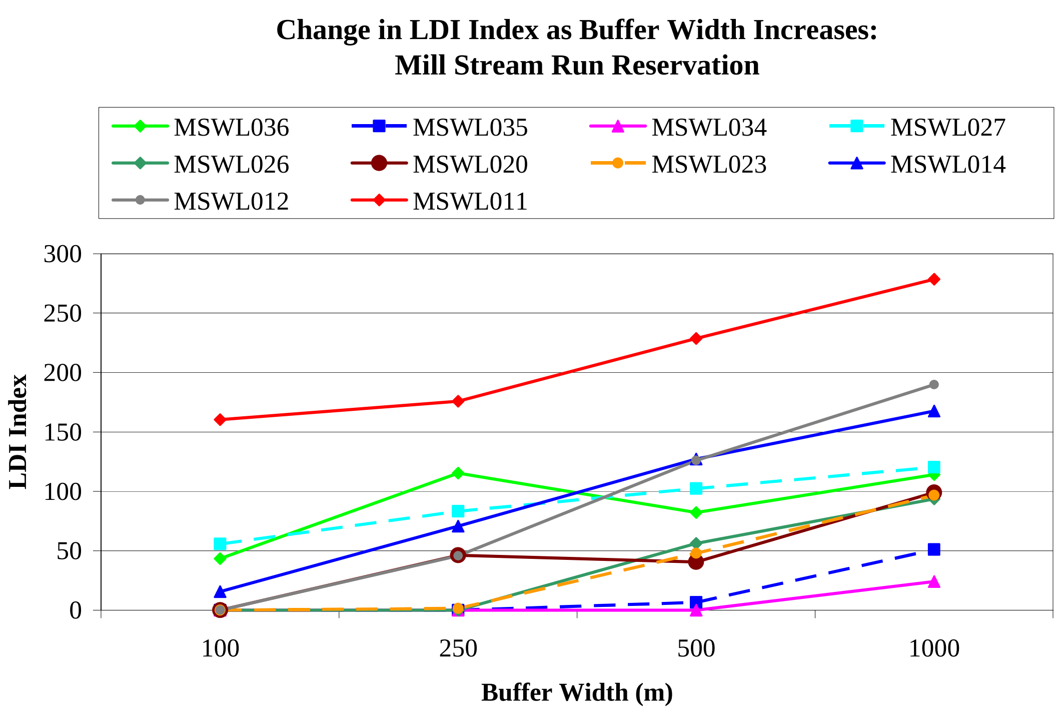

Figure 15B. Mill Stream Run Reservation

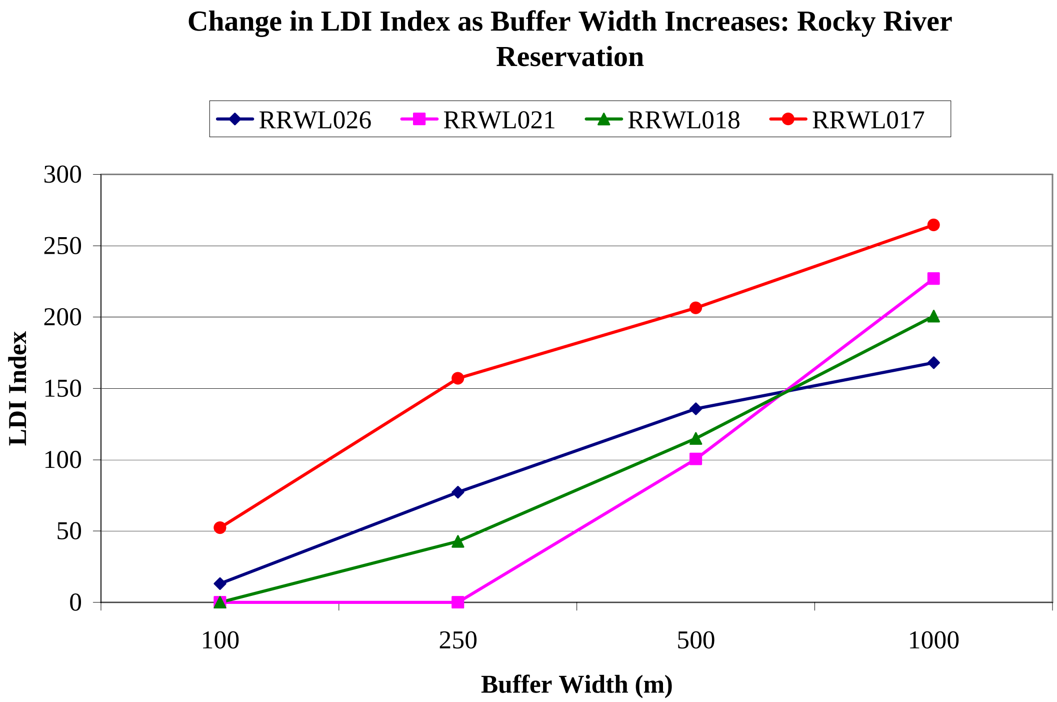

Figure 15C. Rocky River Reservation

Figure 15. Change in landscape development intensity (LDI) index at (A) Hinckley, (B) Mill Stream Run, and (C) Rocky River Reservations as buffer width increases

The average LDI scores of MSR sites increased from 28 to 124 between 100 and 1000 m. The 1000 m buffer zone included commercial and residential areas (LDI coefficients of 4.65 and 4.04) outside of the park which contributed to these LDI scores.

Nine MSR sites showed either a steady increase in LDI scores as the buffer width increased or some leveling between successive buffer zones (Figure 15B). The exception to this was MSWL036, which is located very close to Bennett Road at the bottom of a cliff at the far southern edge of MSR (Figure 4B). The change in % residential land use accounted for the decrease in LDI score from 115 to 82 between 250 m and 500 followed by an increase to 114 at 1000 m. Site MSWL011 was one of the MSR sites that showed a steady increase in LDI scores as the buffer width increased. It was different from the others, though, because it had a much higher LDI score at each of the buffer widths than the other nine MSR sites (Figure 15B) due to the residential classification (LDI coefficient = 4.04) of the large nearby grassy area, bath house, and parking lot.

Wetlands MSWL034 and MSWL035 are found in the broader southern region of the reservation surrounded mostly by deciduous forest with few trails. These sites had the lowest LDI scores in MSR (Figure 15B) and are comparable to HKWL006 and HKWL001 (Figure 15A). The residential land use impact on LDI scores increased in the middle and northern portions of the reservation where MSR boundaries constrict, providing very little buffer between the park and adjacent areas.

The average LDI scores in RRR increased steadily from 16 at 100 m (lower than both HR and MSR) to 215 at 1000 m (higher than both HR and MSR). All of the RRR sites showed increasing landscape disturbance as the buffer width increased, with one exception (Figure 15C). Wetland RRWL021, located between the Rocky River and a bridle trail, showed no disturbance at 100 m and 250 m, but the LDI scores increased substantially at 500 m and 1000 m due to the increasing influence of surrounding residential, commercial, and urban recreational areas. Site RRWL017 had the highest LDI scores due to its location adjacent to Big Met Golf Course. Golf courses, classified as urban recreational (LDI coefficient = 3.566), are considered to have a greater impact on natural ecosystems than cropland (LDI coefficient = 3.247) but a lesser impact than residential or commercial land use (LDI coefficients = 4.04 and 4.65).

Analysis of variance (ANOVA) was used to compare the mean reservation LDIs at 500 m and 1000 m because the qqplots and tests for normality showed a normal distribution of LDI scores at these buffer widths. Results of ANOVA for the 1000 m buffer width gave evidence that there was a difference between the mean LDIs of at least two reservations (p = 0.02). The Tukey's multiple comparison test showed that the statistically significant difference was between the mean LDIs of HR (57.68) and RRR (215.07) (Figure 16). Though not statistically significant due to the large variation, the mean LDI at 1000 m for MSR falls between the lower LDI of HR and the higher LDI for RRR.

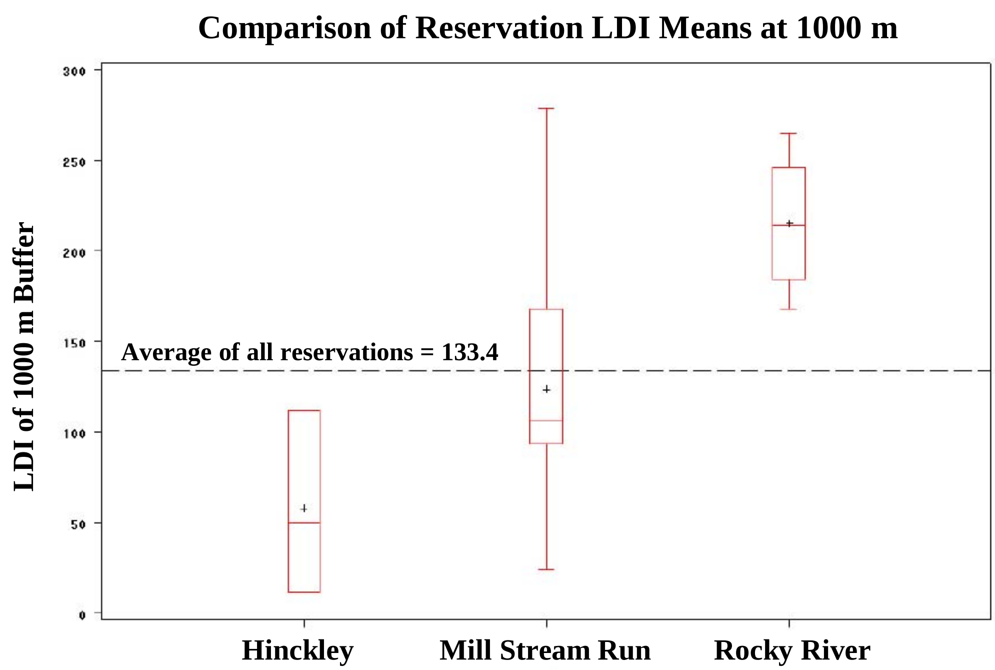

Figure 16. Boxplots showing the mean and range of the landscape development intensity (LDI) index at 1000 m for the three reservations included in this study

Results from Regression Analyses

Simple linear regressions were used to evaluate the relationships between all floristic indices and 1) wetland perimeter, 2) wetland area, 3) wetland perimeter to area ratio, and 4) LDI in 100 m, 250 m, 500 m, and 1000 m. Perimeter, area, and perimeter/area ratio were not predictors of wetland quality for this set of wetlands with one exception: % wetland species and perimeter were significantly correlated (Table 7 and Figure 17A). When the largest perimeter was removed from this data set, however, this correlation no longer existed. The regressions between 1) 250 m LDI and mean C of C, FQAI, and FQAI-WIS, and 2) 500 m LDI and FQAI were statistically significant and useful in predicting wetland quality (Table 7 and Figure 17B-E). The residual plots for these regressions showed no pattern, evidence that a straight line model was appropriate for this analysis. The R^2 values for all statistically significant regressions ranged from 0.27 to 0.31. This indicated that the proportion of variability in the floristic scores that can be explained by variability in the LDI indices produced a weak model fit.

Results of simple linear regressions showed similar correlations between FQAI and the predictor variables and between FQAI-WIS and the predictor variables, which indicates that including FACU and UPL species in the FQAI scores did not affect the final correlation results.

In addition to FQAI scores that included herbaceous and woody species, the FQAI was also calculated without shrubs and trees. Simple linear regressions of this FQAI with perimeter, area, perimeter/area ratio, and the LDIs of all four buffers yielded one statistically significant correlation: FQAI and 500 m LDI ($p = 0.04$ and $R^2 = 0.25$).

Table 7. Regression statistics: ability of size and landscape development intensity (LDI) indices to predict floristic quality. Statistically significant at p = 0.05 (*).

Response variable	Predictor variables	Slope	R^2	p
% Wetland Species	**Perimeter**	**< 0.01**	**0.28**	**0.03***
	Area	1.95	0.22	0.06
	Perimeter/Area	-0.70	0.03	0.47
	LDI 100 m	0.02	0.01	0.64
	LDI 250 m	0.01	< 0.01	0.84
	LDI 500 m	0.02	0.02	0.63
	LDI 1000 m	< 0.01	< 0.01	0.91
Mean C of C				
	Perimeter	< -0.01	0.05	0.38
	Area	< -0.01	< 0.01	0.92
	Perimeter/Area	0.03	0.02	0.56
	LDI 100 m	< -0.01	0.20	0.07
	LDI 250 m	**< -0.01**	**0.30**	**0.02***
	LDI 500 m	< -0.01	0.22	0.06
	LDI 1000 m	< -0.01	0.16	0.11
FQAI				
	Perimeter	< -0.01	0.03	0.51
	Area	-0.11	< 0.01	0.79
	Perimeter/Area	0.07	< 0.01	0.84
	LDI 100 m	-0.03	0.16	0.11
	LDI 250 m	**-0.04**	**0.31**	**0.02***
	LDI 500 m	**-0.03**	**0.27**	**0.03***
	LDI 1000 m	-0.02	0.16	0.11
FQAI-WIS				
	Perimeter	< 0.01	0.01	0.69
	Area	0.95	0.03	0.51
	Perimeter/Area	-0.43	< 0.01	0.74
	LDI 100 m	-0.10	0.15	0.12
	LDI 250 m	**-0.13**	**0.27**	**0.03***
	LDI 500 m	-0.11	0.20	0.07
	LDI 1000 m	-0.08	0.16	0.11

