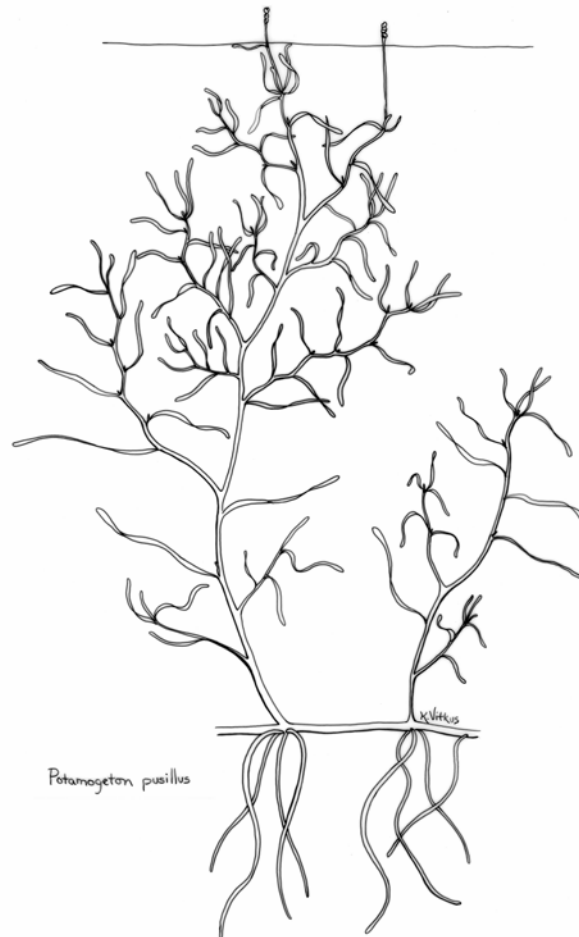


A Comparison of the Distribution and Density of Aquatic Plants in Lake Wissota, Chippewa County, Wisconsin, Between 1989 and 2005



Citizen Science Center
Fall Creek, Wisconsin
March 2006

A Comparison of the Distribution and Density of Aquatic Plants in Lake Wissota, Chippewa County, Wisconsin between 1989 and 2005

By D. Jo Heuschele

**Beaver Creek Reserve, Citizen Science Center
Fall Creek, WI**

Contents

3	Acknowledgments
4	Introduction
4	Methods
	Field Methods, 4
	Data Analysis, 5
6	Results
	Water Quality, 6
	Lake Morphometry, 7
	Shoreline Land Use, 7
	Sediment Composition, 8
	Sediment Influence, 9
	Species Present, 10
	Frequency of Occurrence, 10
	Density, 11
	Dominance, 12
	Distribution, 13
	Aquatic Plant Community, 16
18	Discussion
21	Conclusions
22	References
23	Appendices

Acknowledgments

Field Work

Michele Skahaug
Lake Wissota Improvement and Protection Association
Deborah Konkel

Lake Maps

Mike Molnar

Advice and Comments

Buzz Sorge
Deborah Konkel
Susan Borman
Rob Olson
Sara Schmidt

This project was made possible by the following grants awarded to the Friends of Beaver Creek Reserve:

**Xcel Energy Natural Resources Fund
Wisconsin Department of Natural Resources Lake Planning Grant**

I. INTRODUCTION

Lake Wissota is a 6,300-acre impoundment created in 1917 by the construction of a hydroelectric dam on the Chippewa River. The lake is located east of Chippewa Falls, Wisconsin (T 28-29 N, R 8-9 W). Lake Wissota has a maximum depth of 72 feet and approximately 56 miles of shoreline.

Throughout its existence, Lake Wissota has had late winter drawdowns (Appendix A). From 1969-1986, 15-foot drawdowns were the rule; from 1987-1999, drawdowns ranged from 5 to 12 feet. With the belief that the winter drawdowns were adversely affecting aquatic resources, environmentalists and resource agencies pressured Xcel Energy to reduce or eliminate winter drawdowns. In 2001, the Lower Chippewa River Settlement Agreement was reached. This agreement was a balanced effort to maintain energy output and environmental resources (Chippewa River Settlement Team, 2001).

A survey of the aquatic plants in Lake Wissota was conducted during August of 1989 and August of 1990 by Water Resources staff from the Wisconsin Department of Natural Resources (WDNR). The study was funded by the WDNR and Northern States Power Company (now Excel Energy) for baseline information about the aquatic plant community in Lake Wissota.

