LAKE KOSHKONONG WETLANDS: DIVERSITY, FLORISTIC QUALITY, AND COMMUNITY MAPPING

LAKE KOSHKONONG WETLAND ASSOCIATION

JEFFERSON, ROCK, AND DANE COUNTIES, WISCONSIN

June 22, 2006

NRC Project # 04-130

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ABSTRACT

The purposes of this study were to identify and map plant communities in the wetlands associated with Lake Koshkonong, to assess the diversity and floristic quality of these communities, to better understand the impacts that increased water levels on Lake Koshkonong may have on these wetland communities, and to develop a management strategy to ensure long-term protection of these communities. Four major wetland complexes were initially identified adjacent to Lake Koshkonong (Figure 1), and within these complexes, target sample areas were identified. We conducted fieldwork within the sample areas on June 30, 2005 and July 11-15, 2005. Our sampling protocol included identifying and mapping the different plant communities present within the target sample areas, based upon accepted major plant associations of the Midwest. All species within each plant stand were identified, to the greatest extent possible. We sampled a total of 526 acres of wetland and identified and mapped 48 plant stands (representing five different community types). Plant community types identified were sedge meadow, emergent marsh, transitional marsh, forested wetland, and mud flats (Figure 2). In addition, two areas were identified and mapped that contained a monoculture of reed canary grass (*Phalaris arundinacea*) and hybrid cattail (*Typha* x *glauca*). Mean CC and FQI were calculated for each stand (n=48), for the five different plant communities, and for the entire study area. A total of 215 vascular plant species were identified in the entire study area, of which 25 (12%) are non-native, representing approximately 11% of the total cover within our sample areas. The most common non-native species encountered was reed canary grass. The entire sample area has an FQI of 57.3 and a mean CC of 4.0, demonstrating that the Lake Koshkonong wetlands have considerable floristic value. Dominant species include bur-reed (*Sparganium eurycarpum*), reed canary grass, broad-leaved arrowhead (*Sagittaria latifolia*), marsh skullcap (*Scutellaria galericulata*), rice cut grass (*Leersia oryzoides*), and field mint (*Mentha arvensis*). Of the community types, sedge meadows possessed the greatest number of species, the most distinctive species (not found in other community types), and the highest FQI. In addition, sedge meadows are often the communities most sensitive to damage from increases in water levels. This study has important implications for protecting, enhancing, and promoting the health of Lake Koshkonong's wetland communities by contributing to the overall management strategy for Lake Koshkonong and the Rock River.

PREFACE

On behalf of the Lake Koshkonong Wetland Association (LKWA), and in partial fulfillment of a Wisconsin Department of Natural Resources (WDNR) $10,000 Lake Planning Grant award, Natural Resources Consulting, Inc. (NRC) has completed a floristic survey and assessment of several of the wetlands associated with Lake Koshkonong.

The Lake Koshkonong Wetland Association (LKWA) was formed in 2003 in an effort to protect the existing wetlands on Lake Koshkonong and the Rock River and to promote the health of natural plants, fish, birds, and other forms of wildlife in the basin. Lake Koshkonong is a natural widening of the Rock River that was impounded in the early 1900's. This is a very shallow lake with conditions marginally favorable for navigation by recreational boaters during late-season periods of low water, especially as watercraft size increases. Because of these circumstances, the Rock-Koshkonong Lake District (RKLD), current owner of the dam, proposed to modify the operating order, increasing the lake water levels by 6 to 8 inches throughout the growing season. The DNR denied this change order permit application, and a contested case hearing was scheduled for 2006. LKWA was concerned that the proposed increase water levels might have adverse impacts to the more than 4000 acres of wetlands adjacent to the lake. These concerns prompted the LKWA to apply for a Lake Planning Grant to assess these wetlands and their vulnerability to increased lake water levels. In addition, LKWA has undertaken other projects within the basin such as: aquatic weed programs; wood duck nesting box construction; and osprey nesting platform construction.

The LKWA has funded several other preliminary studies on various wetland communities around the lake to assess the potential impacts of increased water levels. One of these projects, which was also funded by the DNR through the River Protection Grants Program, was a comprehensive study assessing the relationship of water levels to growth rates in floodplain forest trees.

More than 4000 acres of wetlands border Lake Koshkonong and consist of shallow marsh, floodplain forest, open water, and other habitat. These wetland plant communities provide habitat for all types of wildlife, function as important migration corridors in the landscape, and provide many valuable ecosystem functions. Wetland plants have evolved to survive, and often flourish, in the wet conditions characteristic of their particular habitat. A change in the environmental and/or hydrologic conditions would, therefore, often lead to a change in vegetation, which could then lead to changes throughout the ecosystem. The primary objective of this study was to identify and map plant communities and to assess the diversity and floristic quality in the wetlands associated with Lake Koshkonong by documenting what is present in order to better understand the impacts increased water levels on Lake Koshkonong may have on these wetlands. This study has valuable implications for protecting, enhancing, and promoting the health of these wetland communities by contributing to the overall management strategy for Lake Koshkonong and the Rock River.

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INTRODUCTION

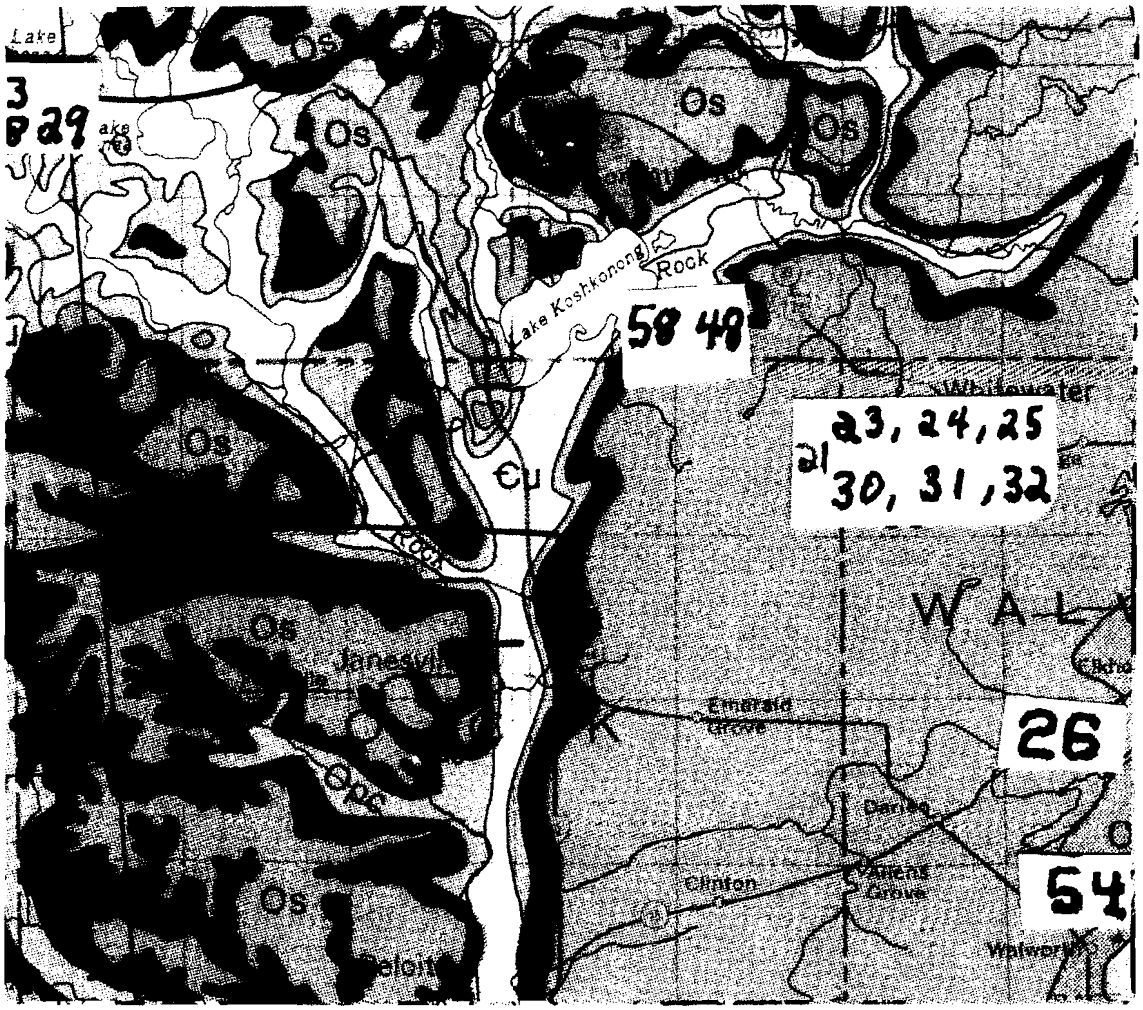
Prior to construction of the dam at Indianford, water level fluctuations in Lake Koshkonong were determined primarily by weather and climate. Typical of southern Wisconsin, highest lake levels would have been seen in spring and early summer, when snowmelt and rainfall lead to excess overall precipitation as compared to the rate of evapotranspiration. Winter would have seen the seasonal low for lake levels, since much of the precipitation would have been held as snow. Climatic patterns and extreme weather events partially determine which species can survive in lakes with dynamic water levels like Lake Koshkonong (Mitch and Gosselink 1993). Species must have traits that allow them to both thrive in the climatic norms and survive the extremes of weather. Basic wetland hydrology principles describe dynamic wetland water levels in terms of depth, duration and frequency (Shaffer et al. 2000, Kraemer 2003). Plant communities around dynamic lakes usually show strong "zonation" around these factors (Spence 1982). Typical zones include those perennially inundated (deep to shallow marshes), periodically flooded (shallow marshes, floodplain forests and some sedge meadows) and occasionally flooded (other sedge meadows, wet forests and wet prairies) (Eggers and Reed 1997). Changes in climate, weather patterns, and/or hydrology can, therefore, influence the zonation and presence of certain plant communities and species (Busch et al. 1998, Bledsoe and Shear 2000).

Keeping in mind both the historical natural dynamics of Lake Koshkonong and the recent proposal to permanently increase the water levels on the lake, the purpose of this study was to identify and map plant communities currently present in the wetlands associated with Lake Koshkonong and to assess their diversity and floristic quality. This information was then used to evaluate the potential impacts increased water levels could have on the wetland vegetation.

The Origin and Early History of Lake Koshkonong

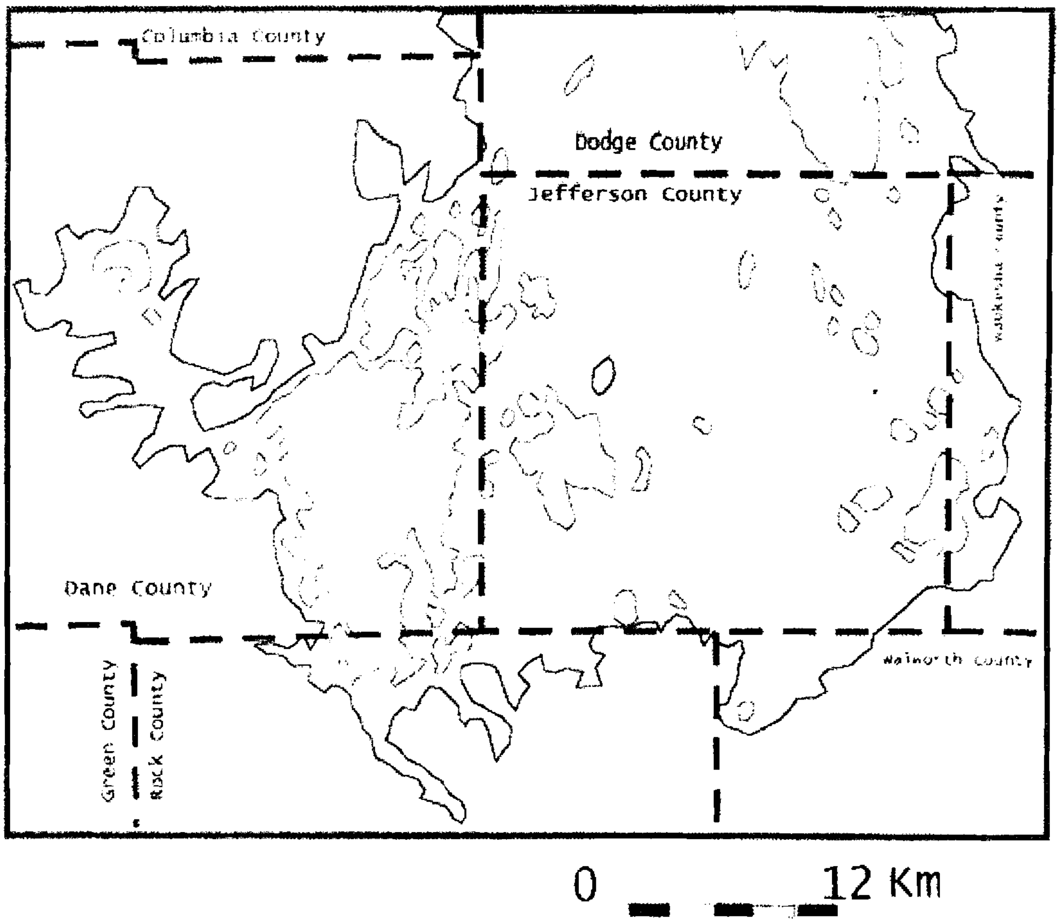
Before the glacial era, the land around what is now Lake Koshkonong was much like what we see today in southwestern Wisconsin - deep valleys connected in an orderly drainage system. The ancestral Rock River drained southwest through the southern edge of Jefferson County, some miles east of where it leaves today and at least two hundred feet lower than at present (Figure 3, from WGNHS 1982). Over time it cut down through Ordovician deposits (blues and greens in Figure 3) and reached the lower level of Cambrian sandstone (orange in Figure 3). In the last of several major continental glaciations ("the Wisconsinan), ice from the "Green Bay Lobe" came down the center of the state in addition to the Lake Michigan path. As the ice flowed through central Wisconsin, it scoured the land underneath generating immense quantities of mostly sand and fine silt. Streams within the glacier sorted some deposits to concentrate gravels and cobbles, and, often on top of the ice, large boulders hitch-hiked down from northern Wisconsin and Canada. This debris filled valleys along the way and accumulated in terminal moraines wherever the glacier paused.