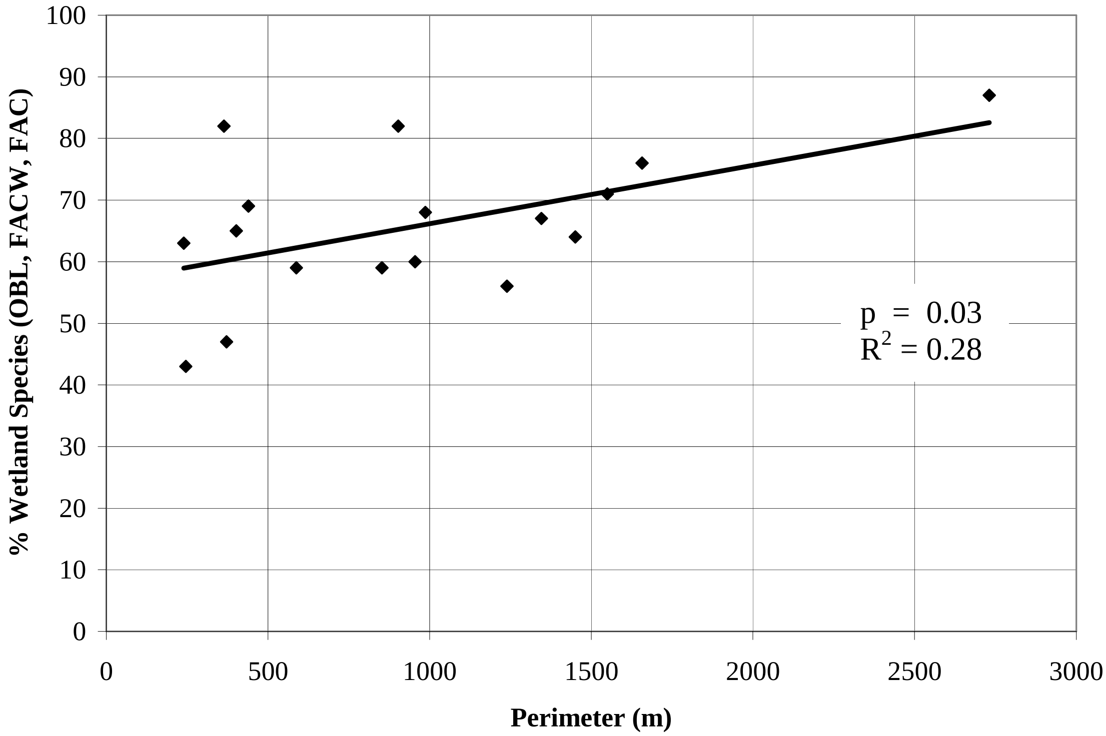

Figure 17A. Perimeter and % wetland species

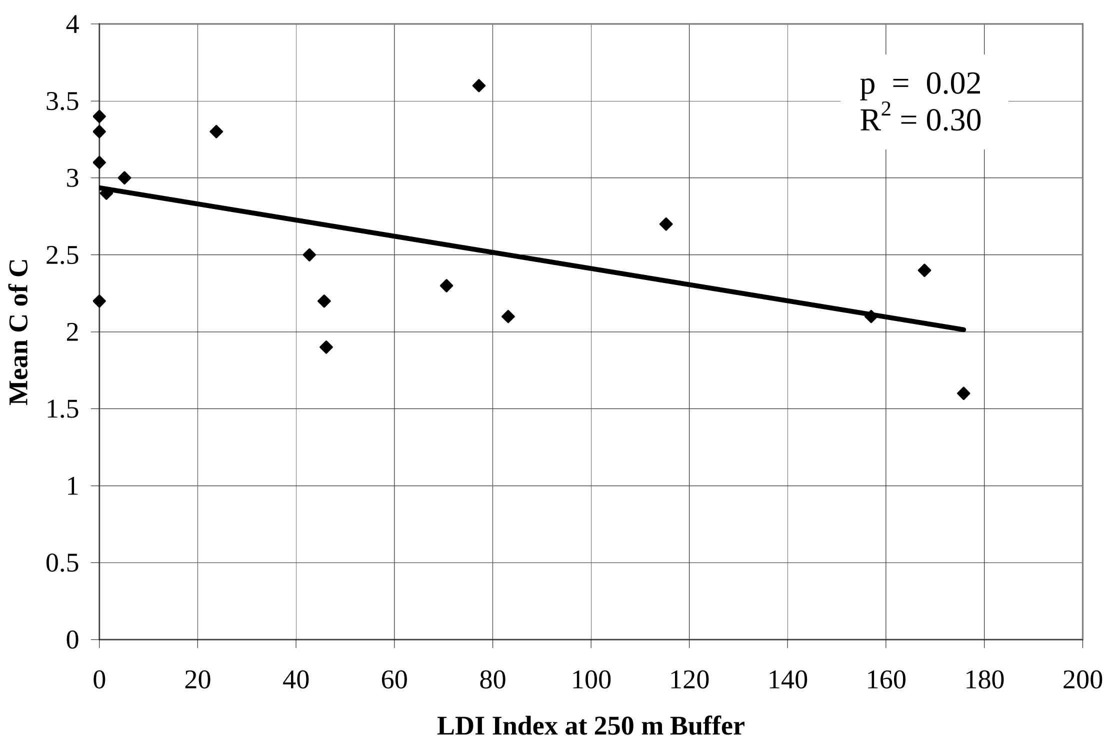

Figure 17B. LDI index at 250 m buffer and mean coefficient of conservatism

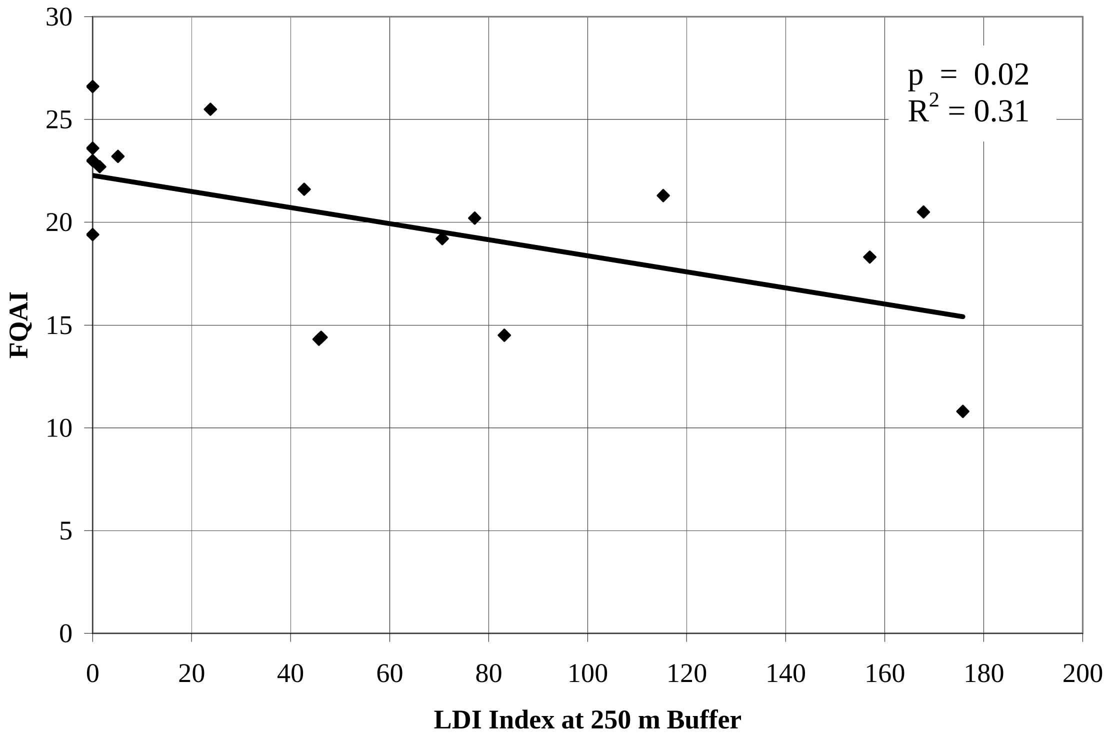

Figure 17C. LDI index at 250 m buffer and FQAI

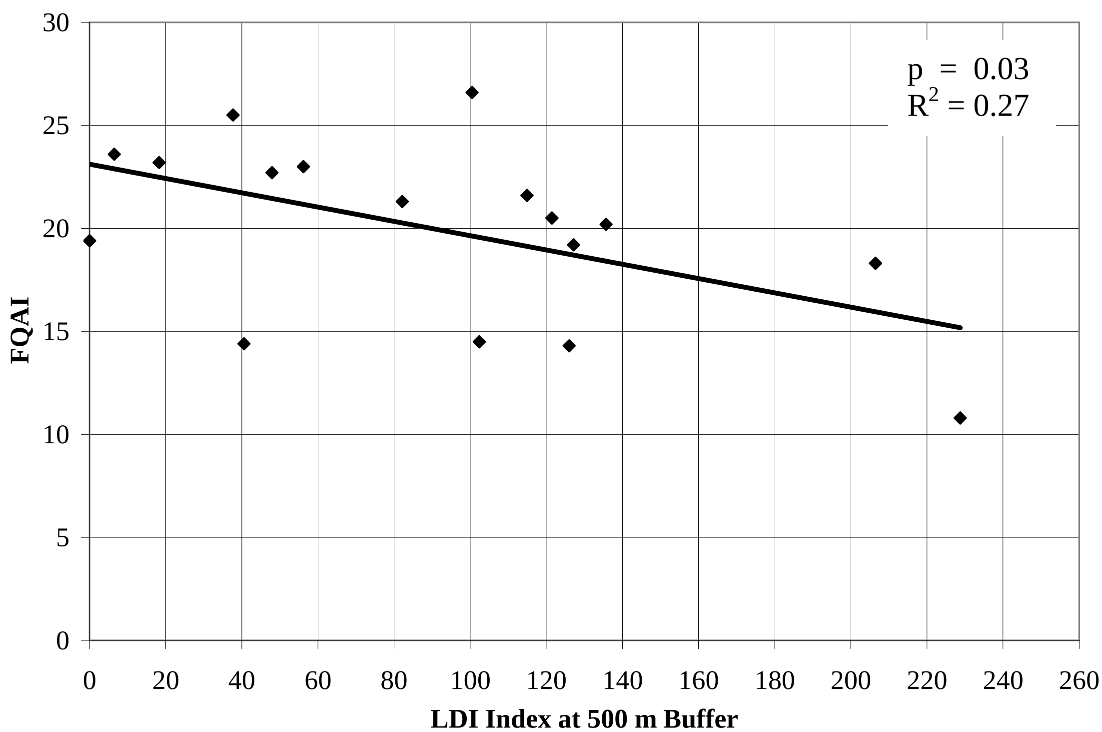

Figure 17D. LDI index at 500 m buffer and FQAI

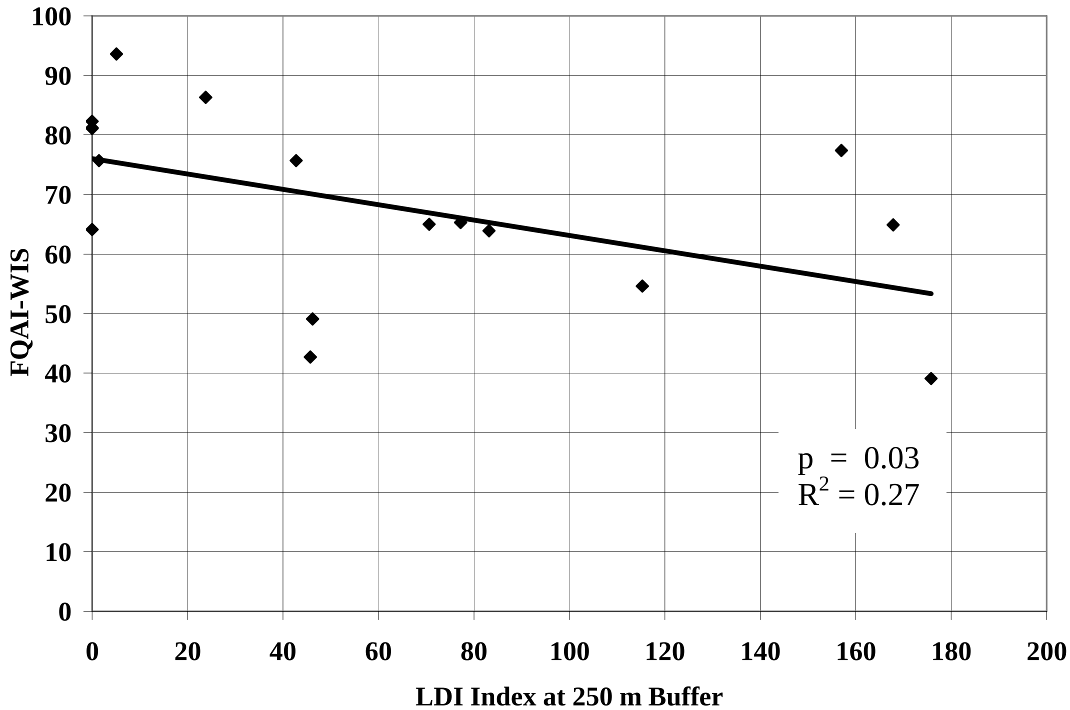

Figure 17E. LDI index at 250 m buffer and FQAI-WIS

Figure 17. Significant linear regressions between response (quality indicator metrics) and predictor (size and buffer LDIs) variables

CHAPTER IV

DISCUSSION

Floristic Indices

Plants are classified as native or non-native depending upon their modes of arrival and establishment in a particular area. Those that arrived through natural means and survived without human conservation efforts are native species (Morse *et al.* 2008). Plants brought into an area by humans, intentionally or unintentionally, are non-natives. The invasion of non-native species can transform the composition of a wetland, often with negative consequences on biotic interactions and nutrient and hydrologic cycles (Hager 2004). Once established along the perimeter of a wetland, these non-natives can spread rapidly because they have no natural biological controls and can change ecosystems so quickly that native species cannot adapt. They often form monotypic stands reducing biodiversity (USEPA 2003). Long and narrow wetlands and those with irregular shapes have larger perimeter/area ratios than wetlands with more regular geometric shapes and can provide multiple invasion pathways for non-natives. In this study no correlation was found between the % of non-natives and wetland size (perimeter, area, and perimeter/area ratio), suggesting that other factors may affect the %

of non-native species in these protected park wetlands.

Four wetland sites (MSWL026, HKWL006, MSWL035, and RRWL026) are of higher quality than the other study sites based on low percentages of non-native species and a high mean C of C. Three of these sites are located in areas that minimize potential hydrologic and human vectors.

Wetland MSWL026 is a 0.61 ha site located in the Rocky River flood plain and isolated from park activities. Its boundary includes a steep cliff, a gradual rise, and level areas (Figure 4B) that are 100% deciduous forest within the 250 m buffer (Appendix E). Trails that are close by are used infrequently. The Rocky River is approximately 0.25 km distant and, except during large floods, it does not provide a pathway for invasives. The high mean C of C (3.4) is influenced by the presence of *Galium palustre* (C of C = 9), the highest quality plant found in this study, and *Lysimachia terrestris* (C of C = 6), found only at one other study site. Wetland HKWL006 is a 4.17 ha site also isolated from human disturbances. Although near State Road, it is surrounded by deciduous forest and has no adjacent trails. This study found no recent evidence of flooding from the nearby Rocky River as a means of non-native introduction. This wetland had a mean C of C of 3.3 and was one of only two study sites where *Symplocarpus foetidus* (C of C = 7), a ground water indicator, was found. Another high-quality site is MSWL035, an 8.83 ha wetland with a mean C of C of 3.4 that includes forest and open water containing emergent and floating plants. It is in the broad southern portion of MSR which has more level terrain than RRR. The site is within 1 km of the river and is predominantly surrounded by forest. Some paths run close by, but the site has been impacted more from a beaver impoundment than by human activities. The low number of non-natives at

RRWL026, a 0.54 ha site, was surprising because it is located adjacent to Valley Parkway, a well-traveled road that runs the length of MSR and RRR. A bike and walking path also runs along the road. This site is found in a very narrow section of the park bordered by steep cliffs and not far from the river where the major land use is deciduous forest (Appendix E). Although this site had the lowest total species richness (29), it had the highest mean C of C (3.6) and supports habitat-conservative plants. A comparison of these four sites indicates that size, topography, and exposure to human disturbance do not appear to be common factors that account for their floristic quality.

Andreas *et al.* (2004) reported that approximately 23% of vascular plants found in Ohio are non-native. In this study, only 17% of the species were non-native. However, eight of Ohio's top ten non-native invasive species (Ohio Department of Natural Resources - ODNR 2008) were found in at least one of the study sites. Four of these eight species, *Rosa multiflora* (FACU), *Alliaria petiolata* (FACU), *Lonicera morrowii* (FACU), and *Lythrum salicaria* (FACW+), grow in at least five of the study sites with *R. multiflora* by far the most common (13 sites). Other invasive species from this top ten list found at fewer sites are *Lonicera japonica* (FAC-), *Rhamnus frangula* (FAC), *Phragmites australis* (FACW), and *Phalaris arundinacea* (FACW+). Andreas *et al.* (2004) also reported that the C of Cs for all Ohio native vascular plants are somewhat normally distributed with a fairly substantial skew toward the higher end of the range with 34% of Ohio's native plants showing a preference for disturbed ecosystems (C of C = 0-5) and 66% for undisturbed ecosystems (C of C = 6-10). In contrast, most of the species in this study (84%) do not show a preference for a specific habitat and/or can exist in moderately disturbed areas (Table 2).

Previous studies in Pennsylvania (Miller and Wardrop 2006) and Illinois (Matthews *et al.* 2005) also used the % of non-native species and FQAI to measure wetland quality. The Pennsylvania study region included forested ridges and agricultural and urbanized valleys. The Illinois study region contained a variety of land uses, including cropland and low-level urbanization. In the 40 Pennsylvania study wetlands, non-native species averaged 40.3% indicating a great deal of disturbance in the area. In comparison, the Illinois study non-native species averaged 9% for 231 wetlands. This current Ohio study averaged 15.9% for 17 wetlands indicating a lower disturbance than the Pennsylvania wetlands.

Andreas *et al.* (2004) cautioned that researchers should only compare FQAI scores when studies use survey methods of comparable sampling protocol and effort. The Pennsylvania study identified plants in nested plots within 1 acre at each wetland in a survey conducted from 1993 to 2000. The Illinois study did not indicate how the plant list was produced. In my survey, all plant species found within a 0.1 ha (~0.25 acre) plot (except for HKWL001) were identified over a four month sampling period. Since these three studies did not use the same methods, only general comparisons can be made. The average FQAI scores from my research fall in the middle of the range (19.9) suggesting that the RRW wetlands are of higher quality than the Illinois floodplain wetlands (15.42) and of lower quality than the Pennsylvania ridge and valley wetlands (22.9). The natural forests, rivers, and lakes of CMP may provide more protection from human impact than the large Illinois floodplain, with its history of agriculture, logging, and mining. In contrast, the Pennsylvania ridge wetlands were found in forested regions away from the urbanized valleys and likely included high quality wetlands that increased the average FQAI score for the Pennsylvania region.

This comparison points out the difficulties in choosing the proper floristic quality index to use when evaluating wetland quality. The Pennsylvania wetlands appear to have the lowest quality when evaluated by % non-natives but the highest quality when evaluated by FQAI. This suggests that a variety of floristic indices should be used for a more comprehensive assessment of wetland quality.

The FQAI as originally proposed and used by Swink and Wilhelm (1979) has been shown to accurately evaluate wetland quality (Lopez and Fennessy 2002, Andreas *et al.* 2004) and changes in plant communities (Waller and Rooney 2004). Others, though, have argued that non-native species and the influence of species richness should be considered when assessing wetlands (Ervin *et al*. 2006, Miller and Wardrop 2006). They suggest the use of an FQAI' that includes non-native species where $\sqrt{(N_{total\ species})}$ replaces $\sqrt{(N_{native})}$ in Equation 1 (FQAI' will be lower than FQAI due to the inclusion of non-natives in the total number of species) or the mean C of C, which is less sensitive to the effect of species richness. Matthews *et al.* (2005) cited studies to suggest that the mean C of C should be used when comparisons between wetlands of different sizes and/or habitat diversity is desired. When a wetland has a small number of species that are assigned high coefficients of conservatism, its quality ranking when using mean C of C will be higher than when using either FQAI (native species only) or FQAI' (native and non-native species) (Miller and Wardrop 2006). In this study, the correlations (p and R^2 values) between FQAI and FQAI' and all LDI buffers were the same. Additionally, the comparative quality ranking of the wetlands was very similar for FQAI and FQAI' scores.

In comparison, the mean C of C ranked RRWL026 much higher than when ranked by FQAI and FQAI' scores. When compared with other study wetlands, its quality (1 = highest quality and 17 = lowest quality) ranked 10th using FQAI, 9th using FQAI', and 1st using mean C of C. Even though RRWL026 contained a small number of species (30), many had a high C of C between 5 and 8, contributing to its high mean C of C value and higher quality rank. Once again, this difference shows that a variety of floristic indices is helpful when assessing wetland quality.

Wetland sites with a high number of FACU and UPL species may be undergoing ecological succession to a drier habitat due to urban stream syndrome associated with the Rocky River. Urban stream syndrome is characterized by altered stream channels, resulting from a flow rate that is much higher and increases much more quickly during storms than in rivers of more natural areas where there is less impervious surface in the watershed (Walsh *et al.* 2005). In addition, increased runoff from impervious surfaces produces deeper channel incision which in turn lowers the riparian water table, creating dry soils in the riparian zone (Mayer and Striz 2005).

Site MWSL036 is located at the bottom of a steep cliff, with residential areas at the top of the cliff. This wetland is partially bordered by a small stream with steeply incised banks. These steep banks most likely indicate a lower water table and may account for the high number of FACU and UPL species (57%). Site MSWL012 is a forest wetland located in Rocky River's riparian zone; it is also across the river from a large emergent wetland. Because a natural flood plain and minimal bank erosion exists in this part of the river (NOACA 2006), urban stream syndrome does not seem to play a role in the high number of FACU and UPL species (53%) present at this site.

Site RRWL026 contains conservative wetland and upland species that contributed to this site's relatively high mean C of C. Some of the conservative shrub and tree species were *Fraxinus profunda*: OBL-7, *Cephalanthus occidentalis*: OBL-6, *Platanus occidentalis*: FACW-7, *Fagus grandifolia*: FACU-7, and *Liriodendron tulipifera*: FACU-6, suggesting that this area is in a transitional stage between wet and dry habitat. These data also suggested that including FACU and UPL species gave a false assessment of wetland quality by inflating the FQAI value with high C of C non-wetland species but examination of the FQAI-WIS scores did not support this idea.

Land Use and Land Cover (LULC) and Landscape Development Intensity (LDI) Index

The predominant LULC categories around the study sites are deciduous forests, open water, and residential areas (Appendix F). Additionally, cropland is a major LULC category in the landscape surrounding HR sites. Because most of the wetlands are located near the reservation boundaries, the larger buffer zones include land outside of the park. Thus, even wetlands inside the park are subjected to impacts of LULC adjacent to the park, including increased runoff and accompanying materials from impervious surfaces.

The low LDIs of all buffer widths for HR sites reflect the rural nature of the surrounding landscape that was less impacted by human activities than the land around MSR and RRR. Increases in the MSR LDI scores between 100 m and 1000 m reflect the urbanizing nature of the surrounding landscape. Residential land use effect on LDI scores increases in the middle and northern portions of the reservation where MSR boundaries narrow, providing very little buffer between the park and adjacent areas. The RRR sites are located in the narrow belt between Rocky River and the park boundary which is defined by steep valley walls (Figure 4C). Around the RRR sites, the effect of human disturbance is minimal in the lower buffer widths but is more substantial at the 1000 m buffer because only approximately 25-33% of this buffer is inside the park boundaries.

The difference between the mean LDIs of HR and RRR at 1000 m can be explained by the more rural landscape outside HR in Medina County as compared to the relatively higher urbanized landscape outside RRR in Cuyahoga County. The large variance in the MSR mean LDI in 1000 m reflects the unevenness of residential and commercial land use in the urbanizing landscape. The differences between the mean LDI scores at the narrower buffer widths (100 m, 250 m, and 500 m) were not significant due to the high percentage of forest and open water (LDI coefficients = 0) that is present around the wetlands in both of these reservations, both inside and outside the park. Confirmation of these results could be provided by additional studies that would add to the current study's sample size at each of the reservations.

Landscape development intensity scores based on Minnesota LDI coefficients (Brandt-Williams and Campbell 2006) are available for wetlands in the Cuyahoga River (Fennessy *et al*. 2007b) and Rocky River Watersheds (this study). The Cuyahoga River Watershed (CRW), located immediately east of the RRW, covers approximately 2,101 km^2 (812 mi^2) and includes large portions of Cuyahoga, Geauga, Portage, and Summit Counties along with small portions of Medina and Stark Counties. An assessment of 232 wetlands in the CRW produced LDI scores for 100 m, 250 m, 500 m, 1000 m, 2000 m, and 4000 m.

The upper CRW, located in rural Geauga County where forest and agriculture land uses predominate (Fennessy *et al.* 2007b), and the RR East Branch and Mainstem subwatersheds, located in Cuyahoga and Medina where land uses are primarily forest, open water, and residential, have similar LDI indices at 100 m and 250 m (Figure 18). These comparable LDI scores may be due to similarities in the rural parklands surrounding the wetland sites where there is little human disturbance. At the wider 500 m and 1000 m buffers, differences between the upper CRW and the RR subwatersheds LDIs increase, reflecting increased human disturbance outside the park boundaries.

The RR subwatersheds have lower LDIs at all the buffer widths when compared to the middle and lower CRW, indicating less human disturbance. The middle CRW, located in Portage, Summit, and Stark Counties, includes forest, agriculture, wetland, and urban land uses while the lower CRW, located in Medina and Cuyahoga Counties, is extensively urbanized (Fennessy *et al.* 2007b). A comparison of the lower CRW with the RR East and Mainstem subwatersheds is especially informative in this study because both watersheds are in Medina and Cuyahoga Counties. The lower LDIs in the RR subwatersheds are most likely due to 1) the protection against development provided by the park system at the smaller buffer widths and 2) less commercial development adjacent to the park compared to the more industrial areas associated with two large cities, Cleveland and Akron, in the lower CRW. Further study that includes a greater number of wetlands in the RRW could determine if the low LDI scores in this study are an accurate reflection of the entire watershed or apply only to the protected parkland.

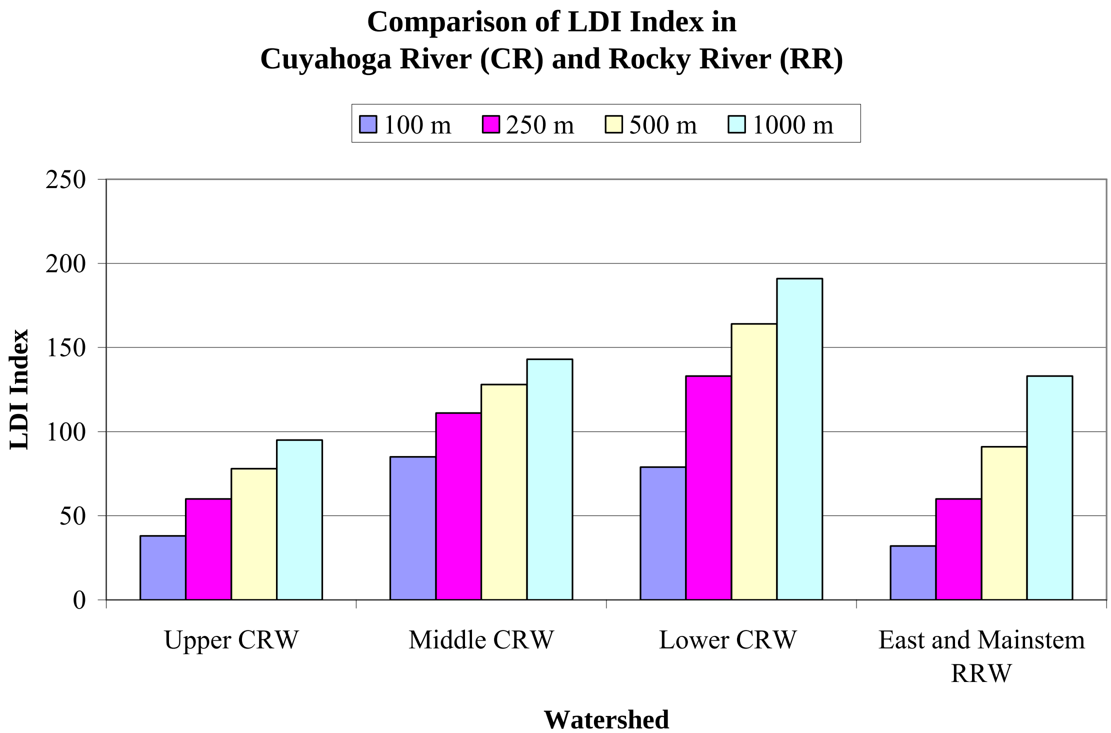

Figure 18. Comparison of buffer landscape development intensity (LDI) scores for wetlands in the Cuyahoga River and Rocky River watersheds

Wetland Quality and Wetland Size

A correlation between species richness and wetland area is predicted by the theory of island biogeography. This theory states that the size of an island and the distance from the species source pool determine the number of species that form the island's community (MacArthur and Wilson 1967). This theory has often been applied to wetlands due to their isolation within drier surrounding landscapes and fragmentation caused by landscape disturbance (Hall *et al.* 2004, Angeler *et al.* 2005). In a summary of studies investigating the relationship between area and species richness in wetlands, Hall *et al.* (2004) noted that many did not find the correlation between species richness and area. This relationship may not apply to wetlands in urban environments because human activities have reduced the number of source populations for small and large wetlands in the entire region. Additionally, some small isolated wetland areas may be more diverse than larger wetlands because they support remnant native populations. For example, the smallest site, MSWL023, had a species richness of 52 that included 87% native species.