Figure 3: Bedrock geology of Lake Koshkonong area (figure from WGNHS 1982)



As the glaciers moved south, they reached points where summer melting equaled winter snow accumulation upstream, and large terminal moraines formed. The most prominent of these in our area are named the "Milton" and the "Johnstown" moraines for the current cities sitting upon them. The glaciers in this situation could be likened to giant conveyor belts bringing debris and water from the north and dumping it in the south. About 12,500 years ago, climatic conditions changed and the Green Bay Lobe retreated north to the central part of Wisconsin. As it did so, large pro-glacial lakes formed in the area between the highest moraines and the current ice front. In our area the proglacial lake was called "Glacial Lake Scuppernong," (Figure 4), and it covered most of Jefferson County and parts of Dane and Rock (Clayton and Attig 1997b). The glacier to the north continued to pour out sand and silt in huge rivers which fed the lake and raised its level until it flowed over the lowest points on the moraines (ca. 850 ft or about 100 feet above our current lake). Much of the glacier's sand was left in central Wisconsin but much of the fine silt remained suspended in the outwash streams until it reached the pro-glacial lake. Here it settled out blanketing much of Jefferson County with thin silt deposits in the upper, sloping areas but thick deposits in the lower, flatter areas. Eventually the overflowing lakes cut down through the moraines until they either encountered bedrock or accumulated an armored layer of large boulders which slowed the erosion. The major outlet for Glacial Lake Scuppernong did not happen to fall over the ancestral valley outlet but rather upon a harder dolomite ridge at Indianford. This chance event combined with the large amount of fill deposited in the old Rock Valley, left a small shallow lake in a wide, silt-filled area of the old Rock Valley (Historical/geology information summarized from Clayton and Attig 1997 and 1997b and Michelson and Clayton 1983).

Figure 4: Glacial Lake Scuppernong (figure from Clayton and Attig 1997)



All across the county, shallow lakes formed in silt-filled depressions. Most of those that were isolated from drainageways eventually filled, first with lake sediments and then with peat, until they appeared as tamarack swamps or sedge meadows when the settlers arrived. Those along streams were likely to form sedge meadows or, where alluvium was deposited by larger streams and rivers, swamp forests. Thus, Lake Koshkonong was surrounded by a mosaic of wetland types: deep to shallow marsh in the lake itself; swamp forests of silver maple, ash and swamp white oak where creeks and the Rock River entered; sedge meadows with a gradual transition to wet prairie in the adjoining, gradually sloping areas just above lake level. We have original descriptions of what Lake Koshkonong looked like 150 years ago. Below is a description of Lake Koshkonong, written in 1877 by Thure Kumlein, Lake Koshkonong's most famous naturalist.

Lake Koshkonong
By an Old Settler

"Lake Koshkonong is principally situated in Jefferson county, Wisconsin, but its southwest end touches Dane county, and its southern part, Rock county. Its main length is about nine miles, in the direction of northeast and southwest; its broadest part about four miles. Its shape is somewhat irregular, and it has its bays and promontories, and which are known as Buffalo and Bingham's bays, and Lee's, Taylor's and Bingham's "points." Rock river enters the lake at the northeast end, at Blackhawk Island, and it leaves it at the southwest end, at Newville. On the northwest side, Koshkonong creek and Alpeter's creek, and on the southeast side, Otter creek, add to the volume of its water, as also do innumerable springs all around and in many places even in the lake, which is rather a shallow sheet of water, with mostly muddy bottom.

What is called "Blackhawk Island" is an island only at high water and is formed by having the Rock river on the east, and the lake on the south and west side, being connected with the main land only by a narrow strip of low land on the north.

The land surrounding the lake consists to a great extent of low and very extensive marshes, on which thousand of tons of hay are annually cut; but limestone bluffs exist in many places all around the lake, viz: at C. Lee's, R. Bingham's, Taylor's point, Newville, E. Binghams's and the place of Mr. Langhoff.

The lake, with its, in many places, marshy shores and hundreds of acres of wild rice, and the grass-like plant, known to botanists as *Vallieneria spiralis*, growing in it in the greatest abundance, used to be a great favorite place for ducks, and especially the far-famed Canvassback (*Aythya vallisneria*), which, with the Redhead, is particularly fond of the *Vallisneria spiralis*. Geese, cormorants and white pelicans were also very numerous, and fifty to one hundred of those latter birds could be seen at one time in the latter part of April or first of May. . ."

Thure Kumlein's description of the Lake Koshkonong area 150 years ago tell us that the lake and its associated wetlands were much different than those we see today. Early photos and paintings confirm that (at least in the upper part) the lake was largely covered with emergent vegetation such as reeds and wild rice. The "thousands of tons of hay" that the settlers were cutting certainly imply that grasses were the major components of the adjoining wetlands and that the wetlands dried down sufficiently to allow people on them to scythe the hay and horses or oxen upon them to haul it home. The grasses present were likely blue joint grass (*Calamagrostis canadensis*) and prairie cordgrass (*Spartina pectinata*) but marsh timothy (*Muhlenbergia glomerata*) and marsh brome (*Bromus ciliatus*) may have also been present.

With rising water levels (caused by the combination of the higher dams and higher runoff characteristics of the changing landscape in the watershed), the grass components of the early wetlands would have diminished and been replaced by sedges such as lake sedge (*Carex lacustris*) or more aquatic species such as bur-reed (*Sparganium eurycarpum*) that could survive the new hydrologic regime. At the same time, in the newly enlarged emergent zone, the longer reaches of open water allowed greater wind fetch, which in turn made it more difficult for the emergents to survive in the deeper zones. This positive feedback cycle was likely already diminishing the emergent zone, but the addition of Carp to the equation would have accelerated the process greatly. Simultaneously, water quality issues (turbidity, eutrophication and toxics) were also working against the emergents. Thus, the drastic change that has occurred in the wetlands of Lake Koshkonong was caused by the interactions of several factors.

Rising water levels also increased the area of Lake Koshkonong. This larger pool came primarily at the expense of the surrounding wetlands in the bays and river deltas. These areas lost wetlands differentially for the same reasons that the wetlands were extensive there to begin with: nearly flat topography and a thick deposit of impervious material left by glacial Lake Scuppernong. Over the millennia after glaciation, shallow peat deposits had formed in the bays and thin sand and silt deposits in the deltas, both over the well-consolidated deposits of glacial lake silt. As waves worked at the edges of the peat, the wetland edge retreated, and as the lake undermined the shallow roots of trees growing over the glacial lake layer, winds toppled the fringing trees. Both of these processes are easy to observe in the lake yet today wherever the shoreline is unprotected.

General Settings of Current Lake Koshkonong Wetlands

Using techniques described in the methods section below, we identified four major wetland complexes associated with Lake Koshkonong (Figure 1). The general settings of these major wetland areas are the result of the interactions of the pre-glacial topography and the Wisconsinan glaciation. The bedrock map suggests that the pre-glacial Rock River entered about where it does today (Area 3) and flowed out of the lake to the west of Area 4. A secondary valley entered the ancestral Rock from the north. This valley was bounded by a major bedrock ridge to the east (Oakland Highlands) and the even larger Albion Highlands to the west. It ran north to the Lake Mills area and now contains numerous lakes (Red Cedar, Ripley, Hope, Mud, Rock), marshes and drained peatlands. A minor ridge ending at Carcajou Point divides the northern valley into two outlets as it approaches the current lake. On the west, Koshkonong Creek drains a large area associated with the east slopes of the Albion Highlands and runs northwest most of the way to Madison; it enters the lake in Area 1 of this study, just west of Carcajou Point. The eastern outlet drains a much smaller area between Red Cedar Lake and the west slope of the Oakland Highlands via Kump's Creek, which enters Area 2. The large delta associated with the current position of Koshkonong Creek argues that the creek has used this outlet for a long time; however, the relatively flat topography and the continuous peatlands between Koshkonong Creek and Kump's Creek in the vicinity of Klement Road raise the possibility that, at some time(s), it may have emptied into the lake at the western edge of Area 2. Area 3 is associated with the mouth of the Rock River and Area 4 results from a complex interaction of the pre-glacial valley structure, the Milton Moraine, two rocky points (Stony and Thiebeau) and Otter Creek.

The general setting of each area is described below.

Area 1 is primarily a deltaic formation of sand and silt but includes some areas of shallow peat, especially in the Crescent Bay area. All areas sampled were underlain by glacial lake silt within a meter of the surface; thus, the stream deposits appear shallow. Older maps and photos plus testimony of current residents agree that the delta used to extend much further into the lake and that the mouth of Koshkonong Creek changes locations over time. Wetlands found here are barely above current average lake level and are all under water during major flood events.

Area 2 contains a large, continuous peat deposit on the eastern side, a low, sandy ridge that runs all the way to the lake and a smaller peat deposit on the west side of this ridge. Highway 106 crosses the larger wetland area near its northern end, and during major flood events, water levels rise to just below the current elevation of State Highway 106. Kump's Creek crosses Highway 106 west of the major wetland but enters it from the northwest after crossing a low spot in the sandy ridge. The smaller, western portion of Area 2 is an embayment with a low sand ridge separating it from the lake. During high water time, the sandbar is under water (personal observation, Q. Carpenter).

Area 3 is associated with the mouth of the Rock River and contains two large wetlands behind paired natural silt levees. Behind the north levee ("Blackhawk Island") is a wetland with a shallow marsh in the middle called "Mud Lake"; it receives some water independently from springs and a tiny drainage area but is frequently flooded by the Rock River. On the south side of the river is another wetland but it seems to lack spring sources and is consequently somewhat drier except when the river overflows the levee.

Area 4 wetlands are dominated by the effects of the close-by Milton Moraine. This moraine lies across the old outlet of the Rock forcing the current river outlet farther west to Newville and Indianford. The moraine also contains numerous kettle lakes and peat-filled lakebeds a hundred feet or more above Lake Koshkonong; these resulted from high levels of Glacial Lake Scuppernong depositing fine silts which seal the bottoms. The kettle lakes generally do not have surface water outlets but the largest lakebed marsh (Lima Marsh) drains via Otter Creek. In addition, one finds many "dry kettles", which, along with the generally coarse moraine soils, provide excellent infiltration opportunities for rainfall. All this infiltration results in copious discharge of groundwater into Otter Creek but also directly into many wetlands of Area 4.

STUDY SITES AND METHODS

Study Sites

The primary objectives of this project were to identify and map the major wetlands and plant communities adjacent to Lake Koshkonong and to assess their diversity and floristic quality. In order to meet these objectives, we needed to first do a broad-scale analysis in order to identify major wetland complexes in the area and then to identify target sample areas within the wetland complexes such that the number of plant communities sampled would be maximized.

We initially identified four major wetland complexes adjacent to Lake Koshkonong using aerial photograph interpretation and Geographic Information Systems (GIS) technology (Figure 1). These four wetland complexes are referred to as "Project Areas" within our figures and text. The following resources and documents were utilized in the identification process:

- Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), excerpts from the *Soil Survey of Jefferson County, Wisconsin* and the *Soil Survey of Rock County, Wisconsin*;
- NRCS list of hydric soils for Jefferson and Rock Counties;
- Topographic mapping and aerial photography available for the area;
- The Wisconsin Wetland Inventory (WWI) map for the area.

We then used three criteria to identify target sample areas within the major wetland complexes. First, all wetland complexes were included in the target sample area. Second, areas likely to transition between communities were included. This criterion was used in order to gain an understanding of the number and types of plant communities present in the wetlands adjacent to the lake. Third, areas that are likely to be affected by a change in lake water levels were identified and included in the study area to the greatest extent possible. In general, sites which meet the above criteria are located in areas with moderate to low inundation, where vegetation density and diversity are not limited by permanent standing water and anoxic soil conditions. Extensive open water areas, therefore, generally were not included in our target sample areas.

Aerial photos and GIS technology were used in conjunction with ground truthing, expert advice, and verification by local community members to identify study sites that matched the above criteria. Once identified, target sample areas were then mapped onto aerial photographs using GIS technology. Field work was conducted within these target sample areas as described in the 'Field Methods' section which follows. During field work, the four target sample areas were further divided into plant stands (also referred to as plant communities), areas of distinctive vegetation and species associations, based upon visual assessment by field crews, and data were collected within each plant stand. The size of the plant stands, or samples, was dependent upon the extent of that community type within the target sample area. Each plant stand identified during field work has been assigned a unique number using the target sample area (1, 2, 3, or 4) and consecutive numbers representing the number of stands identified (ex. 4-3 represents the third plant stand identified within sample area 4) within that sample area (Figure 2 and Appendix F).

Field Methods

Field studies were conducted in mid July, an appropriate time during the growing season to enable the identification of the maximum number of species, many which have different phenologies. Field crews used aerial photographs and Global Position System (GPS) units with sub-meter accuracy to guide surveys within the target sample areas. Field crews consisted of professional botanists, primarily responsible for the identification of species and the accurate mapping of plant communities, and community volunteers, who assisted the botanists with various tasks. A meander sampling technique was used within the target sample areas. All species encountered within each plant stand were identified, and their cover/abundance within that stand was recorded using the following classes:

1 = present but uncommon (contributes $\leq$1% cover to the plant community);

2 = common (not a dominant or sub-dominant species; contributes >1% but $\leq$10% to the plant community);

3 = abundant (a dominant or sub-dominant species; contributes >10% but $\leq$ 90% of cover to the plant community);

4 = A monoculture (areas where one species such as *Phalaris arundinacea*, *Phragmites australis*, *Typha angustifolia* or *T.* X *glauca* comprises >90% cover within the plant community).

The approximate boundary of each plant community or stand was mapped onto aerial photos. Plant community types were determined based on major plant associations such as those outlined in the Wisconsin Natural Heritage Inventory Natural Community Descriptions. A general description and assessment of each plant community was recorded and included notes on the overall vegetation diversity, substrate (mineral, peat, etc.), wetness (dry, standing water, etc.), evidence and location of springs or seeps, and evidence, type, and location of observed disturbances.

Traditional Analyses

Data Summary

Plant stand boundaries were digitized and overlain on aerial photographs available for the area (Figure 2), and the size of each plant community was calculated (in acres) using GIS technology. Vegetation data from the 48 plant stands (samples) were organized into what is traditionally called a "species by site matrix," which contained the abundance/cover value assigned to each species within each plant stand. Sub-matrices were organized for each of the four project areas, and later for the five different community types. Multivariate analyses, described in the next section of the text, were used to determine what plant community types were present within our data and which stands/samples were categorized within the community types. The sub-matrices for the community types were developed after stands/samples were categorized. All of these data contained within the original matrix and the sub-matrices were summarized using traditional ecological measures such as species richness (S = total number of species identified within a given area), proportion of non-natives within the stand, etc.