Two recent studies have documented a strong positive correlation between species richness and wetland area ($\log_{10}$). Houlahan *et al.* (2006) investigated 58 wetlands in eastern Ontario, Canada between the St. Lawrence and Ottawa Rivers. These wetlands, average size of 66.7 ha and average species richness of approximately 159, were quite large with complex plant communities. Matthews *et al.* (2005) studied 231 wetlands in the Beaucoup Creek floodplain in southern Illinois. The wetlands in this study were smaller and less diverse than in the Houlahan *et al.* (2006) study, with a mean size of 0.82 ± 0.12 ha and a mean species richness of 31.20 ± 1.10. Even though the wetlands in the current study, mean size of 2.4 ± 2.8 ha and mean species richness of 49.5 ± 11.4, showed no correlation ($p = 0.70$) between species richness and wetland area ($\log_{10}$) for 17 CMP wetlands, there was a pattern in the results of these three studies. The wetlands with the largest average area had the highest average species diversity and those with the smallest average size had the lowest average species diversity, which suggests support for the theory of island biogeography as applied to wetlands. The lack of correlation between species diversity and area in this study may be a reflection of the small sample size ($n = 17$) and the relatively small size range (0.19 – 9.39 ha). Further study including a larger number of sites could determine if these results accurately describe the relationship between species richness and area for the park wetlands and for wetlands in the entire

RRW. Additionally, an extension of this study could determine if habitat heterogeneity is a better predictor of species richness than area (Baldi 2008).

The quality of some of the smaller wetlands was higher than the quality of some larger sites. Because small wetlands are essential in preserving a region's biodiversity (Semlitsch and Brodie 1998), they should be protected by park land management policies and regulations.

Wetland Quality and Surrounding Land Use

Because there was no significant correlation between wetland quality and LDI in the 100 m and 1000 m buffers and only a weak correlation between three of the floristic quality indices (mean C of C, FQAI, and FQAI-WIS) and LDI in the 250 m and 500 m buffers, other types of disturbance may contribute to wetland quality and should be investigated.

Nichols *et al.* (2006) suggested that an FQAI that includes shrubs and trees may not adequately express current disturbance since woody plants do not respond as quickly as herbaceous plants. When testing FQAI at different stratification layers against a disturbance index in adjacent and 500 m buffer zones, they found a significant correlation between FQAI and the disturbance index of the adjacent buffer in the herbaceous layer but no significance at the 500 m buffer level. Additionally, neither buffer scale was significant when all vegetation layers were grouped into one FQAI score. Since eight of my study sites were either forest depressions or included a substantial forested portion, I calculated FQAI with the shrubs and trees eliminated from the species list. The results showed that the presence of shrubs and trees did not mask the effects of current disturbance within the 250 m buffer and did not support the findings of Nichols *et al.* (2006).

Impervious and compacted surfaces may play a more important role in wetland quality than the aggregate LDI index, in particular as pathways for invasive species introduction. Roads, bike paths, hiking trails, and bridle paths are common in CMP and many are close to or adjacent to the wetland sites within the 100 m buffer. These surfaces are often under the forest canopy and therefore not included in calculating the LDI index. A study that includes these surfaces could determine if there is a significant correlation between this type of disturbance within the 100 m buffer zone and wetland quality. Impervious surface in the 250 m and 500 m buffers may also show a stronger correlation with wetland quality than seen with LDIs. The furthest sections of the 1000 m LDI may be too distant to have any significant affect on individual wetland quality in the park.

Prior land modifications such as ditches for agriculture could be more important to current wetland condition than present-day urbanization impacts (Ehrenfeld 2004). Before it was set aside as parkland, areal photos from the 1930s show that the Rocky River valley was primarily farmland, with large trees found only along the river (Thomas, personal communication, July 10, 2008). Grazing farm animals also adversely affected native plant diversity and contributed to lower floristic quality in the region. Other historical land use along the Rocky River included sandstone quarries which operated until 1939 (Case Western Reserve University 1997). These quarries were located in the region now occupied by the northern section of MSR, bordered by the city of Berea. Future studies could determine whether there is a stronger connection between wetland quality and past or present LULC, including agriculture and mining, or if the current wetland quality is due to a combination of past and present LULC influences.

The large population of white-tailed deer *(Odocoileus virginianus)* in CMP is currently impacting floristic quality (C. R. Thomas, personal communication, July 10, 2008). Deer browse on wetland species such as *Viburnum dentatum* and *Impatiens sp.* Deer-browsed plants were plentiful at most of the study sites. Over the past decade, the white-tailed deer population has varied from 14-60/mi^2 in MSR and 11-60/mi^2 in RRR (R. C. Tyler, personal communication, August 12, 2008). Although this density is not as high as that found in other CMP reservations (e.g. over 100/mi^2 in Bedford and Brecksville Reservations before deer management), it very likely played a role in the quality of wetlands in my study. An on-going CMP deer browse study will provide data to further explore this idea.

CHAPTER V

CONCLUSION

A park system provides an excellent outdoor lab in which the interactions between wetlands and surrounding land use and land cover, both natural and anthropogenic, can be studied. Intense anthropogenic disturbances such as agriculture and urbanization are generally not immediately adjacent to these park wetlands but are often found close by in the surrounding landscape. Thus, these protected wetlands can be placed into an ecological category that bridges the gap between strictly urban and rural wetlands. Data derived from studies of protected urban wetlands will both augment our knowledge of basic ecological principles and provide land managers with the information they need to effectively preserve and protect this valuable resource (Grayson 1999).

In order to adequately assess a wetland's condition, it is helpful to have both remote and on-site assessment methods (Wardrop *et al.* 2007). In my study, I had access to remote land use and land cover data to calculate the landscape development intensity index (LDI) for different buffer widths around each wetland site. I also had access to wetland sizes from previous on-site research conducted by CMP. My field work is an on-site method that provides a detailed survey of the plant community which is necessary to calculate floristic quality indices of each wetland site.

The hypothesis of this study states that wetland size is more accurate than surrounding land use as a predictor of wetland quality in publicly-owned protected wetlands along an urbanization gradient. I tested this hypothesis by examining the relationship between 1) wetland quality and size (perimeter, area, and perimeter/area ratio) and 2) wetland quality and landscape development intensity of four buffer widths. The results of this study did not support my hypothesis. When analyzing wetland quality and size, only perimeter was useful in predicting wetland quality (% wetland species) in this set of wetlands. This correlation, though, did not persist when the largest perimeter wetland was excluded from the data set. This research showed a negative correlation between all quality indices and LDI scores of all buffer widths, but only the correlations between mean C of C and 250 m LDI, FQAI and LDI 250 m LDI, FQAI and 500 m LDI, and FQAI-WIS and 250 m LDI were statistically significant. The other correlations between quality and LDI were not statistically significant but the p-values were less than 0.11, indicating a much stronger relationship between FQAI and LDI than between FQAI and size with much larger p-values (Table 7). This pattern suggests that watershed management practices should include a goal to reduce disturbance around small and large wetlands in the park itself as well as in the surrounding urban communities so that wetland quality can be maintained or improved.

Even though Cleveland Metroparks wetlands are surrounded by different land uses that contribute to landscape disturbance, the present quality of both small and large wetlands, as evaluated by species richness, % non-native species, and FQAI, compares favorably to wetlands in less urbanized regions. The challenge now is to maintain and/or improve their quality by continuing to assess their condition and the effect of landscape disturbance around the wetland. Protection provided by the park, especially in the long, narrow reservations, may not be sufficient to preserve the integrity of wetlands due to the impact of adjacent urban areas. Because wetland preservation is best accomplished at the watershed level, park resource managers should continue to be involved in regional watershed councils. If possible, adjacent land should be acquired to extend the buffer to 500 m to protect the park wetlands, one of our most valuable natural resources.

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APPENDICES

Appendix A. Latitude[1] and Longitude[2] of Site Rebar Stakes

Hinckley Reservation

Site Identification[3]	Map Assistance	Latitude	Longitude
HKWL008	Off Kellogg Road	41.21300	081.73449
HKWL006	Off State Road	41.21097	081.70592
HKWL001	Edge of Hinckley Lake	41.22120	081.71758

Mill Stream Run Reservation

Site Identification	Map Assistance	Latitude	Longitude
MSWL036	Off Bennett Road	41.29527	081.76474
MSWL035	Off West 130th Street	41.30809	081.78844
MSWL034	Royalview Picnic Area	41.30925	081.79379
MSWL027	Strongsville Wildlife Area	41.32395	081.80853
MSWL026	Chalet	41.32378	081.82013
MSWL020	Off Whitney Road	41.34467	081.84161
MSWL023	Off Eastland Road	41.34795	081.84540
MSWL014	South Quarry power lines	41.35316	081.85319
MSWL012	South Quarry woods	41.35574	081.85249
MSWL011	Along Baldwin Lake	41.35897	081.85695

Rocky River Reservation

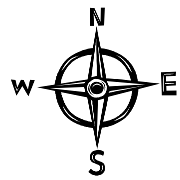
Site Identification	Map Assistance	Latitude	Longitude
RRWL026	Near Willow Bend picnic area	41.38884	081.86942
RRWL021	Along bridle path south of stables	41.42952	081.84886
RRWL018	Behind stables	41.43481	081.84151
RRWL017B	Big Met Golf Course	41.45113	081.83038
RRWL017A	Big Met Golf Course	41.45155	081.83155

[1]degrees north
[2]degrees west
[3]Wetland designations include abbreviations for each reservation (HK = Hinckley; MS = Mill Stream Run; RR = Rocky River); WL = wetland; 3 digit number = CMP 2006 identification number

Appendix B. Plot Orientations and Rebar Stake Positions

1. Each plot is oriented due north-south. The rebar stake is positioned at the northwest corner of the plot at each of these sites.

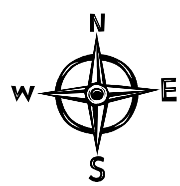
Wetland Site
MSWL036
MSWL035
MSWL034
MSWL027
MSWL020
MSWL014
RRWL026
RRWL018



6	5
7	4
8	3
9	2
10	1

2. Each plot is oriented due east-west. The rebar stake is positioned at the northwest corner of the plot at each of these sites.

Wetland Site
MSWL026
MSWL023
MSWL012
MSWL011

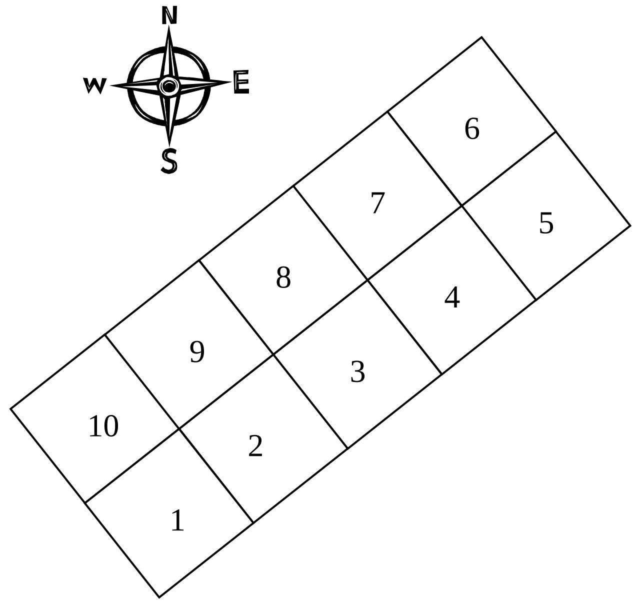


10	9	8	7	6
1	2	3	4	5

Appendix B. (continued)

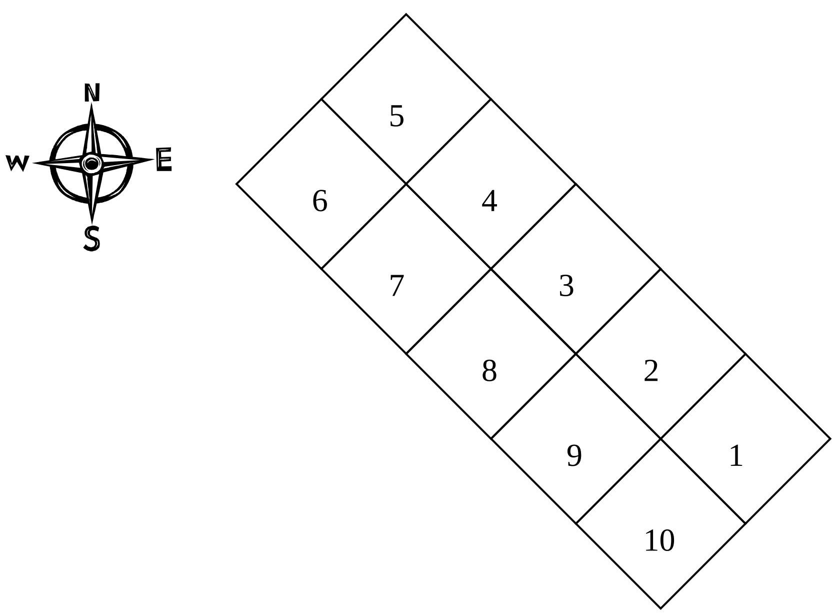
3. Each plot is oriented due northeast-southwest. The rebar stake is positioned at the plot boundary center between modules 1 and 10 at site RRWL021-12 and modules 5 and 6 at site HKWL006-15.

Wetland Site
HKWL006
RRWL021



4. This plot is oriented due northwest-southeast. The rebar stake is positioned at the plot boundary center between modules 5 and 6.

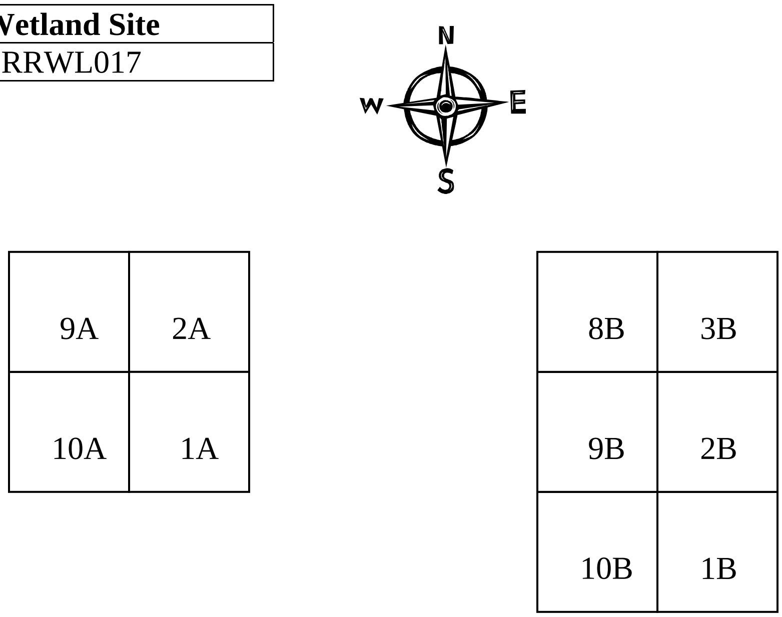
Wetland Site
HKWL008



Appendix B. (continued)

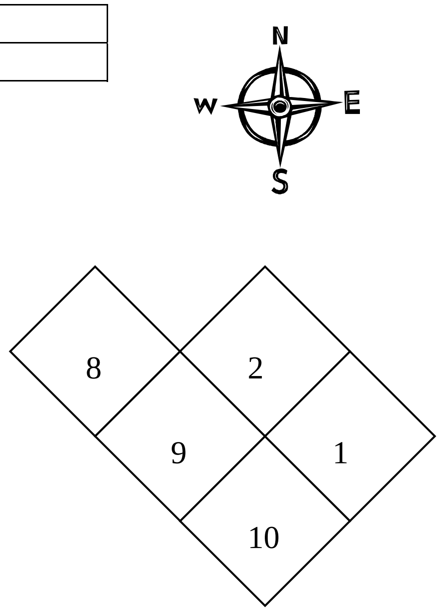
5. This plot is divided into two subplots, each of them oriented due north-south. The numbers were duplicated in the subplots to allow for easier data entry on the field sheet. The 4-module subplot is referred to as “A” and the 6-module subplot is referred to as “B” on the field sheet. The rebar stake is positioned at the northwest corner of each of these subplots.

Wetland Site
RRWL017



6. This plot is oriented due northwest-southeast. It only contains 5 modules due to the site’s shape. The rebar stake is positioned at the east corner of the plot.

Wetland Site
HKWL001



Appendix C. Sample Field Forms for Plant Survey (modified from Mack 2004)

Investigators	KT, CW, MG plot MG, JR survey
Site	MSWL036-05 Bennett
Date	7/9/07 plot 7/10/07 survey

Total Modules	10
Intensive Modules	2,3,8,9
Plot Configuration	20m X 50m
Total Area (ha)	0.1

Centerline Bearing	N/S
NW Corner Lat	41.29527
NW Corner Long	81.76474
Taken on	7/9/07 10:39:41 AM

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Site Pictures						
#	1435	1436	1437	1439	1440	
From	stream to	NE	NW	SW 10m	SE	
To	NE of plot	SW	SE	N	NW	

heard hooded warbler, bl cpd chickadee, am goldfinch
woodpecker (sp?)
east border along a small stream, west line at base of hill

					V	P	mod 2 level	corner 2 cover	mod 2 level	corner 4 cover	mod 3 level	corner 2 cover	mod 3 level	corner 4 cover	mod 8 level	corner 2 cover	mod 8 level	corner 4 cover	mod 9 level	corner 2 cover	mod 9 level	corner 4 cover
% open water							1		1	x	1		1	x	1		1	x	1		1	x
% unvegetated open water							1		1	x	1		1	x	1		1	x	1		1	x
% bare ground							1		1	x	1		1	x	1		1	6	1		1	6
% litter cover							1		1	x	1		1	x	1		1	5	1		1	4
Species name					**V**	**P**																
F	G	S/R	T/B																			
x				Gallium lanceolatum	1		4	5	3				3	3							2	3
	x			Agrostis capillaris	2		4	8	4		2	4	4				1	3	4	5		
	x			sample not located	3		4	4	4		3	4	3		2	5			4	5		
x				Sanicula gregaria	4		4	4			2	3					1	3	2	3	3	2
x				Parthenocissus quinquefolia			4	4					2	4			1	4	2	3	2	
x				Viola sp	5		4	5			4	6	4		4	3			4	4		
x				Solidago caesia	6		4	5														
		x		Carex sp	7		3	5							4	9						
x				Lysimachia nummularia			3	6	3		4	6	4		4	4			2	3		
			x	Rosa multiflora			3	4	4		3	6			3	7	2		2	3	3	2
x				Solidago gigantea	8		3	5	4						3	2	2					
x				Geum aleppicum	9		2	4			3	3	4		3	3	2		2	3	2	
x				Verbesina alternifolia	10		3	4											4	6		
x				Viola striata	11		3	5	3				4	4								
	x			Elymus virginicus	12		2	4	2				1	3								
x				Polygonum virginianum	13		2	3			3	4	3		3	4					2	4
	x			Elymus virginicus	14		4															
		x		Carex sp	15		2	4	3		3	5	3		3	5	2		3	3		
x				Lycopus sp	16		2	3			4	4			2	4					1	3
x				Toxicodendron radicans			2	2			2	3			3	4			3	3		
x				Circaea lutetiana	17		2	3	2		3	4					1	2				

Appendix C. (continued)

Investigators	KT, CW, MG plot MG, JR survey
Site	MSWL036-05 Bennett
Date	7/9/07 plot 7/10/07 survey

Total Modules	10
Intensive Modules	2,3,8,9
Plot Configuration	20m X 50m
Total Area (ha)	0.1

Centerline Bearing	N/S
NW Corner Lat	41.29527
NW Corner Long	81.76474
Taken on	7/9/07 10:39:41 AM

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1	2

Sub or super sample?
Total plot canopy closure %
Total plot herbaceous cover %

Tree Species (only live) M = plot module		dbh (inches)/module												Dead mod	#	
ash (have a sample)	M1	4.3	7.3	11.4		M2	7.1	22.7	15.7	17.0	14.5			1	1	
	M3	1.7				M4	19.8	11.5						2		
	M5	19.2	8.7	26.2	12.8	M7	6.0	13.5	16.9	11.5				3		
	M9	16.2	23.0			M10	12.2	5.3	12.5	11.5	9.1			4		
														5	6	
elm (not red bark) have sample	M1	7.5	7			M2	3.1							6	1	
	M3	8.3	1.5	6.9	5.8									7	2	
	M4	9.4	3.2	1.3	5.9	3.9	1.3	5.2	5					8	3	
	M5	2.9	2.9	2.5	4.4	1.6	2.6			M6	2.3			9	2	
	M9	7.9	20.6	11.2										10	1	
box elder	M1	3.9				M3	3.4	5.5								
hickory?	M1	2.1														
walnut	M6	15.3				M8	8.5			M9	16.8					
tulip	M7	11.7														
black cherry	M9	5.7														
basswood (picture #1438 trunk) leaf sample	M6	7.2	8.8			M8	2.0									
Shrub Species	mod	%cov			mod	%cov			mod	%cov			mod	%cov		
privet?	2	4			3											
honeysuckle	1				3	3			8	4			9	5		
viburnum - nannyberry?	1	5														
multiflora rose	1	4			8	4			3	6						

Appendix D. Species List with Authorities, Coefficients of Conservatism (C of C), Wetland Indicator Status (WIS), and Site Locations

#	Species Name - Sedges and Rushes	Authority	C of C	WIS	Site Locations[1]																
					H08	H06	H01	M36	M35	M34	M27	M26	M20	M23	M14	M12	M11	R26	R21	R18	R17
1	*Carex amphibola*	**Steud.**	5	FAC										**5**					**5**		
2	*Carex blanda*	**Dewey**	1	FAC					**1**												
3	*Carex comosa*	**Boott**	2	OBL			**2**				**2**										
4	*Carex crinita var. brevicrinis*	**Fernald**	3	[OBL]											**3**						
5	*Carex crinita var. crinita*	**Lam.**	3	OBL							**3**	**3**									
6	*Carex cristatella*	**Britton**	3	FACW				**3**			**3**		**3**								
7	*Carex emoryi*	**Dewey**	8	OBL										**8**							
8	*Carex gracillima*	**Schwein.**	4	FACU					**4**												
9	*Carex granularis*	**Muhl. ex Willd.**	3	FACW+						**3**											
10	*Carex grayi*	**J. Carey**	5	FACW+										**5**					**5**		
11	*Carex hyalinolepis*	**Steud.**	5	OBL																**5**	
12	*Carex intumescens*	**Rudge**	5	FACW+		**5**								**5**							
13	*Carex lacustris*	**Willd.**	5	OBL							**5**	**5**			**5**					**5**	
14	*Carex lupulina*	**Willd.**	3	OBL	**3**	**3**		**3**				**3**			**3**						
15	*Carex lurida*	**Wahlenb.**	3	OBL	**3**	**3**				**3**	**3**		**3**		**3**						
16	*Carex pensylvanica*	**Lam.**	3	[UPL]		**3**		**3**					**3**	**3**							
17	*Carex prasina*	**Wahlenb.**	8	OBL					**8**												
18	*Carex radiata*	**(Wahlenb.) Small**	6	[FAC]				**6**													
19	*Carex rosea*	**Schkuhr ex Willd.**	3	[UPL]				**3**													
20	*Carex scoparia*	**Schkuhr ex Willd.**	3	FACW								**3**	**3**								
21	*Carex sp.*		none[2]		**n**	**n**	**n**	**n**	**n**[2]			**n**			**n**	**n**			**n**		**n**
22	*Carex stipata*	**Muhl. ex Willd.**	2	OBL							**2**	**2**			**2**					**2**	
23	*Carex swanii*	**(Fernald) Mack.**	4	FACU	**4**							**4**			**4**						
24	*Carex tribuloides*	**Wahlenb.**	4	FACW+	**4**		**4**			**4**		**4**	**4**		**4**		**4**		**4**	**4**	**4**
25	*Carex tuckermanii*	**Dewey**	8	OBL														**8**			
26	*Carex vulpinoidea*	**Michx.**	1	OBL	**1**					**1**	**1**				**1**		**1**				
27	*Cyperus odoratus*	**L.**	4	FACW			**4**										**4**				**4**
28	*Cyperus sp.*		none									**n**									
29	*Eleocharis acicularis*	**Roem. & Schult.**	5	OBL																	**5**
30	*Eleocharis erythropoda*	**Roem. & Schult.**	4	OBL													**4**				
31	*Eleocharis obtusa*	**Roem. & Schult.**	1	OBL					**1**												

Appendix D. (continued)

#	Species Name - Sedges and Rushes		C of C	WIS	H08	H06	H01	M36	M35	M34	M27	M26	M20	M23	M14	M12	M11	R26	R21	R18	R17
					Site Locations																
32	***Eleocharis palustris***	**(L.) Roem. & Schult.**	5	OBL			**5**														
33	***Juncus acuminatus***	**Michx.**	4	OBL									**4**								
34	***Juncus effusus***	**L.**	1	FACW+	**1**					**1**	**1**	**1**	**1**		**1**		**1**				**1**
35	***Juncus tenuis***	**Willd.**	1	FAC-	**1**					**1**					**1**	**1**					**1**
36	***Juncus torreyi***	**Coville**	3	FACW													**3**				
37	***Scirpus atrovirens***	**Willd.**	1	OBL	**1**				**1**	**1**	**1**				**1**		**1**				
38	***Scirpus cyperinus***	**(L.) Kunth**	1	FACW+						**1**	**1**	**1**	**1**				**1**				
39	***Scirpus validus*** [3]	**Vahl**	2	OBL													**2**				
40	***Sparganium americanum***	**Nutt.**	6	OBL								**6**									
41	***Sparganium eurycarpum***	**Engelm.**	4	OBL			**4**		**4**												
	Species Name - Grasses																				
42	***Agrostis capillaris***	**L.**	*[4]	[UPL]	*			*		*		*			*					*	
43	***Agrostis gigantea***	**Roth**	*	FACW						*	*		*				*			*	
44	***Agrostis sp.***		none				**n**					**n**		**n**	**n**				**n**	**n**	**n**
45	***Agrostis stolonifera var palustris***	**(Huds.) Farw.**	*	FACW				*													*
46	***Anthoxanthum odoratum***	**L.**	*	FACU						*											
47	***Brachyelytrum erectum var. erectum***	**(Schreb.) P. Beauv.**	5	[UPL]										**5**							
48	***Bromus latiglumus***	**Scribn. ex (Shear) Hitchc.**	6	FACW										**6**							
49	***Cinna arundinacea***	**L.**	4	FACW		**4**	**4**							**4**	**4**				**4**	**4**	
50	***Danthonia spicata***	**(L.) P. Beauv. ex Roem. & Schult.**	4	[UPL]	**4**													**4**			
51	***Echinochloa muricata***	**(P. Beauv.) Fernald**	3	FACW+								**3**									
52	***Elymus canadensis***	**L.**	6	FACU+					**6**				**6**	**6**					**6**	**6**	
53	***Elymus hystrix***	**L.**	4	UPL				**4**	**4**												
54	***Elymus virginicus***	**L.**	3	FACW-			**3**	**3**						**3**					**3**		
55	***Eragrostis hypnoides***	**(Lam.) Britton, Sterns & Poggenb.**	4	OBL																	**4**
56	***Festuca filiformis*** [5]	**Pourr.**	*	[UPL]	*				*												
57	***Festuca pratensis***	**Huds.**	*	FACU-			*														
58	***Festuca sp.***		none																	**n**	
59	***Glycera striata***	**(Lam.) Hitchc.**	2	OBL	**2**	**2**		**2**	**2**	**2**		**2**		**2**	**2**	**2**				**2**	**2**
60	***Leersia oryzoides***	**(L.) Sw.**	1	OBL	**1**	**1**	**1**		**1**	**1**	**1**	**1**			**1**		**1**			**1**	**1**
61	***Leersia virginica***	**Willd.**	4	FACW	**4**	**4**		**4**	**4**			**4**		**4**					**4**		
62	***Milium effusum***	**L.**	7	[UPL]					**7**												

Appendix D. (continued)

#	Species Name - Grasses		C of C	WIS	H08	H06	H01	M36	M35	M34	M27	M26	M20	M23	M14	M12	M11	R26	R21	R18	R17
					Site Locations																
63	***Panicum clandestinum***	**L.**	2	FAC+			**2**						**2**	**2**							
64	***Panicum lanuginosum***	**Elliott**	3	FAC								**3**	**3**		**3**						
65	***Phalaris arundinacea***	**L.**	0	FACW+	**0**								**0**	**0**	**0**		**0**		**0**	**0**	**0**
66	***Phleum pratense***	**L.**	*	FACU									*****								
67	***Phragmites australis***	**(Cav.) Trin. ex Steud.**	0	FACW							**0**						**0**				
68	***Poa palustris***	**L.**	5	FACW						**5**											
69	***Poa pratensis***	**L.**	*	FACU						*****										*****	
70	***Setaria viridis***	**(L.) P. Beauv.**	*	[UPL]									*****								
	Species Name - Herbaceous																				
71	***Agrimonia gryposepala***	**Wallr.**	3	FACU	**3**	**3**		**3**		**3**									**3**	**3**	
72	***Agrimonia parviflora***	**Aiton**	2	FAC											**2**						
73	***Agrimonia sp.***		none		**n**		**n**				**n**										
74	***Alisma subcordatum***	**Raf.**	2	OBL			**2**								**2**						**2**
75	***Alisma triviale***	**Pursh**	6	[OBL]																**6**	
76	***Alliaria petiolata***	**(M. Bieb.) Cavara & Grande**	*	FACU-			*****	*****	*****					*****				*****	*****		
77	***Allium canadense***	**L.**	2	FACU				**2**	**2**						**2**	**2**		**2**		**2**	
78	***Allium tricoccum***	**Sol.**	5	FACU+															**5**		
79	***Apocynum cannabinum***	**L.**	1	FACU						**1**		**1**					**1**				
80	***Apocynum sp.***		none								**n**										
81	***Arisaema dracontium***	**(L.) Schott**	5	FACW										**5**					**5**		
82	***Arisaema triphyllum var triphyllum***	**(L.) Schott**	3	[FACU-]	**3**	**3**		**3**						**3**		**3**		**3**	**3**	**3**	
83	***Asclepias incarnata***	**L.**	4	OBL			**4**			**4**	**4**		**4**							**4**	**4**
84	***Aster lateriflorus***	**(L.) Britton**	2	FACW-	**2**	**2**	**2**												**2**		
85	***Aster linariifolius***	**L.**	8	[UPL]											**8**						
86	***Aster pilosus***	**Willd.**	1	UPL										**1**						**1**	**1**
87	***Aster pilosus var. pilosus***	**Willd.**	1	UPL	**1**									**1**	**1**						**1**
88	***Aster pilosus var. pringlei***	**(A. Gray) S. F. Blake**	1	UPL				**1**		**1**			**1**		**1**						
89	***Aster sp***		none									**n**	**n**	**n**							
90	***Aster umbellatus***	**Mill.**	3	FACW									**3**					**3**			
91	***Bidens comosa***	**(A. Gray) Wiegand**	3	FACW		**3**	**3**										**3**				**3**
92	***Bidens connata***	**Muhl.**	3	FACW+																**3**	
93	***Bidens frondosa***	**L.**	2	FACW									**2**	**2**	**2**		**2**			**2**	**2**
94	***Bidens sp.***		none																	**n**	