Identification of Dominant Species

In addition, the matrices were used to identify dominant species within the community types and the project area as a whole. Dominants were identified by calculating an importance value (IV) for each species. The IV is the total sum of the sum of all occurrences of a species within plant stands and the sum of all abundance/cover values assigned to that species within plant stands of a particular community type or the project area as a whole (IV = Σoccurrences + Σabundance/cover values). The twenty most important species (based upon IV) for each community type are listed in Appendix B, and the 27 most important species within the project area as a whole are listed in Table 1 below.

Floristic Quality Analysis

Using values from the WI Floristic Quality Assessment Report (Bernthal 2003), we conducted a floristic quality analysis (FQA) on the forty-eight samples from the four major wetland areas. For each sample we calculated a mean coefficient of conservatism (mean CC), a quantitative mean CC (qmean CC) and a traditional floristic quality index (FQI). The methodology for calculating a mean CC and traditional FQI was developed by and is outlined in Swink and Wilhelm (1994). The mean CC is calculated as the arithmetic mean of the CC values of the species in a particular site, with all species given equal weight irrespective of their abundance. The qmean CC is calculated similarly using the four categories of abundance (1,2,3,4) as weighting factors, and FQI is calculated as mean CC times the square root of the species richness (S) of the site (FQI = meanCC * √S). Since each of these metrics looks at the "quality" and/or diversity of the sites slightly differently, in addition to calculating each value separately, we also calculated a composite index giving equal weight to each metric. To do so, qmean CC and FQI values first were scaled to the average mean CC of the data set, then the composite index was calculated as the average of the three indices.

In addition to performing the above-stated FQA calculations on each individual sample (n=48), we also calculated the traditional FQI and mean CC for the five different community types, which were identified by the multivariate analyses described in detail in the following section. These communities were sedge meadow, emergent marsh, transitional marsh, mud flats, and forested wetlands. First we averaged mean CC and traditional FQI values for all samples/stands within each community type to determine the quality of an average stand of that particular community type. We then combined data from all samples/stands within each community type and calculated the mean CC and traditional FQI for the community as a whole.

Multivariate Analyses

Summary

While each botanist had visually assigned traditional community-type names to their samples in the field at the time of data collection, we wanted to determine community types independently using the original species by site data matrix containing all 48 plant stands and more independent sources of classification. Thus, we searched for vegetation patterns within this matrix using several multivariate analysis techniques contained in the PC-ORD statistical package (McCune and Mefford 1999); specifically, we used Bray-Curtis, DECORANA (also called DCA) and NMS ordination and TWINSPAN classification (Gauch 1982). All techniques gave similar results; DCA was chosen for further exploration because it gave the best spreading of stands/samples (n=48). To clarify the graphics, we then discarded the two monocultures in the original species by site matrix because they added little information, and we removed the seven wetlands that were dominated by trees and clustered tightly to one side of the graphic. Tight clustering generally indicates a distinctive grouping of samples, and the seven which clustered tightly in our analyses comprise the forested wetland plant stands. We then ran the DCA ordination again, this time with only 39 of the original 48 samples. The improved graphic that resulted was used to group the remaining 39 stands/samples into vegetation community types based on clustering within the graphic and on relative abundances, within our data, of typical "indicator species" of particular community types, as identified in local references (Wisconsin Natural Heritage Inventory Natural Community Descriptions--WDNR, Eggers and Reed 1997, Curtis 1959 and past field experience in the area). Figure 1 in Appendix E is the final resulting figure in which samples/stands have been identified by community type. Each point on the graph is a particular stand, and the stand name/number has been replaced by its community type. Figure 2 is the same graphic as Figure 1 except that each point represents one plant stand that is labeled according to the unique assigned sample area and stand number as described in the study sites section above (ex. 4-1). Note that the numbers on the axes do not represent a measured environmental variable; they represent only an arbitrary scale, useful for graphical/visual purposes. After these figures were developed, we used our data to identify "characteristic species" of each community by looking for species that were both abundant in and faithful to stands/samples within a particular community type. For those interested in these analyses, we have provided additional details below. All figures referred to in the following sections are contained within Appendix E.

Identification of Community Types

As summarized above, after dropping the two monoculture samples and the seven forested-wetland samples from the data matrix, we ran DCA again on the reduced matrix of 39 sample sites. While clustering was not tight, it was more interpretable than with the complete matrix. We did not expect to find discrete clusters among these remaining wetlands because that was not what we saw in the field – the wetlands shared many species, and boundaries were gradual rather than abrupt. Since DCA is derived from a reciprocal averaging algorithm, it has the useful property that the "center of mass" of an abundant species plots closely to the "center of mass" of the samples where this species is most abundant (ter Braak 1995). In other words, samples can be plotted on two axes based upon similarity in samples and species composition (Figure 2). Using the same data, each individual plant species can also be plotted on two axes based upon similarity in samples and species composition (Figure 3). The useful property of DCA is that species which are commonly found in a particular community type will be plotted on the species graph (Figure 3) in the same general location as the community type on the samples graph (Figure 2). Therefore, we compared the species plot (Figure 3) to the stand/sample plot (Figure 2), and we looked to see where typical indicator species (based on regional vegetation guides and our previous experiences), plotted.

For example, *Carex stricta* (tussock sedge), *Calamagrostis canadensis* (blue-joint grass) and *Eupatorium maculatum* (Joe-Pye weed) are well-known denizens of southern sedge meadows (Eggers and Reed 1997; Curtis 1959). The same sources point to *Spartina pectinata* (cordgrass), *Lycopus americanus* (American bugleweed), *L. uniflorus* (small bugleweed), *Lathrus palustris* (marsh pea), *Campanula aparanoides* (marsh bellflower), *Thylepteris palustris* (marsh fern) and *Verbena hastata* (blue vervain) as common in sedge meadows. With this list in mind, we looked to see if these species plotted in the same general area of the graphic in Figure 3, which they did—the bottom left corner of the graphic. Note that in Figure 3, the species are represented by an abbreviation, which uses a combination of the first three letters of both parts of each species' scientific name. Once we determined that typical sedge meadow species were found in the bottom left corner of Figure 3, we then compared this corner with the equivalent area on the samples graphic (Figure 2). Because of the reciprocity trait of the algorithm, we could say that samples that plotted in this area were best described as "sedge meadows." Our field data from these samples corroborated the community classification suggested by the multivariate analyses. In the same manner we looked at where such well-known emergent marsh species as *Zizania aquaticus* (wild rice), *Schoenoplectus fluviatilis* (river bulrush), *Schoenoplectus acutus* (hard-stemmed bulrush) and *Phragmites australis* (giant reed) plotted. As these species plotted at the opposite diagonal of the graphic in Figure 3 (the upper right corner), we recognized that we had a classic drier-to-wetter gradient represented by the interaction (diagonal) of the axes of the plot.

Utilizing a similar process to that described above, the samples located in the corners of the Figure 2 were relatively easy to explain. Stands/samples dominated by annuals occupied the lower right corner, and our field notes indicated that these stands were described as "mud flats," a common pioneer wetland type in areas with dynamic water levels. In the upper left corner of the species graphic (Figure 3), we found the "center of mass" of most of our woody perennials: trees (black willow and green ash) and shrubs (dogwoods and willows). Using this information, we classified the three lower-right-corner samples plus two adjacent ones (which, based upon our field data, seemed to have more species in common with these than other potential groupings) as "mudflats." In contrast, only one sample was clearly in the upper left corner (stand 4-3). This stand was described in the field as a shrub carr community. Field data indicated that while shrubs dominated this stand, it also contained many herbaceous species, including many that were also common in the sedge meadow stands in the lower left corner of Figure 2. Rather than create another community category (shrub carr), which, with only one sample included, might be misleading, we included it with the sedge meadows, since it shared many herbaceous species with sedge meadow communities.

Dividing up the large number of samples on the major diagonal (lower left to upper right corners) was not as easy. Here we used another useful feature of PC-ORD – its ability to overlay species abundance (the abundance/cover values assigned to each species in each stand during field work) on the stands/samples graphic. Two examples of these plots are included in Appendix E—tussock sedge (Figure 4) and *Echinocloa* spp. (barnyard grass; Figure 5). In these figures, the triangles represent the abundance/cover values assigned to that species in each stand/sample. Each stand is represented by one triangle, regardless of whether that species was found in that stand or not. Larger triangles indicate that the species was given a higher abundance/cover value in that stand, and the smallest triangles indicate that the species was not found within that stand. Figure 4 shows that tussock sedge, an indicator species of sedge meadows, is abundant in many samples/stands that plotted in the lower left corner of the graphic. Figure 5 indicates that barnyard grass, a typical pioneer of mud flats and other open ground, is most abundant in samples/stands that plotted in the lower right corner of the graphic. Using this type of graphic for many different species, we assigned 16 samples to the "sedge meadow" category and 11 samples to the "emergent marsh" category based on the relative abundance of indicator species. Seven remaining samples, in the center of the graphic, defied clear classification. A closer scrutiny of field data and the available graphics revealed that these sites contained either a moderate number of very common species, which plotted in this general area of the graphic in Figure 3, or they contained a broad range of species, the averages of which plotted there. For convenience, we named this category "transitional marshes," though this category is more a sampling artifact than an ecological category.

In summary, utilizing a combination of available graphics resulting from multivariate analyses, knowledge of typical indicator species of particular community types, and our own field data from the Lake Koshkonong wetlands, we determined appropriate boundaries within the graphics (Figures 1 and 2) for all community types present within our data. The boundaries resulting from these analyses are represented by the circles on Figure 2, which is the same graphic as Figure 1, except that in Figure 1, the stand/sample identification number was replaced by an abbreviation of the community type name after the analyses were completed.

Identification of Characteristic Species

To designate some "characteristic species" of the Lake Koshkonong wetland plant communities, we used the same overlay feature of PC-ORD described above for tussock sedge (Figure 4) and barnyard grass (Figure 5) to explore which species tended to occur most "faithfully" within the respective community category zones (ex. lower right corner for mud flats) on the ordination graphic (Figures 1 and 2). For example, in Figure 4, as evidenced by the large triangles found exclusively in the lower left corner of the graphic (where sedge meadows plotted in Figures 1 and 2), tussock sedge can be considered a characteristic species of the sedge meadows we sampled in the Lake Koshkonong wetlands. Species which were both common and seemed to occur predominately within a particular community type were added to that community type's list. Clearly, this process may be criticized as "circular," yet, as explained above, it has some independence, and it does not rely on the whim of a particular individual. In this it resembles Floristic Quality Analysis.

RESULTS AND DISCUSSION

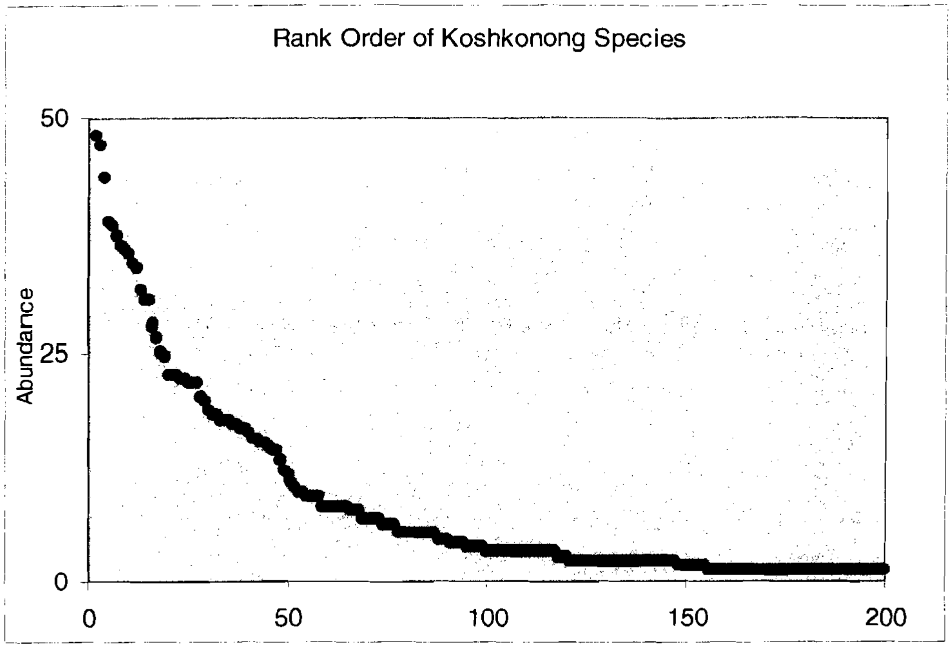
Overview

We sampled a total of 526 acres of wetland and identified and mapped 48 plant stands. As explained in the methods section, we classified these into five community types: sedge meadow, transitional marsh, emergent marsh, forested wetland, and mud flat. In addition, two plots were mapped that contained a monoculture of reed canary grass (*Phalaris arundinacea*) and hybrid cattail, respectively. We identified a total of 215 vascular plant species in the various wetlands, of which 190 (88%) were native and 25 (12%) are non-native. Based on frequency and estimated cover, the ten most abundant species present within the 526 acres are bur-reed (*Sparganium eurycarpum*), reed canary grass (*Phalaris arundinacea*), broad-leaved arrowhead (*Sagittaria latifolia*), marsh skullcap (*Scutellaria galericulata*), field mint (*Mentha arvensis*), rice cut grass (*Leersia oryzoides*), water smartweed (*Polygonum amphibium*), purple-stemmed beggar's tick (*Bidens conatus*), clearweed (*Pilea pumila*), and river bulrush (*Bulboschoenus fluviatilis*). These ten species comprise almost a quarter of our abundance, and about half of our abundance comes from just one-eighth of the 215 species encountered (Table 1). The shape of the abundance versus rank curve (Figure 4) is fairly typical for native communities in our area based on past field experience. The complete species list in alphabetical order may be found in Appendix A.

Table 1: The 27 most abundant species in the plant surveys, which represent 50% of the total abundance (sum of all abundance/cover values assigned to all species in the field) of all species identified. Importance value is the sum of the abundance/cover values and the frequency of occurrence of each species.