Appendix D. (continued)

					Site Locations																
#	Species Name - Herbaceous		C of C	WIS	H08	H06	H01	M36	M35	M34	M27	M26	M20	M23	M14	M12	M11	R26	R21	R18	R17
95	*Boehmeria cylindrica*	(L.) Sw.	4	FACW+		4	4		4	4								4	4		
96	*Calystegia sepium*	R. Br.	1	FAC-													1				
97	*Campsis radicans*	(L.) Seem.	1	FAC																1	
98	*Caulophyllum thalictroides*	(L.) Michx.	7	[UPL]															7		
99	*Ceratophyllum demersum*	L.	2	OBL			2														
100	*Chelone glabra*	L.	6	OBL		6															
101	*Cicuta bulbifera*	L.	3	OBL			3														
102	*Cicuta maculata*	L.	3	OBL											3						
103	*Circaea lutetiana*	L.	3	FACU	3	3		3						3					3		
104	*Cirsium arvense*	(L.) Scop.	*	FACU							*		*				*				*
105	*Cirsium vulgare*	(Savi) Ten.	*	FACU-									*								
106	*Conyza canadensis*	(L.) Cronquist	0	UPL																	0
107	*Crepis capillaris*	(L.) Wallr.	*	[UPL]																	*
108	*Crepis sp.*		none								n										
109	*Cryptotaenia canadensis*	(L.) DC.	3	FAC															3		
110	*Dryopteris carthusiana*	(Vill.) H. P. Fuchs	5	FAC+	5	5			5			5			5						
111	*Dryopteris marginalis*	(L.) A. Gray	5	FACU-		5															
112	*Epilobium coloratum*	Biehler	1	OBL	1	1					1										1
113	*Epilobium sp.*		none						n	n			n		n						
114	*Equisetum arvense*	L.	0	FAC																0	
115	*Equisetum sp.*		none					n													
116	*Erechtites hieraciifolia*	(L.) Raf.	2	FACU					2		2	2	2		2			2			2
117	*Euonymus fortunei*	(Turcz.) Hand.-Mazz.	*	[UPL]												*			*		
118	*Euonymus obovatus*	Nutt.	5	[FAC]					5												
119	*Eupatorium perfoliatum*	L.	3	FACW+	3		3			3	3										
120	*Eupatorium purpureum*	L.	5	FAC	5	5															
121	*Eupatorium rugosum*	Houttuyn.	3	[FACU]				3						3							3
122	*Euthamia graminifolia*	(L.) Nutt.	2	FAC							2				2						2
123	*Fragaria virginiana*	Duchesne	1	FACU						1											
124	*Galium lanceolatum*	Torr.	5	[UPL]	5			5													
125	*Galium palustre*	L.	9	OBL							9	9									
126	*Galium pilosum var pilosum*	Aiton	4	[UPL]			4														
127	*Galium sp.*		none							n											

Appendix D. (continued)

#	Species Name - Herbaceous		C of C	WIS	Site Locations H08	H06	H01	M36	M35	M34	M27	M26	M20	M23	M14	M12	M11	R26	R21	R18	R17
128	***Galium triflorum***	**Michx.**	4	FACU				**4**													
129	***Geranium maculatum***	**L.**	4	FACU		**4**			**4**									**4**			
130	***Geum aleppicum***	**Jacq.**	3	FAC				**3**		**3**	**3**									**3**	
131	***Geum canadense***	**Jacq.**	2	FACU	**2**	**2**										**2**				**2**	
132	***Geum sp.***		none		**n**	**n**				**n**				**n**	**n**			**n**	**n**	**n**	
133	***Geum virginianum***	**L.**	3	FAC-		**3**		**3**													
134	***Glechoma hederacea***	**L.**	*	FACU				*****											*****		
135	***Hackelia virginiana***	**(L.) I. M. Johnst.**	2	FACU				**2**													
136	***Hedera helix***	**L.**	*	[UPL]												*****					
137	***Helianthus tuberosus***	**L.**	3	FAC										**3**							
138	***Heliopsis helianthoides***	**(L.) Sweet**	5	[UPL]															**5**		
139	***Heracleum lanatum***	**Michx.**	4	FACU-															**4**		
140	***Hesperis matronalis***	**L.**	*	FACU-				*****						*****							
141	***Hieracium aurantiacum***	**L.**	*	[UPL]									*****								
142	***Hydrophyllum canadense***	**L.**	5	FACU															**5**		
143	***Hypericum punctatum***	**Lam.**	2	FAC-						**2**											
144	***Impatiens capensis***	**Meerb.**	2	FACW		**2**		**2**		**2**	**2**				**2**						
145	***Impatiens pallida***	**Nutt.**	3	FACW			**3**												**3**		
146	***Impatiens sp.***		2[6], 3	FACW	**2**				**2**			**2**		**2**			**2**			**2**	
147	***Lactuca sp.***		none		**n**																
148	***Laportea canadensis***	**(L.) Wedd.**	5	FACW										**5**					**5**		**5**
149	***Lemna minor***	**L.**	3	OBL			**3**														**3**
150	***Lemna sp.***		none														**n**				
151	***Lemna valdiviana***	**Phil.**	8	OBL			**8**		**8**												**8**
152	***Lilium canadense***	**L.**	5	FAC+			**5**														
153	***Lindernia dubia***	**(L.) Pennell**	2	OBL																	**2**
154	***Lobelia cardinalis***	**L.**	5	FACW+	**5**																
155	***Lotus corniculatus***	**L.**	*	FACU-									*****								
156	***Ludwigia palustris***	**(L.) Elliott**	3	OBL		**3**			**3**	**3**					**3**						**3**
157	***Lycopus americanus***	**Muhl.**	3	OBL			**3**	**3**						**3**							
158	***Lycopus sp.***		none					**n**	**n**	**n**		**n**			**n**				**n**	**n**	
159	***Lycopus uniflorus***	**Michx.**	3	OBL	**3**																

Appendix D. (continued)

#	Species Name - Herbaceous		C of C	WIS	H08	H06	H01	M36	M35	M34	M27	M26	M20	M23	M14	M12	M11	R26	R21	R18	R17
					Site Locations																
160	*Lycopus virginicus*	L.	3	OBL			3							3	3		3				3
161	*Lysimachia ciliata*	L.	4	FACW	4														4		
162	*Lysimachia nummularia*	L.	*	OBL	*		*	*		*	*			*	*				*	*	*
163	*Lysimachia terrestris*	(L.) Britton, Sterns & Poggenb.	6	OBL							6	6									
164	*Lysimachia thyrsiflora*	L.	6	OBL																	6
165	*Lythrum salicaria*	L.	*	FACW+					*								*	*		*	*
166	*Mentha arvensis var. canadensis*	(L.) Kuntze	2	FACW							2						2				2
167	*Mimulus alatus*	Aiton	6	OBL	6																
168	*Mitchella repens*	L.	5	FACU								5									
169	*Myosotis arvensis*	(L.) Hill	*	UPL			*														
170	*Myosotis laxa*	Lehm.	7	OBL			7														
171	*Myosotis scorpioides*	L.	*	OBL													*				*
172	*Nymphaea odorata*	Aiton	6	OBL			6														
173	*Onoclea sensibilis*	L.	2	FACW		2	2		2	2	2					2		2			2
174	*Oxalis corniculata*	L.	*	FACU						*											
175	*Oxalis sp.*		none												n						
176	*Oxalis stricta*	L.	0	UPL	0			0				0		0		0					0
177	*Parthenocissus quinquefolia*	(L.) Planch.	2	FACU	2	2		2		2	2	2	2	2	2	2		2	2	2	2
178	*Peltandra virginica*	(L.) Schott & Endl.	5	OBL			5														
179	*Penthorum sedoides*	L.	2	OBL	2	2															
180	*Pilea pumila*	(L.) A. Gray	2	FACW				2						2	2						
181	*Plantago major*	L.	*	FACU																	*
182	*Polygonum amphibium*	L.	4	OBL					4												
183	*Polygonum hydropiper*	L.	1	OBL							1	1			1				1		
184	*Polygonum hydropiperoides*	Michx.	6	OBL		6	6		6		6	6		6					6	6	6
185	*Polygonum pensylvanicum*	L.	0	FACW																	0
186	*Polygonum persicaria*	L.	*	FACW													*			*	*
187	*Polygonum sagittatum*	L.	2	OBL	2	2	2			2	2	2			2						
188	*Polygonum scandens*	L.	2	FAC															2		
189	*Polygonum sp.*		none		n							n								n	
190	*Polygonum virginianum*	L.	3	FAC	3	3		3	3	3				3	3	3		3	3	3	
191	*Polystichum acrostichoides*	(Michx.) Schott	3	FACU-		3															
192	*Potamogeton nodosus*	Poir.	3	OBL			3		3												

Appendix D. (continued)

#	Species Name - Herbaceous		C of C	WIS	H08	H06	H01	M36	M35	M34	M27	M26	M20	M23	M14	M12	M11	R26	R21	R18	R17
					Site Locations																
193	***Potentilla simplex***	**Michx.**	1	FACU-						**1**			**1**								
194	***Prenanthes altissima***	**L.**	4	FACU-	**4**							**4**									
195	***Prunella vulgaris***	**L.**	0	FACU+	**0**							**0**			**0**						
196	***Pycnanthemum incanum***	**(L.) Michx.**	6	[UPL]													**6**				
197	***Pycnanthemum muticum***	**(Michx.) Pers.**	6	FACW						**6**			**6**								
198	***Ranunculus acris***	**L.**	*	FAC+						*****											
199	***Ranunculus hispidus var. nitidus***	**(Elliott) T. Duncan**	4	FAC															**4**		
200	***Ranunculus sceleratus***	**L.**	1	OBL											**1**						**1**
201	***Ranunculus sp***		none											**n**							
202	***Rorippa palustris var palustris***	**(L.) Besser**	2	OBL																	**2**
203	***Rubus allegheniensis***	**Porter**	1	FACU-	**1**	**1**			**1**	**1**			**1**		**1**	**1**				**1**	
204	***Rubus flagellaris***	**Willd.**	1	FACU								**1**									
205	***Rubus hispidus***	**L.**	5	FACW		**5**						**5**									
206	***Rubus occidentalis***	**L.**	1	[UPL]		**1**									**1**						
207	***Rumex crispus***	**L.**	*	FACU	*****					*****				*****	*****						*****
208	***Sagittaria latifolia***	**Willd.**	1	OBL													**1**				
209	***Sanicula gregaria***	**E. P. Bicknell**	3	FACU				**3**						**3**					**3**		
210	***Scutellaria lateriflora***	**L.**	3	FACW+	**3**	**3**	**3**		**3**					**3**	**3**				**3**		
211	***Scutellaria x churchilliana*** [7]	**Fernald**	3	FACW+					**3**			**3**									
212	***Sedum ternatum***	**Michx.**	5	[UPL]				**5**													
213	***Senecio obovatus***	**Muhl.**	4	FACU-				**4**					**4**								
214	***Silphium perfoliatum***	**L.**	6	FACU		**6**															
215	***Sium suave***	**Walter**	6	OBL		**6**															
216	***Solanum dulcamara***	**L.**	*	FAC-		*****	*****				*****				*****		*****			*****	*****
217	***Solidago caesia***	**L.**	5	FACU				**5**													
218	***Solidago canadensis***	**L.**	1	FACU		**1**				**1**	**1**		**1**		**1**		**1**		**1**		
219	***Solidago flexicaulis***	**L.**	5	FACU						**5**											
220	***Solidago gigantea***	**Aiton**	3	FACW				**3**		**3**									**3**		
221	***Solidago patula***	**Muhl.**	6	OBL		**6**			**6**												
222	***Solidago rugosa***	**Mill.**	2	FAC				**2**											**2**		
223	***Solidago sp.***		none			**n**	**n**	**n**	**n**	**n**			**n**								
224	***Symplocarpus foetidus***	**(L.) Nutt.**	7	OBL		**7**													**7**		

Appendix D. (continued)