Scientific Name	Common Name	Importance Value
Sparganium eurycarpum	Common bur-reed	105
Phalaris arundinacea	Reed canary grass	96
Sagittaria latifolia	Broad-leaved arrowhead	94
Scutellaria galericulata	Marsh skullcap	87
Mentha arvensis	Field mint	77
Leersia oryzoides	Rice cut grass	76
Polygonum amphibium	Water smartweed	74
Bidens connatus	Purple-stem beggar-ticks	72
Pilea pumila	Canadian clearweed	71
Bulboschoenus fluviatilis	River bulrush	70
Typha latifolia	Broad-leaved cattail	68
Carex lacustris	Lake sedge	67
Cicuta bulbifera	Bulblet water-hemlock	62
Acorus americanus	Sweet-flag	60
Galium trifidum	Small bedstraw	60
Phragmites australis	Common reed grass	55
Iris versicolor	Blue flag	53
Typha X glauca	Hybrid cattail	50
Impatiens capensis	Orange jewelweed	49
Bidens cernuus	Nodding beggar-ticks	45
Lysimachia thyrsiflora	Swamp loostrife	45
Schoenoplectus tabernaemontani	Soft-stem bulrush	45
Boehmeria cylindrica	Small-spike false nettle	44
Typha angustifolia	Narrow-leaved cattail	44
Calamagrostis canadensis	Bluejoint grass	43
Fraxinus pennsylvanica	Green ash	43
Rumex orbiculatus	Great water dock	43

Figure 4: Rank order of species identified during the plant surveys. Abundance (the Y-axis) represents the sum of all abundance/cover values assigned to each species in the field.



Non-native Species

While we found a number of exotic species in this survey, only a few were significantly abundant. Reed canary grass was the most pervasive non-native species in the areas we sampled; it was most abundant in sedge meadows but also common in emergent marshes, transitional marshes, and forested wetlands. Other relatively abundant non-native species included hybrid and narrow-leaved cattail (*Typha x glauca* and *T. angustifolia*), mostly in transitional and emergent marshes; moneywort (*Lysimachia nummularia*), found only in forested wetlands; and bittersweet nightshade (*Solanum dulcamara*), which seemed to show up in small quantities everywhere. Of special note is that purple loosestrife (*Lythrum salicaria*) was found in several (9/48) sample areas. However, it was never abundant; often only a few plants were found, and they were pulled and removed from the wetlands whenever possible. All the giant reed (Phragmites australis) we observed appeared to be the native strain rather than the larger, cosmopolitan variety becoming common along Wisconsin's coasts and Interstate Highways. As mentioned above, non-native species comprise about 12% of the total species identified during our surveys. These 25 non-native species represent approximately 11% of the total cover of all species encountered in our survey areas, although non-native cattails certainly represent more total cover than we identified in our survey areas since the majority of the shallow marshes were not surveyed

Description of Major Wetland Areas

The four major wetland areas sampled differed significantly in the distribution of community types (Table 2 and Figure 2) but were remarkably similar in diversity and floristic quality (Table 3). We encountered sedge meadows primarily in Area 2 and Area 4 but emergent marshes were more common in Area 1 and

Area 3. Transitional marshes and forested wetlands were fairly well distributed but mudflats were mostly in Area 3, not surprising given that this area contained the famous "Mudlake," known for 150 years for its exceptional waterfowl and shorebird habitat.

Table 2: Distribution of samples among major wetland areas

N=number of samples, A=acreage of samples

Community type		Area 1	Area 2	Area 3	Area 4	Total
Sedge meadow (SM)	N	---	N=8	N=2	N=6	N=16
	A		A=25	A=8	A=56	A=89
Emergent Marsh (EM)	N	N=3	N=1	N=5	N=2	N=11
	A	A=23	A=22	A=36	A=36	A=117
Transitional Marsh (TM)	N	---	N=2	N=3	N=2	N=7
	A		A=33	A=54	A=69	A=156
Forested Wetland (FW)	N	N=1	N=1	N=3	N=2	N=7
	A	A=6	A=4	A=13	A=32	A=55
Mud Flat (MF)	N	---	N=1	N=3	N=1	N=5
	A		A=64	A=28	A=15	A=107
Reed canary grass monoculture (PM)	N	---	N=1	---	---	N=1
	A		A=2			A=2
Hybrid cattail monoculture (XM)	N	---	N=1	---	---	N=1
	A		A=1			A=1
Total	N	N=4	N=15	N=16	N=13	N=48
	A	A=29	A=151	A=138	A=208	A=526

Despite differences in their community type composition, the four areas differ little by measures of diversity and floristic quality (Table 3). The typical sample (community) in each area tended to have about 30 species, with a mean Coefficient of Conservatism (CC) of about 4 and a Floristic Quality Index (FQI) of about 20. However, when data from samples are combined for each area, CC remains the same at about 4 and FQI increases, largely because of the greater number of species encountered in the area as a whole compared to the number of species found in each individual community. The apparent differences in the data are as much sampling artifacts as real differences. Area 1 was less species-rich than other areas but both the sample size (4) and the acreage were small, and one of the four samples was from a mature floodplain forest with almost no groundcover present this year. In addition, two of the four samples came from a preliminary survey in June when many annuals were not yet identifiable. The quality rating (CC) of its constituent species, however, was relatively high. Since the FQI adjusts the CC by a species richness factor, the lower FQI is expected in Area 1.

Table 3: Data summary by project area

Project Area	Area sampled (acres)	Number of communities identified	Number of species identified	Average species richness per site	Average FQI per site	Mean CC for the entire area	FQI for the entire area
Area 1	29	4	40	14.3	15.3	3.9	24.8
Area 2	151	15	158	32.2	21.3	3.9	49.6
Area 3	138	16	123	28.2	19.4	4.1	45.0
Area 4	208	13	139	33.2	22.3	3.9	46.3
All areas	**526**	**48**	**215**	**28.9**	**20.5**	**4.0**	**57.3**

Description of Wetland Plant Community Types

Five different types of wetland plant communities were identified and classified based upon species composition. Terminology follows that commonly used in our area of the Midwest (c.f. Curtis 1959; Eggers and Reed 1997, NHI Plant Community Classifications) for four of the vegetation types identified. In addition to the expected vegetation types traditionally found in southern Wisconsin we found a group of sites that were difficult to classify. We named these "Transitional Marshes," which are essentially a sub-community of the shallow marsh. These communities are generally located at the upper margin of the extensive emergent shallow marshes that extend lakeward. Since this area of the wetlands (upper margins) is where we sampled most extensively, these communities may be over represented relative to the emergent shallow marshes.

Table 4 below summarizes the data by vegetation type. Figure 5 below compares various measures of floristic quality among the five community types identified.

Sedge Meadow

Sixteen sedge meadows were identified and mapped within our study areas. They tend to be small, with an average size of 5.6 acres, yet they contain a high number of species, averaging 33 species per sample. 133 species were identified, representing almost two-thirds of the total number of species encountered during our surveys, while the area covered by sedge meadows represents only 17% of the total area surveyed. Thirteen non-native species were identified in the sedge meadows. This community type, as well as representing the highest diversity, also represents high floristic quality. The overall FQI of all sedge meadow species is 47.1, the highest value encountered; the average FQI of each sedge meadow stand is 24.4, second to the transitional marshes, likely a result of small stand size. Sedge meadows also have a relatively high mean CC of 4.1 and a composite index of 4.4. The sedge meadows tended to have more distinctive species than other community types (Appendix C and D) and are relatively easy to distinguish in the field by the shorter stature of their constituent species and by the relative abundance of grasses and sedges in the genus *Carex*. The sedge meadows we sampled are characterized by the presence of several sedges: tussock sedge (*Carex stricta*), lake sedge (*C. lacustris*), Bebb's oval sedge (*C. bebbii*), and common lake sedge (*C. utriculata*). Other characteristic species include black bulrush (*Scirpus atrovirens*), swamp milkweed (*Asclepias incarnata*), blue-joint grass (*Calamagrostis canadensis*), and marsh bellflower (*Campanula aparanoides*). Dominant species found in this vegetation type included common lake sedge, reed canary grass, bur-reed, and field mint. See Appendix B and C for a complete list of dominant and characteristic species, respectively, for each community type and Appendix D for a list of species exclusively found in sedge meadows during our survey.

These communities were most common in Areas 2 and 4 and most commonly occurred as long ribbons between uplands and emergent marsh habitats, on the upper end of the wetland gradient. Based on our observations of location, flood debris, etc., the sedge meadows appear to occur at the extreme upper edge of flooding, and we saw many areas where many or most of the tussock sedge hummocks were dead or damaged, presumably due to recent and prolonged flooding, perhaps in 2004.

Transitional Marsh

Transitional marshes were areas with difficult-to-perceive boundaries. These communities exist along large and complex vegetation gradients. Some were very gradual transitions from sedge meadows to emergent marshes and others were mosaics where physical and vegetation heterogeneity made it difficult to sub-divide an area. Not surprisingly, these areas were the largest of our sample areas averaging over 22 acres, mostly as a result of where we sampled in the wetlands (margins and transitional areas). Seven transitional marshes were mapped and inventoried during the survey. They are characterized by the presence of bur-reed and sweet flag (*Acorus americanus*) but contain many species characteristic of sedge meadows, emergent marshes, and mud flats. Dominant species include bur-reed, marsh skullcap, and purple-stem beggar-ticks. The transitional marsh stands contained an average of 45 species and an average FQI of 26.8. These values, the highest of all community types encountered in our survey, are in large part due to the large average size of each sample/stand. A total of 110 species were identified in these communities, of which 10 are non-native. The transitional marshes as a whole possess a mean CC of 4.3, the highest of all communities, a composite index of 4.4, comparable to the sedge meadows, and an FQI of 44.8, second to sedge meadows.

Emergent Marsh

Eleven emergent marshes were identified and mapped within our sample area. Each stand averaged over 10 acres in size and contained about 23 species per sample, with an average FQI of 19.0. In total, 83 species were identified in the emergent marshes, of which 13 are non-native. The vegetation quality overall is lower than that of both the sedge meadows and transitional marshes: emergent marshes as a community have a mean CC of 3.9, a composite index of 4.0, and an FQI of 35.2. Characteristic species in these communities include river bulrush (*Bolboschoenus fluviatilis*), giant reed grass (*Phragmites australis*), and wild rice (*Zizania aquatica*). The emergent marsh areas we sampled were dominated by river bulrush, bur-reed, and broad-leaved arrowhead, though the emergent marshes in general are also often dominated by cattails. While emergent marshes represent only about one-fourth of our total sample area, they are quite extensive within the wetlands (particularly in Areas 2 and 3 and the western portion of Area 4) and are the most abundant community type in the Lake Koshkonong wetlands. Our sampling was limited in these areas because they are often too unstable to traverse on foot, yet too thickly vegetated to traverse by boat. While these communities are under-represented in our data relative to their abundance in the wetlands, we believe that we were able to sample a sufficient number of them to accurately represent their floristic diversity.

Mud Flats

Five mud flat areas were identified and mapped within our survey area. Individual stands averaged about 21 acres in size within our study area, and an average of 22 species were identified within each sample, possessing an average FQI of 18.5. A total of 55 species were identified within this community type as a whole; 5 of these are non-native. Mud flats we sampled have a mean CC of 4.1, a composite index of 4.0 (comparable to emergent marshes), and an FQI of 30.6. Mud flats form in open areas that fluctuate between shallow open water during periods of high water and exposed silty deposits during periods of low water. These deposits are generally colonized by annuals. Characteristic species include coast barnyard grass (*Echinocloa walteri*), duckweed (*Lemna minor*), American white water lily (*Nymphaea odorata*), purple-stemmed beggar-ticks (*Bidens connatus*) and other beggar-ticks, and water plantain (*Alisma subcordatum*). Smartweeds (*Polygonum*) are also abundant in these communities.

Forested Wetlands

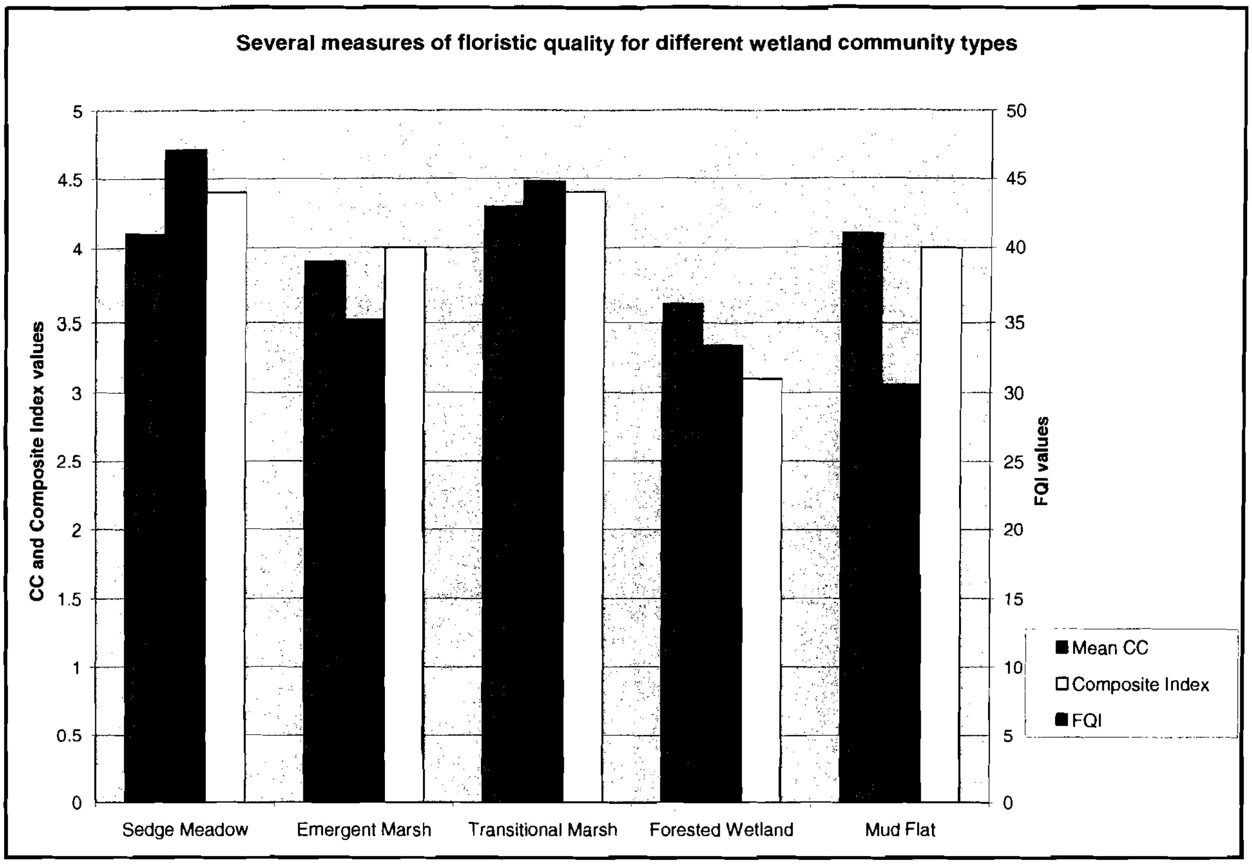
All of the forested wetlands surrounding Lake Koshkonong occur on alluvial deposits. Most of the forested wetlands are floodplain forests; no coniferous forests were encountered during the survey period and none are known to occur in the vicinity of the lake. Seven forested wetlands were sampled, and two types of floodplain forests were encountered—one type is dominated by silver maple (*Acer saccharinu*), green ash (*Fraxinus pennsylvanica*), and/or swamp white oak (*Quercus bicolor*); the other type is dominated by green ash, elms (*Ulmus* spp.), and willows (*Salix* spp.). The former type was associated with the floodplains of the Rock River and the delta of Koshkonong Creek while the latter was associated with smaller creeks. Within our sample area, acreages of individual stands vary widely, but the average is 8 acres. Individual stands contained an average of 25 species with an average FQI of 15.0. A total of 87 species were identified in the forested wetlands, of which 11 are non-native. Average species richness was moderate, with an average of 25 species identified within each sample. The forested wetlands as a whole have a mean CC of 3.6, a composite index of 3.1, and an FQI of 33.4. The comparably low floristic quality for this community type is typical for mature floodplain forests. These communities generally support a low number of species due to the harsh growing conditions that result from both low light levels produced by the closed canopy and annual spring flood events. The herbaceous layer is generally bare or sparse as a result.

Table 4: Data summary by wetland plant community type

Community Type	Area sampled (acres)	Number of stands	Total number of species identified	Average species richness per site	% Native Species	% Cover Non-native species[1]	Average FQI per site	Mean CC	CI [2]	FQI
Sedge Meadow	89	16	133	33	90%	9.1%	24.4	4.1	4.4	47.1
Emergent Marsh	117	11	83	23	84%	11.8%	19.0	3.9	4.0	35.2
Transitional Marsh	156	7	110	45	91%	9.6%	26.8	4.3	4.4	44.8
Forested Wetland	54	7	87	25	87%	19.1%	15.0	3.6	3.1	33.4
Mud Flat	106	5	55	22	90%	4.4%	18.5	4.1	4.0	30.6
All Areas	526	48	215	30	88%	10.9%	21.4	4.0	---	57.3

[1] Approximate coverage, based on coverage classes
[2] CI = Composite Index

Figure 5: Comparison of community types with respect to different measures of floristic quality



CONCLUSIONS

Data collected during our field surveys indicate that the wetlands associated with Lake Koshkonong have considerable floristic quality and diversity. Of the community types we identified, sedge meadows possess the highest species richness and floristic quality (see Figure 4 above) and the greatest number of distinctive species (species rarely found in other community types). The species composition of the sedge meadows represented nearly two-thirds of all plant species identified, yet these communities represent only a small portion of the communities present on Lake Koshkonong. In general, sedge meadows tend to be found higher on the wetland gradient (i.e. at higher elevations) than emergent marshes and other communities subject to semi-permanent inundation. Our data support this claim, as we tended to find sedge meadows in the upland portion of the upland-wetland ecotone. Sedge meadows, because they are generally not subject to semi-permanent inundation, can be damaged and/or destroyed by prolonged flooding.

The shallow marsh communities we surveyed, both the "emergent" and "transitional" shallow marshes proved to be highly diverse wetland communities as well. Many of the shallow marsh wetland communities in southern Wisconsin are comprised of monocultures or near monocultures of broad and/or narrow leaved cattails. This is not the case in the Lake Koshkonong shallow marshes, as the shallow marsh wetlands that we surveyed contained a high level of plant species diversity, especially near the upper margins ("transitional marshes"). While these communities do contain a high density of cattail, they also support many other important plant species such as but not limited to bur reed, bulrushes, sedges, wild rice, arrow leaf, sweet flag, and water lily. Our general observation in these wetland communities was that areas with deeper pockets of standing water had lower species diversity caused either by: 1) a shift to cattail monocultures; or 2) a shift to open water and less emergent vegetation cover.

The floodplain forest wetland communities are also quite extensive around Lake Koshkonong. We identified several areas of floodplain forest wetland adjacent to Lake Koshkonong that are high quality and regionally rare wetland communities in southern Wisconsin. Comparable large, intact stands of floodplain forest of this size and quality in southern Wisconsin occur primarily along the Lower Wisconsin River and stretches of the Sugar River. This forest type is extremely uncommon in southeastern Wisconsin, since it is usually associated with large rivers the size of the Wisconsin or Mississippi. The largest stand of floodplain forest we identified in the Lake Koshkonong area occurs along Koshkonong Creek. Other major stands occur along the Rock River near the inlet to Lake Koshkonong. Some of these forests, including the ones sampled for this study, are typical well-developed floodplain forests of high quality. They have a closed canopy and very low light levels at the forest floor. The low light penetration to the ground level, and repeated natural disturbance associated with spring flooding of the soils, produces a very open understory having very little herbaceous vegetation in the forest groundlayer. Although these forests have been logged in the past, they are dominated by large trees at this time and provide important habitat for wildlife and bird species.

Many mud flat wetlands were identified during our survey. These communities are characterized by the abundance of annual wetland species that cover these seasonally flooded areas. The prevalence of the mud flats we identified were a result of unusually low water levels in 2005. Mean growing season (May-Oct.) water levels were the lowest since 1988 averaging only 776.17 ft. These low water levels were the result of a combination of drought conditions and recently repaired wicket gates at the Indianford dam (allowing better water level control). The low water levels allowed more surface area of mud flat exposure. Many local residences expressed that this was the most wild rice that they had seen on the Lake in decades. Mud flats are very important wetland community types for various reasons. The abundance of annual species (wild rice, smart weed, barnyard grass, beggars tick, etc.) that colonize the soils provides an important food base for wildlife. Aquatic invertebrates become exposed in these areas, also providing an important and readily available food base for wildlife. The exposed soils provide resting areas for waterfowl and wading birds. The exposed soils, when exposed for long enough duration, provide the medium for establishment of perennial emergent species that can not germinate under inundated conditions.

Increased Water-level Implications

Hydrology is the overriding most important factor that determines the distribution of wetland plants and plant communities (Castelli et al. 2000, Kraemer 2003, Henskey 2004). Because the water levels in Lake Koshkonong are already kept high and are held unnaturally constant during what would normally be the late-season, low water period, a small change in this late season water level will cause a major shift in the plant communities. The natural late-season drawdown of the groundwater in wetlands is crucial for oxygenating the soil to enable root growth of wetland plants. Basic wetland hydrology principles applied to a relatively flat landscape such as that which is present in Lake Koshkonong can be used to make several general predictions as to how an increase in water levels will affect the communities we identified and described above.

The most susceptible wetland communities on Lake Koshkonong to significant adverse impacts include the floodplain forests, sedge meadows, and mudflat communities. The low lying floodplain forests of this size and quality are regionally sparse and provide important habitat for wildlife, aesthetic value, and economic value from timber harvest. The floodplain forests can be expected to decline resulting from widespread loss of the dominant tree species. Dead trees will be wind-thrown and uprooted, especially those on the immediate shores of the lake. This will render the shoreline unprotected from erosion and there will be a further recession of the shoreline and loss of wetlands. Swamp white oak can be expected to become nearly eradicated as it is already occurring in the highest elevations of the forested wetlands (Kraemer and Reinartz 2005).

Sedge meadow communities will be significantly reduced. These communities are poorly suited to shift upslope when average water levels rise. The sedge meadows that we identified generally already occur at the upper limits of available habitat. Sedge meadows cannot simply migrate into agricultural fields, shrub thickets, or wet meadows. They are best suited to the peat substrate that they themselves create over a long period of time and reach their highest diversity when their primary water sources are rainfall and groundwater discharge (Kercher et al. 2004). While most can survive occasional partial inundation, they are not well-suited to either complete inundation for more than a brief period or perennial partial inundation. Based on quantitative floristic quality assessments, the sedge meadow communities contained the highest number of plant species, representing nearly two thirds of all wetland plant species present on Lake Koshkonong and had the highest level of diversity and floristic quality. There were 25 species that we identified that occurred only in sedge meadow communities (Appendix D - Sedge meadow dependant species list). Most of these are native species with moderate to high coefficients of conservatism. The Mean C of the 25 species exclusive to sedge meadows is 5.2.

In addition to the impacts on these wetlands, shallow marsh communities can be expect to continue to decrease as open water areas increase. While shallow marsh communities likely will become established in place of the sedge meadow communities, based on the rate of shallow marsh loss historically, there will still be a net overall loss of shallow marsh.

Mudflat exposure obviously will be greatly reduced, as the exposed mudflats that we observed were typically only 0.5 ft or less above the lake level. This will result in reduced foodbase (primarily annual plants) for wildlife and decrease establishment of perennial emergent plant species requiring these exposed soils to germinate.

Virtually none of the wetland plant communities surrounding the lake will be growing where they belong from a hydrological perspective if late season water levels are increased by 0.6 ft in Lake Koshkonong. The outer (lakeside) margin of the marshes will no longer support emergent vegetation, the lower portions of wet meadows and sedge meadows will convert to shallow marsh. The disturbance associated with this hydrologic change will leave these communities susceptible to colonization by invasive plants (Lindig-Cisneros and Zedler 2002, Kercher et al. 2004). During the hydrologic disturbance, many established native species will become stressed and/or die which will provide opportunistic species, many of which are invasive non-native, the opportunity to colonize resulting in decreased floristic diversity (Silvertown et al. 1999). The ever-increasing prevalence of invasive species place the wetland vegetation at greater risk each time the water level regime is altered in Lake Koshkonong.

MONITORING AND MANAGEMENT RECOMMENDATIONS

The overall management goal is to maintain a diversity of plant communities and plants within the Lake Koshkonong wetlands. Several issues, including increased water level and invasive species, are of management concern within these wetlands. These issues can be addressed through further monitoring, which is an important component of an adaptive approach to management.

Recommended monitoring and possible subsequent management actions within the Lake Koshkonong wetlands will depend largely on the outcome of the current water level controversy. However, regardless of whether water levels are raised, monitoring will be key to determining what changes occur in vegetation composition and what management techniques to utilize, if any. Water levels tend to fluctuate from year to year, depending on precipitation and other climatic factors, and, likewise, the extent of communities such as mud flats will fluctuate, and the abundance of species such as wild rice that depend upon periodic draw-downs will also fluctuate. However, large-scale, long-term degradation or loss of plant communities can be observed with periodic monitoring. Baseline data have been collected through this study for portions of the wetlands, and the vascular plants present in these areas should be inventoried periodically (every 2-3 years) to document overall trends in changes in vegetation composition. Additionally, a comprehensive survey, such as the one implemented in 2005 incorporating community mapping and quantitative analyses, should be undertaken approximately every five years. These periodic inventories will be particularly important to document vegetation change if the water levels on the lake are increased, and should occur at more frequent intervals should large-scale changes be observed.

In addition to monitoring overall vegetation change in the Lake Koshkonong wetlands, special attention should be paid to those areas identified as high quality communities, particularly the sedge meadows. Sedge meadows, which are the most diverse community type and possess high floristic quality, are highly vulnerable to degradation from invasive species and increased water levels. Given the importance of this community to the overall diversity of the wetlands, it is important that they all be documented and monitored. Areas near the upper end of the wetland-upland gradient that were not surveyed during the 2005 survey should be the focus of further study, and all sedge meadows within these areas should be identified, inventoried and mapped. All identified sedge meadows should then be resurveyed in subsequent years (approximately every 2-3 years) in order to monitor degradation of and damage to these communities. These areas should be surveyed periodically, regardless of the outcome of the current water level controversy.

Currently, reed canary grass is the most pervasive invasive species found within the sedge meadows. It was often found on the margins of the sedge meadows, sometimes surrounding the sedge meadow pocket. Reed canary grass is known to invade in areas where the native vegetation has been compromised or stressed in some way, from, for example, a change in hydrology or from damage due to an extreme disturbance. One approach to preventing the further spread of reed canary grass into the sedge meadows would be to maintain a healthy, diverse mix of species within these areas. If damage to one of these communities does occur in an area where reed canary grass is present, then a mix of aggressive, native sedge meadow species could be seeded or planted in the damaged area in order to be able to compete with reed canary grass. Another approach to reed canary grass control is the use of herbicides. If an area of management concern is identified where reed canary grass removal is needed and would likely be successful, then a glyphosate herbicide (such as Rodeo) or a grass-specific herbicide (such as Vantage) could be applied three times per year starting in the spring, followed by a native planting or seeding in late fall. This could be done on a large or small scale as needed. Managers should carefully analyze the need, goals, costs and potential benefits and outcomes of undertaking such a project on a large-scale basis, because reed canary grass is difficult to completely eradicate. However, in areas where native vegetation is established and thriving, control of the further spread of reed canary grass can be quite successful.

Several other invasive species of management concern were found within the Lake Koshkonong wetlands. Of particular note is purple loostrife, which, although found in several locations, was neither abundant nor common. In 2005 it was found in very low numbers, and when encountered was pulled, bagged, and disposed of. Because of its ability to reproduce and spread prolifically, an annual or biannual survey should be conducted, preferably in June-July. The plant flowers July-September in Wisconsin and can produce seeds as soon as flowering begins. Early identification of this species is important, as a mature plant can produce over two million seeds per year. If the infestation is low (as was the case in 2005), then all plants should be pulled as early in the season as they can be identified. They can be bagged and disposed of in a capped landfill or can be dried and burned. Mechanical and/or chemical control are options for heavier infestations, and biological control is now considered the most viable option for purple loosestrife populations that can not be controlled by other means (WDNR 2004). The annual or biannual survey can be conducted by boat, though a small boat will be necessary to allow access to the shallow water areas of the wetlands. All occurrences of purple loosestrife should be mapped and/or recorded with a GPS each year.