													Site Locations								
#	**Species Name - Herbaceous**		**C of C**	**WIS**	**H08**	**H06**	**H01**	**M36**	**M35**	**M34**	**M27**	**M26**	**M20**	**M23**	**M14**	**M12**	**M11**	**R26**	**R21**	**R18**	**R17**
225	***Teucrium canadense***	**L.**	3	FACW-															**3**		
226	***Teucrium canadense var canadense***	**L.**	3	FACW-										**3**							
227	***Thalictrum pubescens***	**Pursh**	5	FACW+												**5**					
228	***Toxicodendron radicans***	**(L.) Kuntze**	1	FAC	**1**	**1**		**1**	**1**	**1**		**1**	**1**		**1**	**1**		**1**	**1**	**1**	**1**
229	***Trifolium repens***	**L.**	*	FACU-			*****														
230	***Typha angustifolia***	**L.**	*	OBL			*****				*****		*****							*	
231	***Urtica dioica var. dioica***	**L.**	*	[FACU]										*****			*****		*****		
232	***Urtica dioica var. procera***	**(Muhl.) Wedd.**	1	[FAC-]													**1**				
233	***Urtica sp.***		none											**n**							
234	***Verbena hastata***	**L.**	4	FACW+						**4**	**4**		**4**								
235	***Verbena urticifolia***	**L.**	3	FACU	**3**									**3**			**3**				
236	***Verbesina alternifolia***	**(L.) Britton**	5	FAC			**5**	**5**		**5**		**5**		**5**			**5**		**5**		**5**
237	***Veronia gigantea***	**(Walter) Trel.**	2	FAC			**2**														
238	***Veronica arvensis***	**L.**	*	[UPL]									*****								
239	***Veronica filiformis***	**Sm.**	*	[UPL]	*****																
240	***Veronica officinales***	**L.**	*	FACU-	*****																
241	***Vinca minor***	**L.**	*	[UPL]															*****		
242	***Viola sororia***	**Willd.**	1	FAC-				**1**						**1**					**1**		
243	***Viola sp.***		none					**n**													
244	***Viola striata***	**Aiton**	5	FACW				**5**													
245	***Vitis riparia***	**Michx.**	3	FACW	**3**							**3**							**3**	**3**	**3**
246	***Wolffia columbiana***	**H. Karst**	3	OBL																	**3**
247	***Zizia aurea***	**(L.) Koch**	6	FAC															**6**		
	Species Name - Shrubs and Trees																				
248	***Acer negundo***	**L.**	3	FAC+				**3**						**3**					**3**	**3**	**3**
249	***Acer rubrum***	**L.**	2	FAC		**2**	**2**		**2**	**2**			**2**		**2**	**2**		**2**	**2**		
250	***Acer saccharinum***	**L.**	3	[FAC]																**3**	
251	***Acer saccharum***	**Marshall**	5	FACU-	**5**	**5**				**5**		**5**				**5**		**5**	**5**		
252	***Aesculus glabra***	**Willd.**	6	FACU+										**6**					**6**	**6**	
253	***Carpinus caroliniana***	**Walter**	5	FAC	**5**	**5**	**5**		**5**	**5**								**5**			
254	***Carya cordiformis***	**(Wangenh.) K. Koch**	5	FACU+								**5**						**5**	**5**		
255	***Carya ovata***	**(Mill.) K. Koch**	6	FACU-		**6**			**6**												
256	***Cephalanthus occidentalis***	**L.**	6	OBL														**6**			**6**

Appendix D. (continued)

#	Species Name - Shrubs and Trees		C of C	WIS	Site Locations																
					H08	H06	H01	M36	M35	M34	M27	M26	M20	M23	M14	M12	M11	R26	R21	R18	R17
257	***Cercis canadensis***	**L.**	3	FACU-		**3**															
258	***Cornus amomum var. amomum***	**Mill.**	2	FACW	**2**														**2**		
259	***Cornus florida***	**L.**	5	FACU+			**5**					**5**									
260	***Cornus racemosa***	**Lam.**	1	FAC-		**1**				**1**					**1**						
261	***Cornus sericea***	**L.**	3	FACW+						**3**										**3**	
262	***Crataegus coccinea***	**L.**	3	[UPL]						**3**						**3**					
263	***Crataegus crus-galli***	**L.**	3	FACU	**3**	**3**	**3**								**3**					**3**	
264	***Crataegus laevigata***	**(Poir.) DC.**	none					**n**													
265	***Crataegus punctata***	**Jacq.**	3	[UPL]																**3**	
266	***Fagus grandifolia***	**Ehrh.**	7	FACU														**7**			
267	***Fraxinus americana***	**L.**	6	FACU	**6**			**6**				**6**			**6**					**6**	
268	***Fraxinus pennsylvanica var. #1*** [8]	**Marshall**	3	FACW					**3**	**3**				**3**				**3**	**3**		**3**
269	***Fraxinus pennsylvanica var. #2*** [9]	**(Vahl) Fernald**	3	FACW	**3**	**3**	**3**		**3**		**3**			**3**		**3**				**3**	**3**
270	***Fraxinus profunda***	**Bush ex Britton**	7	OBL														**7**		**7**	
271	***Gleditsia triacanthos***	**L.**	4	FAC-											**4**						
272	***Juglans nigra***	**L.**	5	FACU				**5**													
273	***Ligustrum vulgare***	**L.**	*	FACU	*****			*****		*****					*****	*****			*****		
274	***Lindera benzoin***	**(L.) Blume**	5	FACW-	**5**	**5**				**5**		**5**		**5**				**5**	**5**	**5**	**5**
275	***Liriodendron tulipifera***	**L.**	6	FACU			**6**	**6**		**6**		**6**				**6**		**6**			
276	***Lonicera japonica***	**Thunb.**	*	FAC-	*****					*****											
277	***Lonicera morrowii***	**A. Gray**	*	FACU		*****							*****		*****	*****				*****	
278	***Lonicera sp***		none					**n**													
279	***Lonicera x bella*** [10]	**Zabel**	*	FACU												*****				*****	*****
280	***Morus alba***	**L.**	*	UPL																	*****
281	***Nyssa sylvatica***	**Marshall**	7	FAC											**7**	**7**					
282	***Ostrya virginiana***	**(Mill.) K. Koch**	5	FACU-	**5**					**5**											
283	***Pinus strobus***	**L.**	*	FACU	*****																
284	***Platanus occidentalis***	**L.**	7	FACW-												**7**		**7**		**7**	
285	***Populus deltoides***	**Marshall**	3	FAC										**3**		**3**			**3**	**3**	**3**
286	***Prunus serotina***	**Ehrh.**	3	FACU	**3**	**3**		**3**				**3**		**3**					**3**		
287	***Pyrus baccata***	**L.**	none							**n**											

Appendix D. (continued)

					Site Locations																
#	**Species Name - Shrubs and Trees**		**C of C**	**WIS**	**H08**	**H06**	**H01**	**M36**	**M35**	**M34**	**M27**	**M26**	**M20**	**M23**	**M14**	**M12**	**M11**	**R26**	**R21**	**R18**	**R17**
288	***Quercus bicolor***	**Willd.**	7	FACW+					**7**						**7**						
289	***Quercus palustris***	**Münchh.**	5	FACW								**5**	**5**		**5**	**5**				**5**	
290	***Quercus rubra***	**L.**	6	FACU-		**6**									**6**				**6**		
291	***Rhamnus frangula***	**L.**	*	FAC						*****			*****		*****						
292	***Ribes americanum***	**Mill.**	4	FACW		**4**															
293	***Ribes odoratum***	**J. C. Wendl.**	*	FACU															*****		
294	***Ribes sp.***		none										**n**								
295	***Robinia pseudoacacia***	**L.**	0	FACU-												**0**					
296	***Rosa multiflora***	**Thunb.**	*	FACU	*****		*****	*****	*****	*****	*****			*****	*****	*****		*****	*****	*****	*****
297	***Rosa setigera***	**Michx.**	4	FACU						**4**										**4**	
298	***Salix alba***	**L.**	*	FACW							*****										*****
299	***Salix eriocephala***	**Michx.**	2	FACW			**2**														
300	***Salix exigua***	**Nutt.**	1	OBL													**1**				
301	***Salix nigra***	**Marshall**	2	FACW+			**2**										**2**				
302	***Sambucus canadensis***	**L.**	3	FACW-							**3**		**3**								
303	***Smilax rotundifolia***	**L.**	4	FAC								**4**									
304	***Tilia americana***	**L.**	6	FACU				**6**	**6**												
305	***Ulmus americana***	**L.**	2	FACW-		**2**		**2**	**2**	**2**								**2**		**2**	
306	***Ulmus pumila***	**L.**	*	[UPL]												*****					
307	***Ulmus rubra***	**Muhl.**	3	FAC	**3**	**3**				**3**				**3**	**3**	**3**		**3**	**3**	**3**	
308	***Viburnum dentatum***	**L.**	2	FAC	**2**		**2**			**2**			**2**		**2**			**2**			
309	***Viburnum dentatum var. lucidum*** [11]	**Aiton**	2	FAC								**2**									
310	***Viburnum dentatum var. scabrellum***	**Torr. & A. Gray**	2	FAC					**2**	**2**			**2**			**2**				**2**	
311	***Viburnum lentago***	**L.**	5	FAC					**5**												
312	***Viburnum opulus var. opulus***	**L.**	*	FACW						*****						*****				*****	
313	***Viburnum plicatum*** [12]	**Thunb.**	*	NI[13]										*****							
314	***Viburnum prunifolium***	**L.**	4	FACU		**4**															
315	***Viburnum sp***		none					**n**													

Appendix D. (continued)

*** Plant identification follows Gleason & Cronquist (2003), Holmgren (1998), Braun (1967), Braun (1961), and USDA Plant List (2008).**

Assistance in plant identification was provided by John J. Mack and Charles R. Thomas, Division of Natural Resources, Cleveland Metroparks System

and James K. Bissell, Botany Department, Cleveland Museum of Natural History.

Plant samples will be deposited in the Herbarium of the Cleveland Museum of Natural History in accordance with collection permit procedures.

[1]H08=HKWL008; H06=HKWL006; H01=HKWL001;

M36=MSWL036; M35=MSWL035; M34=MSWL034; M27=MSWL027; M26=MSWL026; M20=MSWL020; M23=MSWL023; M14=MSWL014; M12=MSWL012; M11=MSWL011; R26=RRWL026; R21=RRWL021; R18=RRWL018; R17=RRWL017

[2]not used to calculate FQAI

[3]listed as *Schoenoplectus tabernaemontani* in Andreas *et al.* (2004)

[4]indicates a non-native species

[5]listed as *Festuca ovina* in Andreas *et al.* (2004)

[6]used to calculate FQAI

[7]According to Gleason and Cronquist (2003), this plant is intermediate between S. lateriflora (C of C = 3; WIS = FACW+) and S. galericulata (C of C = 6; WIS = OBL).

[8]variety is *pennsylvanica*

[9]variety is *subintegerrima*

[10]According to Gleason and Cronquist (2003), this plant is a hybrid of *L. tataria* and *L. morrowii* both of which are non-native and have a WIS of FACU.

[11]Andreas *et al.* (2004) excludes this variety; WIS may be closer to FACW since Gleason and Cronquist (2003) state that this plant is found in moist woods and swamps; not found in the USDA plant database

[12]According to Gleason and Cronquist (2003), this plant has escaped from cultivation.

[13]According to the USDA (2008a) plant database, the data is not sufficient to determine the WIS.

Appendix E. Land Use and Land Cover (LULC) Percentages

100 m buffer width

Study ID	deciduous	evergreen	pasture	crop	open water	residential	commercial	bare/mining	urban recr'l	herb. wetland	woody wetland
HKWL008	14.06	23.44	0.00	60.94	0.00	0.00	0.00	0.00	0.00	0.00	1.56
HKWL006	97.89	0.00	0.00	2.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HKWL001	54.29	0.00	0.00	0.00	45.71	0.00	0.00	0.00	0.00	0.00	0.00
MSWL036	89.29	0.00	0.00	0.00	0.00	10.71	0.00	0.00	0.00	0.00	0.00
MSWL035	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSWL034	91.97	8.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSWL027	87.89	0.00	0.00	0.00	0.00	1.04	11.07	0.00	0.00	0.00	0.00
MSWL026	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSWL020	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSWL023	83.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.13
MSWL014	96.15	0.00	0.00	0.00	0.00	3.85	0.00	0.00	0.00	0.00	0.00
MSWL012	87.18	0.00	0.00	0.00	12.82	0.00	0.00	0.00	0.00	0.00	0.00
MSWL011	20.66	0.00	0.00	0.00	39.67	39.67	0.00	0.00	0.00	0.00	0.00
RRWL026	96.74	0.00	0.00	0.00	0.00	3.26	0.00	0.00	0.00	0.00	0.00
RRWL021	79.66	0.00	0.00	0.00	20.34	0.00	0.00	0.00	0.00	0.00	0.00
RRWL018	86.89	0.00	0.00	0.00	13.11	0.00	0.00	0.00	0.00	0.00	0.00
RRWL017	79.75	0.00	0.00	0.00	6.33	5.70	0.00	0.00	8.23	0.00	0.00

Appendix E. (continued)

250 m buffer width

Study ID	deciduous	evergreen	pasture	crop	open water	residential	commercial	bare/mining	urban recr'l	herb. wetland	woody wetland
HKWL008	15.73	24.27	0.00	51.69	0.00	0.00	0.00	0.00	0.00	0.00	8.31
HKWL006	92.46	0.00	0.00	7.33	0.22	0.00	0.00	0.00	0.00	0.00	0.00
HKWL001	48.31	6.42	2.70	0.68	41.89	0.00	0.00	0.00	0.00	0.00	0.00
MSWL036	69.60	0.00	0.00	9.52	0.00	20.88	0.00	0.00	0.00	0.00	0.00
MSWL035	98.11	1.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSWL034	96.00	3.11	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00
MSWL027	80.24	0.00	0.00	0.00	1.34	4.02	14.39	0.00	0.00	0.00	0.00
MSWL026	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSWL020	87.71	1.65	0.00	0.00	0.00	0.00	9.93	0.00	0.00	0.00	0.71
MSWL023	75.09	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	24.56
MSWL014	79.75	0.00	0.00	0.00	2.76	17.48	0.00	0.00	0.00	0.00	0.00
MSWL012	81.13	0.00	0.00	0.00	7.55	11.32	0.00	0.00	0.00	0.00	0.00
MSWL011	27.71	0.00	0.00	0.00	28.92	42.41	0.96	0.00	0.00	0.00	0.00
RRWL026	80.89	0.00	0.00	0.00	0.00	19.11	0.00	0.00	0.00	0.00	0.00
RRWL021	90.42	0.00	0.00	0.00	9.58	0.00	0.00	0.00	0.00	0.00	0.00
RRWL018	80.53	0.00	0.00	0.00	8.89	10.58	0.00	0.00	0.00	0.00	0.00
RRWL017	52.10	0.00	0.00	0.00	7.78	29.34	0.00	0.00	10.78	0.00	0.00

Appendix E. (continued)