Finally, and most importantly, a recommended management action is to oppose the currently proposed hydrologic modification to the lake, in part because of the adverse impacts, outlined above, that this proposed manipulation may have on plant communities currently found within the Lake Koshkonong wetlands. Additionally, our study suggests that periodic draw downs of the water level in the lake, as occurred naturally in 2005 due to drought conditions, may be beneficial for the persistence of some plant communities, such as mud flats, and some important plant species, such as wild rice.

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APPENDIX A

COMPLETE SPECIES LIST

Appendix A

Lake Koshkonong Wetland Plant Survey - July 2005

Vascular Plant Species List

Scientific Name	Common Name	Coefficient of Conservatism	Wetland Indicator Status
Acer negundo	box elder	0	FACW-
Acer saccharinum	silver maple	2	FACW
Acorus americanus	sweet-flag	7	OBL
Agrimonia gryposepala	common agrimony	2	FACU+
Agrostis gigantea	redtop	0	FAC
Agrostis stolonifera	creeping bent grass	0	FACW
Alisma subcordatum	American water-plantain	3	OBL
Alliaria petiolata	garlic mustard	0	FAC
Amaranthus tuberculatus	rough-fruited amaranth	3	OBL
Ambrosia artemisiifolia	common ragweed	0	FACU
Ambrosia trifida	giant ragweed	0	FAC+
Amorpha fruticosa	false indigo	6	FACW+
Amphicarpaea bracteata	hog-peanut	5	FAC
Anemone canadensis	Canada anemone	4	FACW
Angelica atropurpurea	great angelica	6	OBL
Apios americana	common groundnut	5	FACW
Apocynum androsaemifolium	spreading dogbane	2	UPL
Asclepias incarnata	swamp milkweed	5	OBL
Asclepias syriaca	common milkweed	1	UPL
Aster firmus	shining aster	6	FACW+
Aster lanceolatus	white panicle aster	4	FACW
Aster lateriflorus	calico aster	3	FACW-
Aster puniceus	swamp aster	5	OBL
Aster umbellatus	flat-top aster	6	FACW
Barbarea orthoceros	American yellow-rocket	0	OBL
Berula erecta	cut-leaved water-parsnip	10	OBL
Bidens cernuus	nodding beggar-ticks	4	OBL
Bidens connatus	purple-stem beggar-ticks	6	OBL
Bidens coronatus	northern tickseed-sunflower	7	OBL
Bidens frondosus	common beggar-ticks	1	FACW
Boehmeria cylindrica	small-spike false nettle	6	OBL
Bolboschoenus fluviatilis	river bulrush	6	OBL
Butomus umbellatus	flowering-rush	0	OBL
Calamagrostis canadensis	blue-joint grass	5	OBL
Campanula americana	American bellflower	4	FAC
Campanula aparinoides	marsh belflower	7	OBL
Cardamine bulbosa	spring-cress	6	OBL
Carex aquatilis	water sedge	7	OBL
Carex bebbii	Bebb's oval sedge	4	OBL
Carex blanda	common wood sedge	3	FAC
Carex comosa	bristly sedge	5	OBL
Carex grayi	bur sedge	7	FACW+
Carex hystericina	bottlebrush sedge	3	OBL
Carex intumescens	greater bladder sedge	5	FACW+
Carex lacustris	lake sedge	6	OBL

Appendix A

Scientific Name	Common Name	Coefficient of Conservatism	Wetland Indicator Status
Carex lasiocarpa	woolly-fruit sedge	9	OBL
Carex lupulina	common hop sedge	6	OBL
Carex pellita	broad-leaved woolly sedge	4	OBL
Carex prairea	fen panicled sedge	10	FACW+
Carex retrorsa	deflexed bottlebrush sedge	6	OBL
Carex sartwelli	running marsh sedge	7	FACW+
Carex sp.	sedge		
Carex sp. (ovales group)	oval sedge		
Carex stipata	common fox sedge	2	OBL
Carex stricta	common tussock sedge	7	OBL
Carex trichocarpa	hairy-fruit sedge	7	OBL
Carex utriculata	common yellow lake sedge	7	NI
Carex vesicaria	blister sedge	7	OBL
Carex vulpinoidea	brown fox sedge	2	OBL
Carya cordiformis	bitter-nut hickory	6	FAC
Chelone glabra	turtlehead	7	OBL
Cicuta bulbifera	bulblet water-hemlock	7	OBL
Cicuta maculata	common water-hemlock	6	OBL
Circaea lutetiana	broad-leaf enchanter's-nightshade	2	FACU
Cirsium arvense	Canada thistle	0	FACU
Cirsium palustre	bull thistle	0	NI
Convolvulus sp.			
Cornus racemosa	gray dogwood	2	FACW-
Cornus stolonifera	red-osier dogwood	3	FACW
Crataegus crus-galli	cockspur hawthorn	3	FAC
Cryptotaenia canadensis	Canadian honewort	4	FAC
Cuscuta gronvii	common dodder	4	
Cuscuta sp.	dodder		
Cyperus esculentus	field nut sedge	0	FACW
Cyperus strigosus	false nut sedge	1	FACW
Decodon verticilliatus	swamp loostrife	7	OBL
Desmodium glutinosum	cluster-leaf tick-trefoil	6	UPL
Dioscorea villosa	wild yam	4	FAC-
Dryopteris sp.	wood fern		
Echinochloa crus-galli	barnyard grass	0	FACW
Echinocloa sp.	barnyard grass		
Echinocloa walteri	coast barnyard grass	8	OBL
Echinocystis lobata	wild-cucumber	2	FACW-
Eleocharis acicularis	needle spike-rush	5	OBL
Eleocharis palustris	marsh spike-rush	6	OBL
Eleocharis sp.	spike-rush		
Elymus virginicus	common eastern wild-rye	6	FACW-
Epilobium ciliatum	American willow-herb	3	FACU
Epilobium coloratum	eastern willow-herb	3	OBL
Epilobium leptophyllum	American marsh willow-herb	8	OBL
Equisetum arvense	common horsetail	1	FAC
Equisetum fluviatile	water horsetail	7	OBL
Erechtites hieracifolia	fireweed	2	FACU

Appendix A

Scientific Name	Common Name	Coefficient of Conservatism	Wetland Indicator Status
Erigeron strigosus	daisy fleabane	2	FAC-
Eupatorium maculatum	Joe-pye weed	4	OBL
Eupatorium perfoliatum	boneset	6	FACW+
Fraxinus nigra	black ash	8	FACW+
Fraxinus pennsylvanica	green ash	2	FACW
Galium aparine	annual bedstraw	2	FACU
Galium asprellum	rough bedstraw	7	OBL
Galium boreale	northern bedstraw	5	FAC
Galium tinctorium	stiff bedstraw	5	OBL
Galium trifidum	small bedstraw	6	FACW+
Geranium maculatum	wild geranium	4	FACU
Geum allepicum	yellow avens	3	FAC+
Geum canadense	white avens	2	FAC
Glechoma hederacea	creeping Charlie	0	FACU
Glyceria striata	fowl manna-grass	4	OBL
Gratiola neglecta	clammy hedge-hyssop	5	OBL
Hackelia virginiana	stickseed	3	FAC-
Helenium autumnale	common sneezeweed	4	FACW+
Heliopsis helianthoides	false sunflower	5	UPL
Impatiens capensis	orange jewelweed	2	FACW
Iris versicolor	blue flag	5	OBL
Laportea canadensis	Canadian wood-nettle	4	FACW
Lathyrus palustris	marsh vetchling	5	FACW
Leersia oryzoides	rice cut grass	3	OBL
Lemna minor	common duckweed	4	OBL
Lycopus americanus	American water-horehound	4	OBL
Lycopus uniflorus	northern bugleweed	4	OBL
Lysimachia ciliata	fringed loostrife	5	FACW
Lysimachia nummularia	moneywort	0	FACW+
Lysimachia quadriflora	narrow-leaved loostrife	9	OBL
Lysimachia quadrifolia	whorled loostrife	6	UPL
Lysimachia terrestris	swamp-candles	7	OBL
Lysimachia thyrsiflora	swamp loostrife	7	OBL
Lythrum alatum	winged loostrife	6	OBL
Lythrum salicaria	purple loostrife	0	OBL
Menispermum canadense	Canadian moonseed	5	FAC
Mentha arvensis	field mint	3	FACW
Mimulus ringens	monkey-flower	6	OBL
Myosotis scorpoides	common forget-me-not	0	OBL
Nasturtium officinale	watercress	0	OBL
Nymphaea odorata	white water-lily	6	OBL
Onoclea sensibilis	sensitive fern	5	FACW
Oxalis sp.	wood-sorrel		
Packera aurea	golden ragwort	6	FACW
Parthenocissus quinquefolia	Virginia creeper	5	FAC-
Penthorum sedoides	ditch stonecrop	3	OBL
Phalaris arundinacea	reed canary grass	0	FACW+
Phragmites australis	common reed grass	1	FACW+

Appendix A

Scientific Name	Common Name	Coefficient of Conservatism	Wetland Indicator Status
Phyla lanceolata	lance-leaf fog-fruit	5	OBL
Pilea pumila	Canadian clearweed	3	FACW
Plantago major	common plantain	0	FAC+
Poa pratensis	Kentucky bluegrass	0	FAC-
Polygonatum biflorum	Solomon's-seal	4	FACU
Polygonum amphibium	water smartweed	5	OBL
Polygonum hydropiper	water-pepper	0	OBL
Polygonum hydropiperoides	false water-pepper	6	OBL
Polygonum lapathifolium	curly-top knotweed	2	FACW+
Polygonum pensylvanicum	Pennsylvania smartweed	1	FACW+
Polygonum punctatum	dotted smartweed	5	OBL
Pontederia cordata	pickerel-weed	8	OBL
Populus deltoides	cottonwood	2	FAC+
Populus tremuloides	aspen	2	FAC
Potamogeton crispus	curly pondweed	0	OBL
Prunus virginiana	chokecherry	3	FAC-
Quercus bicolor	swamp white oak	7	FACW+
Quercus macrocarpa	burr oak	5	FAC-
Ranunculus acris	common buttercup	0	FACW-
Ranunculus flabellaris	yellow watter buttercup	8	OBL
Ranunculus hispidus	bristly buttercup	6	FAC
Ranunculus sceleratus	cursed crowfood	3	OBL
Rhamnus cathartica	common buckthorn	0	FACU
Rhamnus frangula	glossy buckthorn	0	FAC+
Rorippa palustris	common yellow-cress	3	OBL
Rorippa sylvestris	creeping yellow-cress	0	OBL
Rumex crispus	curly dock	0	FAC+
Rumex orbiculatus	great water dock	8	OBL
Rumex verticillatus	swamp dock	6	OBL
Sagittaria latifolia	broad-leaved arrowhead	3	OBL
Salix amygdaloides	peach-leaved willow	4	FACW
Salix bebbiana	Bebb's willow	7	FACW+
Salix discolor	pussy willow	2	FACW
Salix exigua	sandbar willow	2	OBL
Salix nigra	black willow	4	OBL
Salix petiolaris	meadow willow	6	FACW+
Sanicula canadensis	Canadian black snakeroot	6	FACU+
Schoenoplectus acutus	hard-stem bulrush	6	OBL
Schoenoplectus pungens	common three-square bulrush	5	OBL
Schoenoplectus tabernaemontani	soft-stem bulrush	4	OBL
Scirpus atrovirens	black bulrush	3	OBL
Scirpus cyperinus	wool-grass	4	OBL
Scutellaria galericulata	marsh skullcap	5	OBL
Scutellaria lateriflora	mad-dog scullcap	5	OBL
Sium suave	water-parsnip	5	OBL
Solanum dulcamara	bittersweet nightshade	0	FAC
Solidago canadensis	Canada goldenrod	1	FACU
Solidago gigantea	giant goldenrod	3	FACW

Appendix A

Scientific Name	Common Name	Coefficient of Conservatism	Wetland Indicator Status
Sparganium eurycarpum	common bur-reed	5	OBL
Spartina pectinata	prairie cord-grass	5	FACW+
Spiraea alba	white meadowsweet	4	FACW+
Spiraea tomentosa	steeplebush	6	FACW
Stachys palustris	marsh hedge-nettle	5	OBL
Stachys tenuifolia	smooth hedge-nettle	6	FACW+
Stellaria longifolia	long-leaved stitchwort	5	FACW+
Symplocarpus foetidus	skunk cabbage	8	OBL
Teucrium canadense	wood sage	4	FACW-
Thalictrum dasycarpum	purple meadow-rue	4	FACW-
Thelypteris palustris	marsh fern	7	FACW+
Toxicodendron radicans	poison ivy	4	FAC+
Typha angustifolia	narrow-leaved cattail	0	OBL
Typha latifolia	broad-leaved cattail	1	OBL
Typha X glauca	hybrid cattail	0	OBL
Ulmus americana	American elm	3	FACW-
Urtica dioica	stinging nettle	1	FAC+
Utricularia vulgaris	common bladderwort	7	OBL
Verbena hastata	blue vervain	3	FACW+
Vernonia fasciculata	common ironweed	5	FACW
Veronica anagallis-aquatica	water speedwell	4	OBL
Viola sororia	common blue violet	3	FACU
Viola sp.	violet		
Vitis riparia	river bank grape	2	FACW-
Zanthoxylum americanum	prickly ash	3	
Zizania aquatica	annual wild rice	8	OBL

Total Species = 215

APPENDIX B

DOMINANT SPECIES BY COMMUNITY TYPE

Appendix B

Top 20 Species in 16 Sedge Meadows

Scientific Name	Coefficient of Conservatism	Wetland Indicator Status	Cover Value[a]	Presence Value[b]	Importance Value
Carex lacustris	6	OBL	28	13	41
Phalaris arundinacea	0	FACW+	25	13	38
Sparganium eurycarpum	5	OBL	25	13	38
Mentha arvensis	3	FACW	24	12	36
Sagittaria latifolia	3	OBL	22	13	35
Scutellaria galericulata	5	OBL	21	14	35
Acorus americanus	7	OBL	21	12	33
Calamagrostis canadensis	5	OBL	19	12	31
Carex stricta	7	OBL	20	11	31
Polygonum amphibium	5	OBL	20	11	31
Galium trifidum	6	FACW+	16	14	30
Eleocharis sp.			18	10	28
Lysimachia thyrsiflora	7	OBL	16	10	26
Leersia oryzoides	3	OBL	16	9	25
Typha latifolia	1	OBL	15	10	25
Pilea pumila	3	FACW	15	9	24
Campanula aparinoides	7	OBL	12	11	23
Carex utriculata	7	NI	15	8	23
Typha X glauca	0	OBL	15	7	22
Asclepias incarnata	5	OBL	10	10	20

[a] Cover value is the sum of all abundance/cover values assigned to that species in stands/samples where it was present

[b] Presence value is the frequency of occurrence of each species within stands/samples

Appendix B

Top 20 Species in 11 Emergent Marshes

Scientific Name	Coefficient of Conservatism	Wetland Indicator Status	Cover Value[a]	Presence Value[b]	Importance Value
Bulboschoenus fluviatilis	6	OBL	26	9	35
Sparganium eurycarpum	5	OBL	21	10	31
Sagittaria latifolia	3	OBL	18	10	28
Phragmites australis	1	FACW+	16	8	24
Scutellaria galericulata	5	OBL	15	9	24
Bidens connatus	6	OBL	14	7	21
Phalaris arundinacea	0	FACW+	13	8	21
Zizania aquatica	8	OBL	14	6	20
Cicuta bulbifera	7	OBL	12	8	20
Typha latifolia	1	OBL	12	8	20
Sium suave	5	OBL	11	6	17
Mentha arvensis	3	FACW	10	7	17
Eleocharis sp.			9	5	14
Galium asprellum	7	OBL	8	5	13
Rumex verticillatus	6	OBL	8	5	13
Alisma subcordatum	3	OBL	7	6	13
Schoenoplectus acutus	6	OBL	7	6	13
Iris versicolor	5	OBL	7	4	11
Typha X glauca	0	OBL	7	4	11
Bidens cernuus	4	OBL	6	5	11

[a] Cover value is the sum of all abundance/cover values assigned to that species in stands/samples where it was present

[b] Presence value is the frequency of occurrence of each species within stands/samples

Appendix B

Top 20 Species in 11 Transitional Marshes

Scientific Name	Coefficient of Conservatism	Wetland Indicator Status	Cover Value[a]	Presence Value[b]	Importance Value
Sparganium eurycarpum	5	OBL	19	7	26
Scutellaria galericulata	5	OBL	15	7	22
Bidens connatus	6	OBL	14	6	20
Polygonum amphibium	5	OBL	13	6	19
Sagittaria latifolia	3	OBL	11	7	18
Bulboschoenus fluviatilis	6	OBL	13	5	18
Typha angustifolia	0	OBL	12	6	18
Typha latifolia	1	OBL	11	6	17
Pilea pumila	3	FACW	11	5	16
Rorippa palustris	3	OBL	11	5	16
Acorus americanus	7	OBL	11	4	15
Bidens cernuus	4	OBL	9	6	15
Galium trifidum	6	FACW+	9	6	15
Leersia oryzoides	3	OBL	9	6	15
Phalaris arundinacea	0	FACW+	10	5	15
Carex lacustris	6	OBL	9	5	14
Cicuta bulbifera	7	OBL	8	5	13
Impatiens capensis	2	FACW	7	6	13
Mentha arvensis	3	FACW	8	5	13
Urtica dioica	1	FAC+	8	5	13

[a] Cover value is the sum of all abundance/cover values assigned to that species in stands/samples where it was present

[b] Presence value is the frequency of occurrence of each species within stands/samples

Appendix B

Top 20 Species in 7 Forested Wetlands

Scientific Name	Coefficient of Conservatism	Wetland Indicator Status	Cover Value[a]	Presence Value[b]	Importance Value
Fraxinus pennsylvanica	2	FACW	18	7	25
Acer saccharinum	2	FACW	16	6	22
Pilea pumila	3	FACW	11	6	17
Lysimachia nummularia	0	FACW+	12	5	17
Phalaris arundinacea	0	FACW+	8	5	13
Vitis riparia	2	FACW-	7	5	12
Boehmeria cylindrica	6	OBL	8	4	12
Impatiens capensis	2	FACW	6	5	11
Leersia oryzoides	3	OBL	7	4	11
Myosotis scorpioides	0	OBL	7	4	11
Iris versicolor	5	OBL	5	5	10
Ulmus americana	3	FACW-	6	4	10
Aster lateriflorus	3	FACW-	5	4	9
Urtica dioica	1	FAC+	5	4	9
Bidens connatus	6	OBL	4	4	8
Rhamnus cathartica	0	FACU	5	3	8
Laportea canadensis	4	FACW	4	3	7
Salix nigra	4	OBL	4	3	7
Bidens cernuus	4	OBL	3	3	6
Carex sp. (ovales group)			3	3	6

[a] Cover value is the sum of all abundance/cover values assigned to that species in stands/samples where it was present

[b] Presence value is the frequency of occurrence of each species within stands/samples

Appendix B

20 Top Species in 5 Mudflats

Scientific Name	Coefficient of Conservatism	Wetland Indicator Status	Cover Value[a]	Presence Value[b]	Importance Value
Echinocloa walteri	8	OBL	14	5	19
Leersia oryzoides	3	OBL	11	5	16
Bidens connata	6	OBL	10	4	14
Polygonum amphibium	5	OBL	10	4	14
Sagittaria latifolia	3	OBL	8	5	13
Pilea pumila	3	FACW	8	4	12
Cicuta bulbifera	7	OBL	6	4	10
Galium trifidum	6	FACW+	6	4	10
Lemna minor	4	OBL	7	3	10
Sparganium eurycarpum	5	OBL	7	3	10
Acorus americanus	7	OBL	6	2	8
Alisma subcordatum	3	OBL	4	4	8
Nymphaea odorata	6	OBL	5	3	8
Mentha arvensis	3	FACW	5	2	7
Rorippa palustris	3	OBL	5	2	7
Iris versicolor	5	OBL	3	3	6
Lycopus americanus	4	OBL	3	3	6
Phragmites australis	1	FACW+	4	2	6
Polygonum pensylvanicum	1	FACW+	4	2	6
Rumex verticillatus	6	OBL	4	2	6

[a] Cover value is the sum of all abundance/cover values assigned to that species in stands/samples where it was present

[b] Presence value is the frequency of occurrence of each species within stands/samples

APPENDIX C

CHARACTERISTIC SPECIES BY COMMUNITY TYPE

Appendix C

Characteristic Species of Vegetation Types based on Multivariate Analyses

Vegetation Type	Species
Sedge Meadow	*Asclepias incarnata*
	Calamagrostis canadensis
	Carex stricta
	C. bebbii
	C. lacustris
	C. utriculata
	Companula aparinoides
	Eupatorium maculatum
	Eupatorium perfoliatum
	Lathyrus palustris
	Lycopus americanus
	Scirpus atrovirens
	Spartina pectinatus
	Stachys palustris
	Thylepteris palustris
Emergent Marsh	*Phragmites australis*
	Scirpus fluviatilis
	Zizania aquatica
Transitional Marsh	*Acorus americanus*
	Sparganium eurycarpum
Forested Wetland	*Acer saccharinum*
	Fraxinus pensylvanicus
	Quercus bicolor
	Salix nigra
Mud Flat	*Alisma subcordatum*
	Bidens connata
	Echinochloa walteri
	Leersia oryzoides
	Lemna minor
	Nymphea odorata

APPENDIX D
SEDGE MEADOW SPECIES

Appendix D

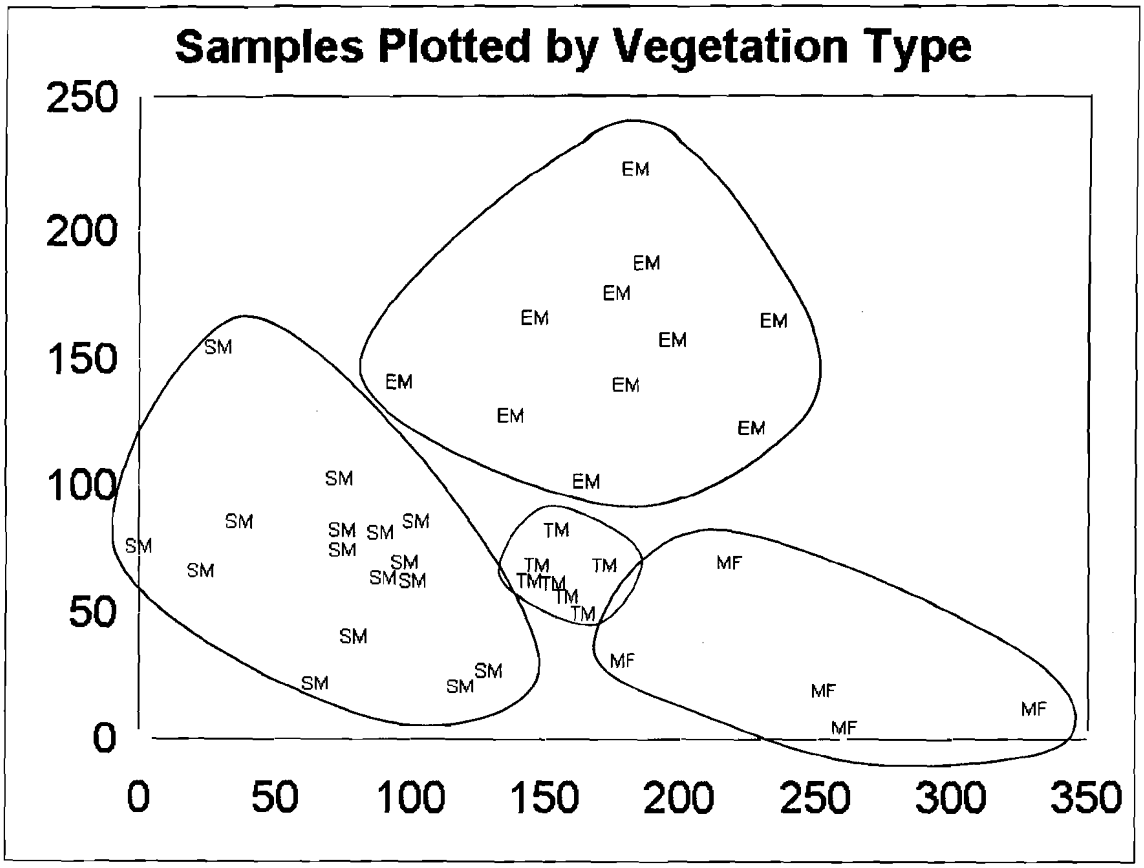
Species found exclusively in sedge meadows based on field surveys conducted in July 2005

Scientific name	Common name	CC
Agrimonia gryposepala	common agrimony	2
Agrostis gigantea	redtop	0
Angelica atropurpurea	great angelica	6
Apocynum androsaemifolium	spreading dogbane	2
Aster firmus	shining aster	6
Aster lanceolatus	white panicle aster	4
Aster umbellatus	flat-top aster	6
Berula erecta	cut-leaved water-parsnip	10
Carex comosa	bristly sedge	5
Carex lasiocarpa	woolly-fruit sedge	9
Carex pellita	broad-leaved woolly sedge	4
Carex prairea	fen panicled sedge	10
Carex retrorsa	deflexed bottlebrush sedge	6
Carex stipata	common fox sedge	2
Carex vesicaria	blister sedge	7
Chelone glabra	turtlehead	7
Epilobium ciliatum	American willow-herb	3
Galium boreale	northern bedstraw	5
Lycopus uniflorus	northern bugleweed	4
Lysimachia quadriflora	narrow-leaved loostrife	9
Lythrum alatum	winged loostrife	6
Ranunculus flabellaris	yellow water buttercup	8
Ranunculus sceleratus	cursed crowfoot	3
Scirpus cyperinus	wool-grass	4
Solidago canadensis	Canada goldenrod	1
Total = 25 species	**Mean CC**	**5.2**

APPENDIX E
MULTIVARIATE ANALYSES FIGURES

Appendix E
Multivariate Analyses Figures

Figure 1: DCA plot of stands/samples identified by community type (n = 39; forested wetland stands were not included). Note that the numbers on the axes are not a measured environmental variable; rather, they should be considered only a reference scale.



EMERGENT MARSHES

TRANSITIONAL MARSHES

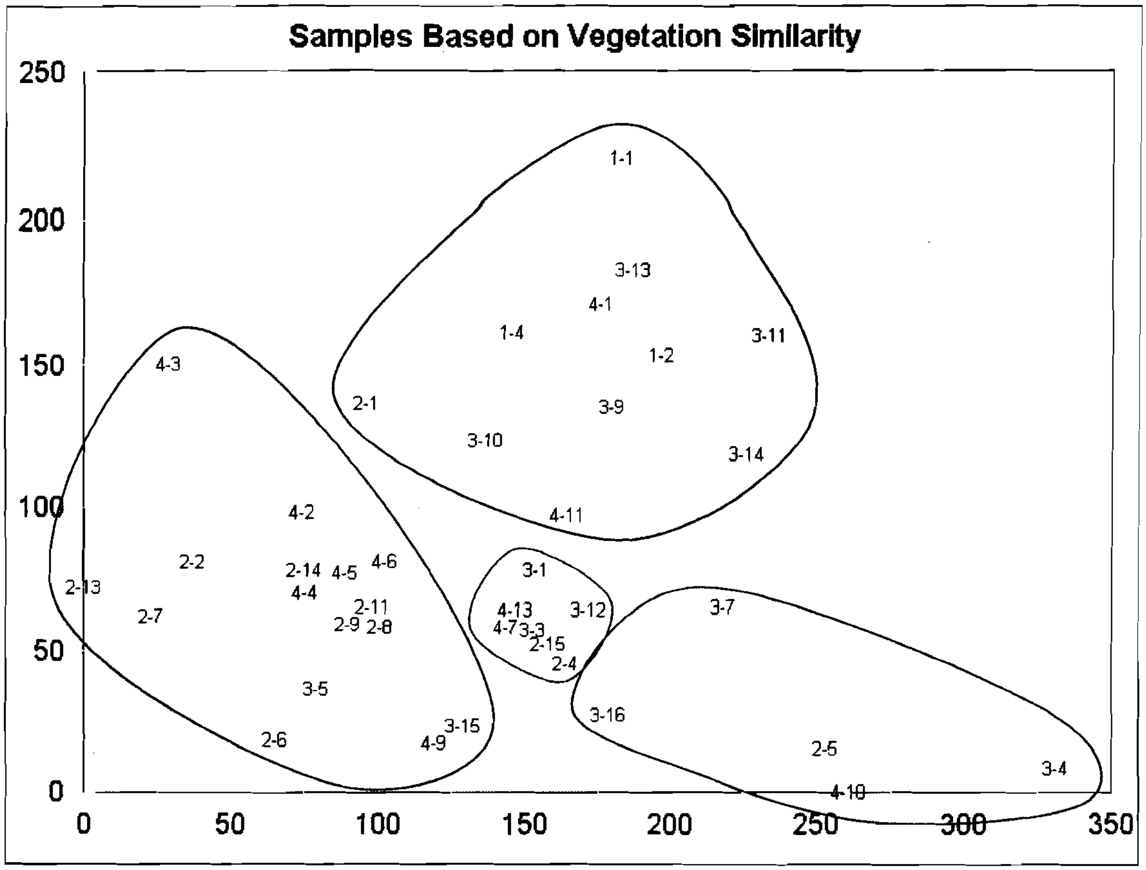
MUD FLATS

SEDGE MEADOWS

Appendix E

Multivariate Analyses Figures

Figure 2: DCA plot of stands/samples based on vegetation similarity (n = 39; forested wetland stands were not included). The sample identification number (ex. 3-7) represents the target sample area number (1, 2, 3, or 4) and the stand number within that area (ex. 3-7 is the 7th stand encountered within sample area 3).