500 m buffer width

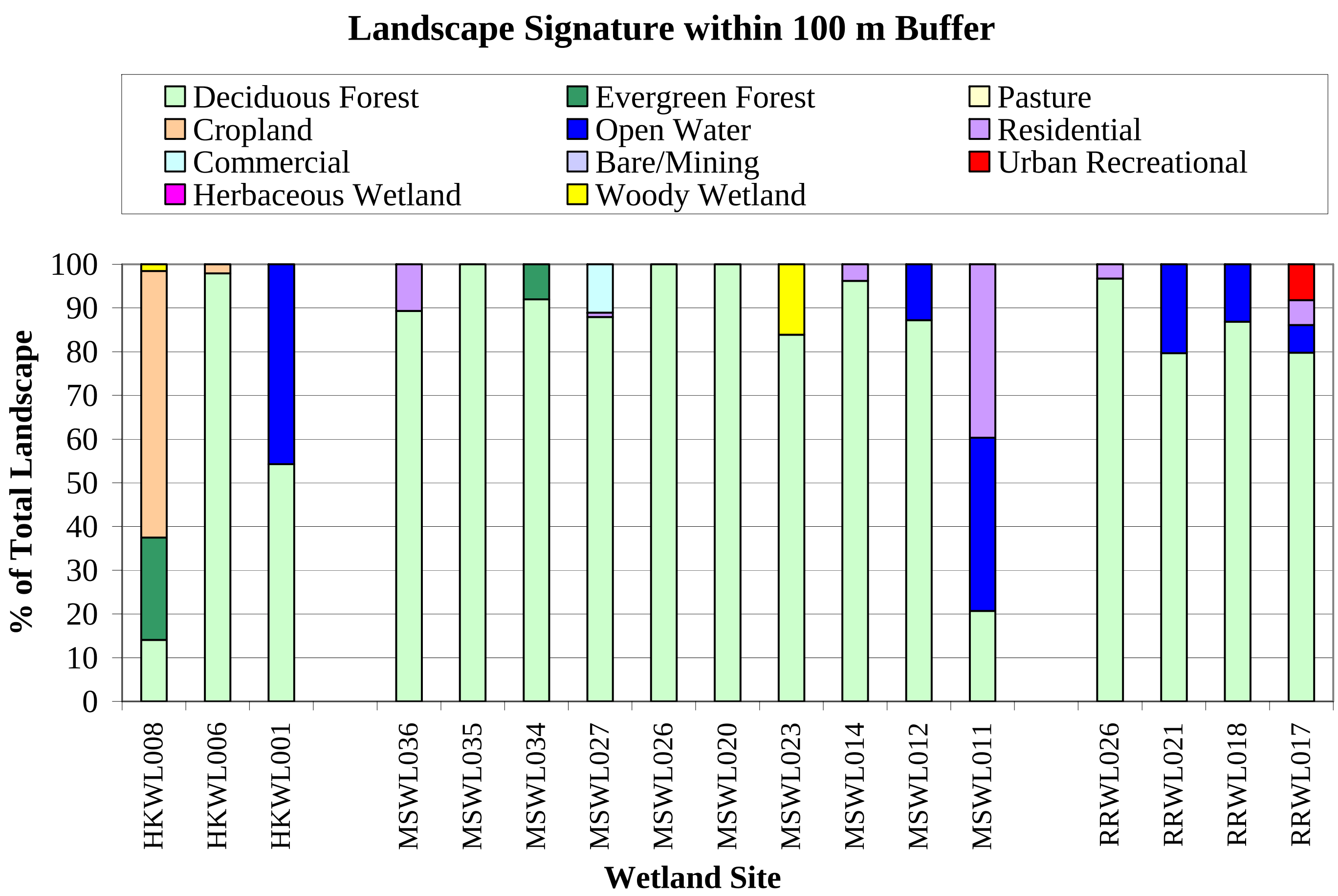
Study ID	deciduous	evergreen	pasture	crop	open water	residential	commercial	bare/mining	urban recr'l	herb. wetland	woody wetland
HKWL008	36.66	17.07	0.00	37.42	0.00	0.00	0.00	0.00	0.00	0.00	8.84
HKWL006	84.64	0.89	0.37	11.48	2.61	0.00	0.00	0.00	0.00	0.00	0.00
HKWL001	60.53	4.29	3.70	4.39	27.10	0.00	0.00	0.00	0.00	0.00	0.00
MSWL036	78.82	0.20	0.00	6.38	0.00	10.44	4.15	0.00	0.00	0.00	0.00
MSWL035	97.70	0.89	0.00	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.00
MSWL034	95.44	3.57	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00
MSWL027	75.98	0.00	0.00	0.00	0.69	6.45	14.91	0.00	1.97	0.00	0.00
MSWL026	87.92	0.00	0.00	0.00	0.00	0.00	12.08	0.00	0.00	0.00	0.00
MSWL020	83.22	4.16	0.00	0.00	0.00	1.73	7.22	0.00	0.00	0.00	3.69
MSWL023	74.67	2.14	0.00	0.00	0.00	9.87	1.73	0.00	0.00	0.00	11.60
MSWL014	64.72	0.00	0.00	0.00	3.61	31.48	0.00	0.00	0.00	0.00	0.19
MSWL012	61.91	0.00	0.00	0.00	6.90	31.19	0.00	0.00	0.00	0.00	0.00
MSWL011	28.76	0.00	0.00	0.00	15.92	46.71	8.61	0.00	0.00	0.00	0.00
RRWL026	66.41	0.00	0.00	0.00	0.00	33.59	0.00	0.00	0.00	0.00	0.00
RRWL021	71.13	0.00	0.00	0.00	4.87	18.33	5.68	0.00	0.00	0.00	0.00
RRWL018	65.94	0.00	0.00	0.00	5.41	26.88	0.00	0.00	1.78	0.00	0.00
RRWL017	42.71	0.00	0.00	0.00	4.86	32.91	3.59	0.00	15.93	0.00	0.00

Appendix E. (continued)

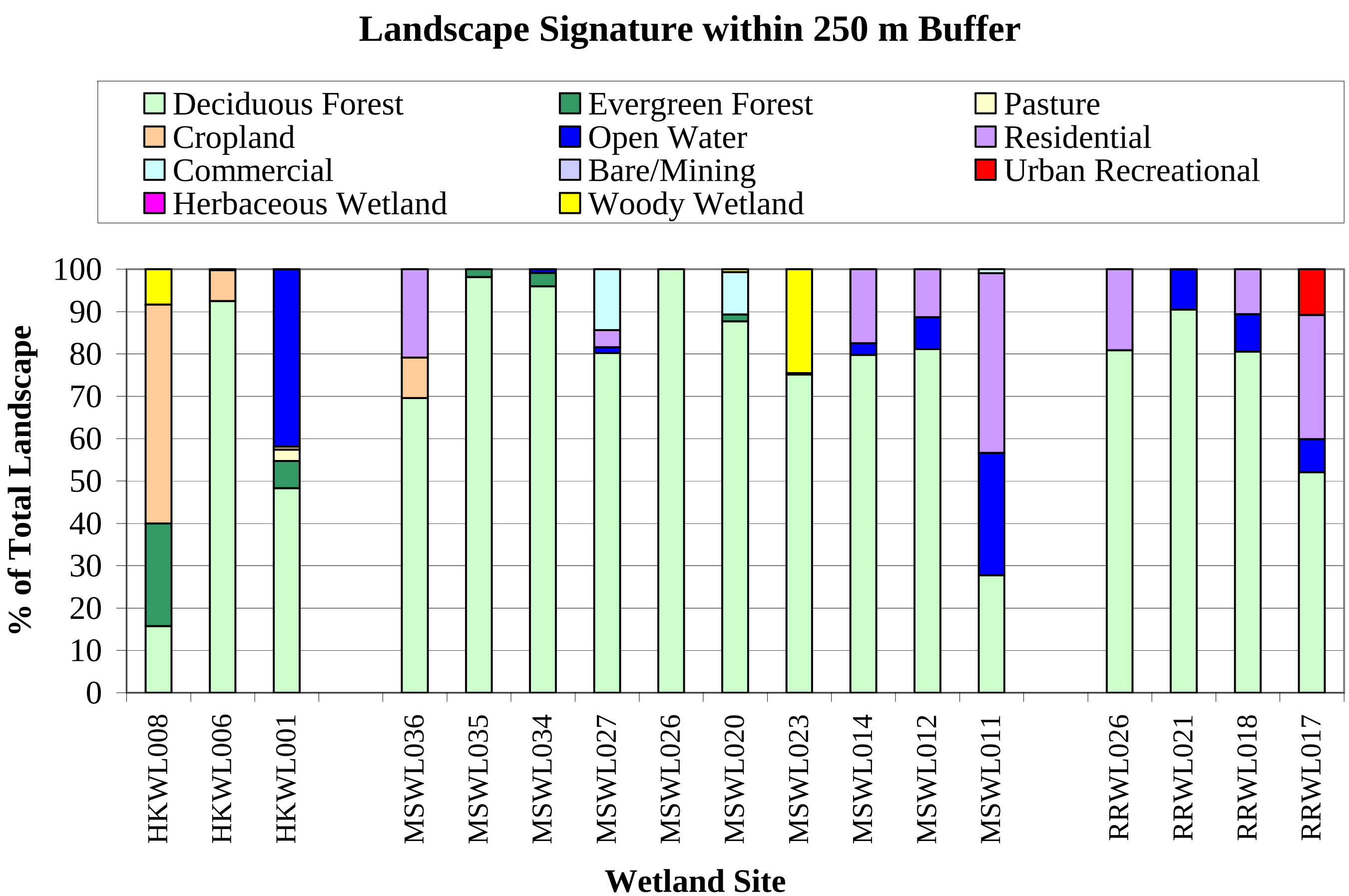
1000 m buffer width

Study ID	deciduous	evergreen	pasture	crop	open water	residential	commercial	bare/mining	urban recr'l	herb. wetland	woody wetland
HKWL008	50.35	6.18	6.68	30.60	0.02	1.34	0.00	0.00	0.00	0.00	4.84
HKWL006	78.92	0.80	1.55	14.82	3.91	0.00	0.00	0.00	0.00	0.00	0.00
HKWL001	82.07	2.04	2.23	2.73	10.94	0.00	0.00	0.00	0.00	0.00	0.00
MSWL036	69.15	2.63	0.00	2.55	0.14	21.28	4.26	0.00	0.00	0.00	0.00
MSWL035	85.93	2.60	0.00	0.00	0.27	2.00	9.21	0.00	0.00	0.00	0.00
MSWL034	90.66	3.54	0.00	0.00	0.30	0.76	3.75	0.00	0.99	0.00	0.00
MSWL027	72.48	0.07	0.00	0.00	0.24	8.69	17.70	0.00	0.82	0.00	0.00
MSWL026	78.80	0.00	0.00	0.00	0.37	3.75	16.14	0.00	0.94	0.00	0.00
MSWL020	71.36	2.04	0.00	0.00	0.00	20.15	3.75	0.00	0.02	0.00	2.67
MSWL023	71.08	1.79	0.00	0.00	0.70	19.33	4.01	0.00	0.00	0.00	3.09
MSWL014	50.58	0.54	0.00	0.00	5.02	38.86	2.29	0.00	0.00	0.00	2.70
MSWL012	45.12	0.00	0.00	0.00	7.54	43.82	2.74	0.00	0.00	0.00	0.78
MSWL011	25.02	0.00	0.00	0.00	7.56	55.69	10.83	0.00	0.91	0.00	0.00
RRWL026	57.45	0.00	0.00	0.15	0.22	35.96	0.00	0.00	6.23	0.00	0.00
RRWL021	41.98	0.00	0.00	0.00	3.04	40.74	10.66	0.07	3.51	0.00	0.00
RRWL018	46.23	0.00	0.00	0.00	3.65	46.28	0.00	0.00	3.84	0.00	0.00
RRWL017	30.95	0.00	0.00	0.00	2.84	44.51	6.88	0.00	14.81	0.00	0.00

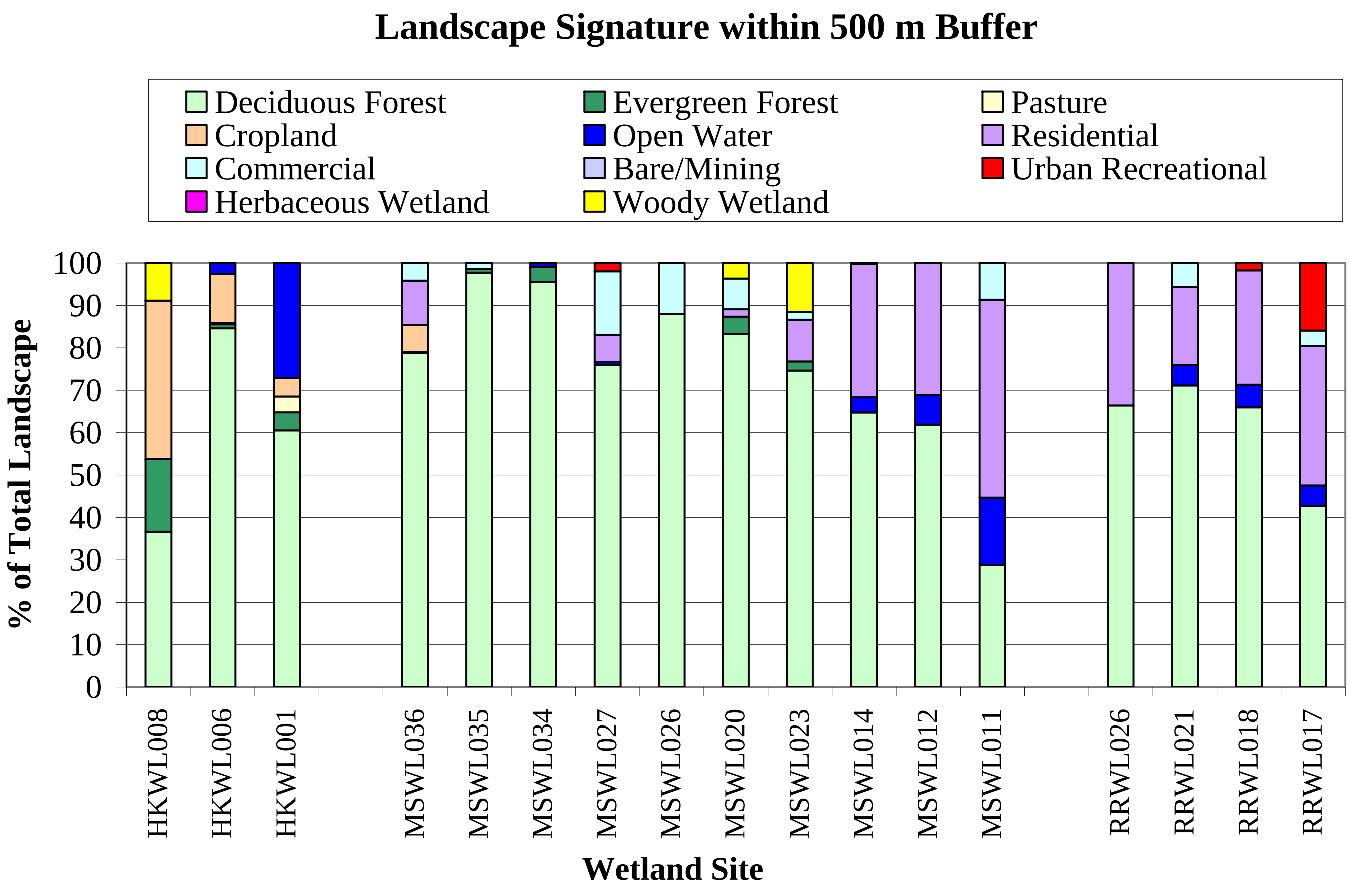
Appendix F. Site Landscape Signatures. Sites are ordered from south to north in the Rocky River valley with the exception of HKWL008-13, which is located west of HKWL006-15. A thick black line indicates a category that has a percent land use and land cover (LULC) category < 1%.



Appendix F. (continued)



Appendix F. (continued)



Appendix F. (continued)