EMERGENT MARSHES

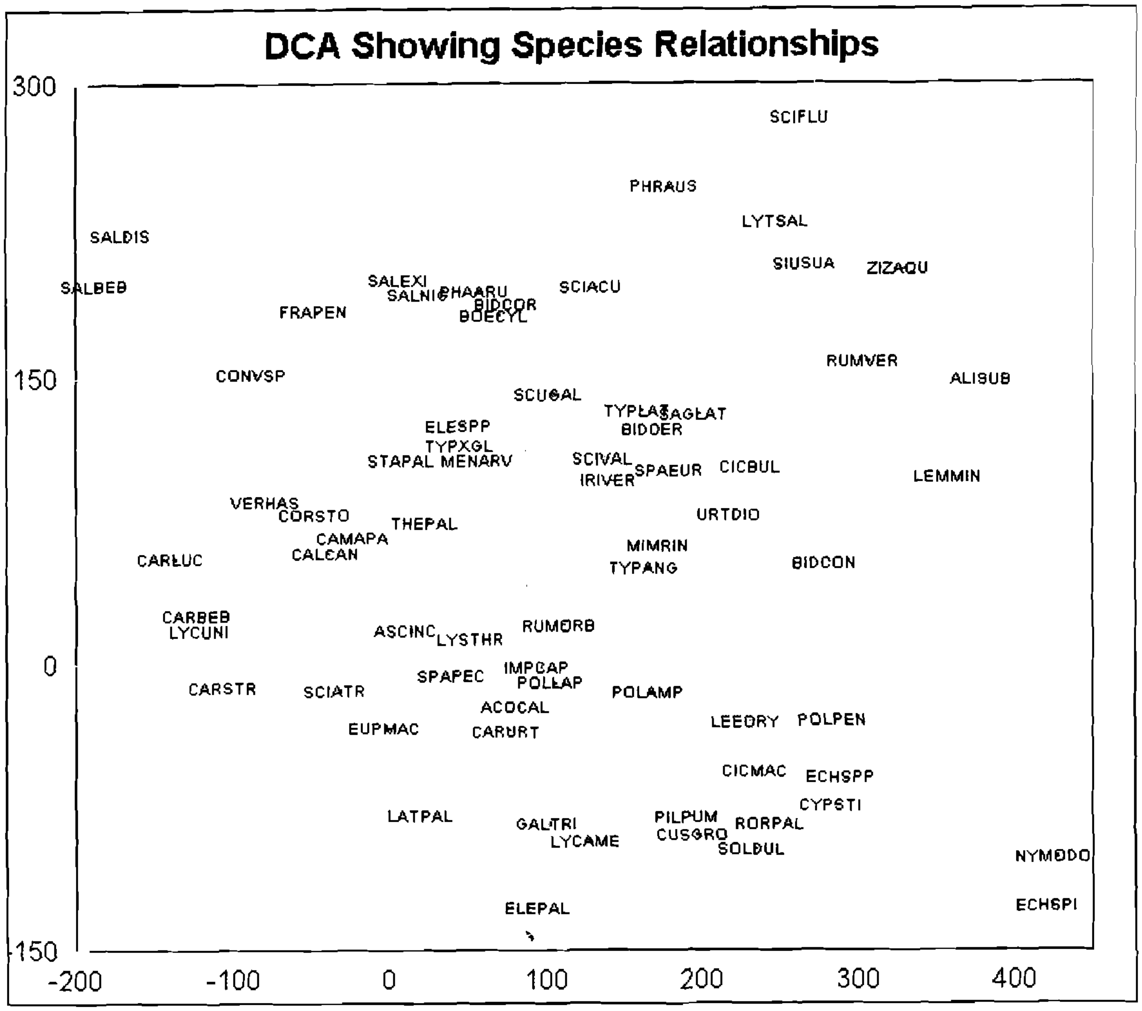
TRANSITIONAL MARSHES

MUD FLATS

SEDGE MEADOWS

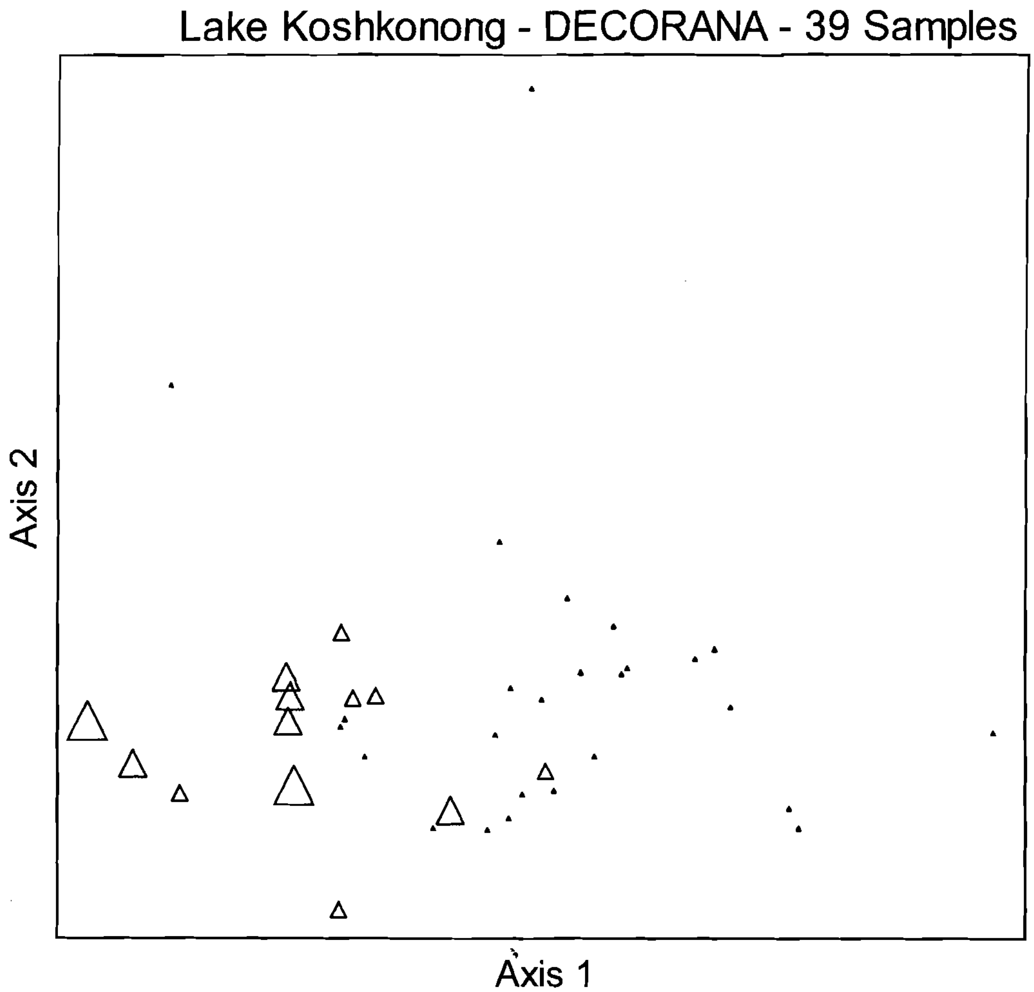
Appendix E
Multivariate Analyses Figures

Figure 3: DCA plot showing species relationships based upon coocurrences within samples. Species are grouped with their closest associates, and as described in the text, the diagonal (lower left corner to upper right corner) represents a typical dry to wet gradient. Species more typically found in "drier" wetlands such as sedge meadows cluster within the lower left corner while typical emergent marsh species (a "wetter" wetland) are found in the upper right corner.



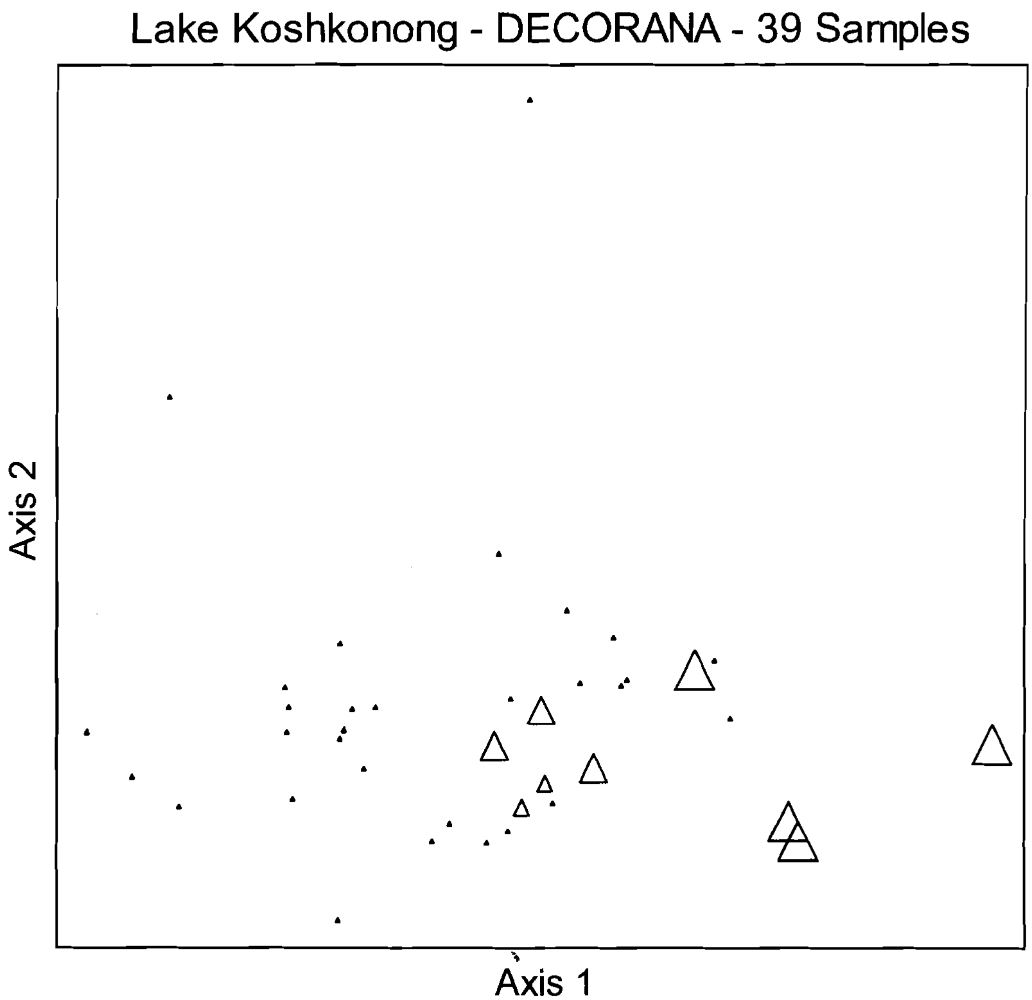
Appendix E
Multivariate Analyses Figures

Figure 4: Distribution of tussock sedge (*Carex stricta*) abundance among stands/samples. Each sample is represented by a triangle, and the size of the triangle represents the abundance/cover value assigned to that species within that stand. The largest triangles represent stands where tussock sedge was abundant, while the smallest triangles represent stands where tussock sedge was absent.



Appendix E
Multivariate Analyses Figures

Figure 5: Distribution of barnyard grass (*Echinocloa* spp.) abundance among stands/samples. Each sample is represented by a triangle, and the size of the triangle represents the abundance/cover value assigned to that species within that stand. The largest triangles represent stands where barnyard grass was abundant, while the smallest triangles represent stands where barnyard grass was absent.



APPENDIX F
COMMUNITY TYPE AND ACREAGE

Appendix F

Summary of community types and acreages by sample

Sample	Community Type	Area (acres)
1-1	emergent marsh	2.6
1-2	emergent marsh	18.8
1-3	forested wetland	5.8
1-4	emergent marsh	1.6
2-1	emergent marsh	22.3
2-2	sedge meadow	5.8
2-3	forested wetland	3.8
2-4	transitional marsh	19.4
2-5	mud flat	63.8
2-6	sedge meadow	0.4
2-7	sedge meadow	2.7
2-8	sedge meadow	4.0
2-9	sedge meadow	2.1
2-10	*Phalaris* monoculture	2.1
2-11	sedge meadow	0.7
2-12	*Typha* x *glauca* monoculture	1.1
2-13	sedge meadow	4.5
2-14	sedge meadow	4.8
2-15	transitional marsh	13.8
3-1	transitional marsh	18.8
3-2	forested wetland	3.4
3-3	transitional marsh	32.9
3-4	mud flat	5.1
3-5	sedge meadow	1.8
3-6	forested wetland	3.3
3-7	mud flat	14.2
3-8	forested wetland	6.0
3-9	emergent marsh	8.2
3-10	emergent marsh	5.2
3-11	emergent marsh	2.3
3-12	transitional marsh	2.1
3-13	emergent marsh	4.2
3-14	emergent marsh	16.0
3-15	sedge meadow	6.0
3-16	mud flat	8.5
4-1	emergent marsh	1.6
4-2	sedge meadow	10.4
4-3	sedge meadow	9.1
4-4	sedge meadow	2.7
4-5	sedge meadow	14.5
4-6	sedge meadow	18.8
4-7	transitional marsh	67.5
4-8	forested wetland	19.1
4-9	sedge meadow	0.5
4-10	mud flat	14.7
4-11	emergent marsh	34.0
4-12	forested wetland	12.7
4-13	transitional marsh	1.9