In 2005, another aquatic plant survey was conducted, this time by Beaver Creek Citizen Science researchers. This study was funded by Xcel Energy Natural Resources Fund and a WDNR Lake Management Planning Grant. 1989/90 and 2005 studies were compared to determine if reduction and ultimate elimination of late winter drawdowns had an impact on the aquatic plant community of Lake Wissota.

II. METHODS

Field Methods

Similar study designs and transects were used in the 1989-1990 and 2005 studies. The study designs were based primarily on the rake-sampling methodology developed by Jessen and Lound (1962).

During the 1989/90-1990 study transect lines running perpendicular to the shoreline were established at 500 ft. intervals. A total of 160 transect lines were created and 480 stratified-random quadrats within those transects were sampled. The location of these transect lines were marked on a lake map and Loran-C readings were taken at the point where each transect line met the shoreline.

In 2005, the same transects were located using the maps created in 1989-1990 and 640 stratified-random quadrats within those transects were sampled. Global positioning system (GPS) coordinates were taken at each stratified-random quadrat and translated into maps using ARCview GIS (ESRI, Redlands, CA). A digital picture was taken of the

shoreline from each transect to improve survey reproducibility during possible future surveys (Appendix E).

Along each of the 160 transects, four depth zones were established in the 1989-90 study and used again in 2005: 0-1.5 ft., 1.5-5 ft., 5-10 ft., and 10-20 ft. The 1989-1990 study did not include the 10-20 ft. zone, due to no plant growth being observed at depths greater than 10 ft. Because late winter drawdowns may have affected the maximum rooting depths, the 10-20 ft zone was included in the 2005 survey to ascertain possible impact.

One 6-foot square quadrat was randomly located in each depth zone. Using long-handled steel-thatching rakes, four raked samples were taken, one in each quarter of the 6-foot square quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given an occurrence rating (0-5) based on the number of rake samples on which it was present at each quadrat (Deppe & Lathrop, 1992).

A rating of 1 indicates the species was present on 1 rake sample

A rating of 2 indicates the species was present on 2 rake samples

A rating of 3 indicates the species was present on 3 rake samples

A rating of 4 indicates the species was present on 4 rake samples

A rating of 5 indicates the species was abundantly present on all 4 rake samples at the quadrat

The actual depth, sediment type, and distance from shore at were recorded at each quadrat. An underwater camera was used to verify sediment type and deep-water plant occurrence.

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of where each transect intercepted with the shore and 30 feet back from the shore, was evaluated. The percentage of each cover type within this 100 ft. X 30 ft. rectangle was estimated.

Visual inspection and periodic samples were taken between transect lines in order to record the presence of any species that did not occur in the sampled quadrats. Specimens of all plant species present were collect and preserved as voucher specimens.

Nomenclature was according to Crow and Hellquist (2000) and Gleason and Cronquist (1991).

Secchi disc measurements were recorded twice a week during July and August 2005. Four sites were sampled based on previous DNR GPS records: one site on Moon Bay, one on the little lake, and two on the main basin. GPS coordinates were retaken and translated to maps using the ARCVIEW GIS program.

Data Analysis

The data for each year was analyzed separately and compared. The percent frequency (number of quadrats at which species occurred / total number of quadrats), relative frequency (number of quadrats at which species occurred / sum of all species

occurrences), mean density (sum of species' occurrence ratings / number of quadrats), relative density (sum of species' occurrence ratings/ sum of all plant densities), and "mean density where present" (sum of species' occurrence ratings / number of quadrats at which the species occurred) were calculated for each species (Appendix B). The relative frequency and relative density were summed to obtain a dominance value for each species (Appendix B).

Secchi disc readings were used to determine the calculated maximum rooting depth (3* Secchi reading) as per Dunst (1982).

The diversity of the plant populations was measured using Simpson's Diversity Index. The 1989/90 and 2005 studies were compared using Sorensen's Coefficient of Community Similarity to indicate similarities and differences between pre- and post-drawdown communities.

An Aquatic Macrophyte Community Index (AMCI), developed for Wisconsin Lakes, was applied to Lake Wissota. Data in seven categories that characterize the aquatic plant community was converted to values 0 – 10 and combined as outlined by Nichols et al. (2000).

Coefficients of Conservatism (\hat{C}) and Floristic Quality Index (I) were used to evaluate the closeness of Lake Wissota aquatic plant community to an undisturbed condition (Nichols, 1999). A Coefficient of Conservatism is an assigned value, 0 – 10, based on the probability that a species will occur in a relatively undisturbed habitat. The Average Coefficient of Conservation (\hat{c}) is the mean of the coefficients of conservatism for all species found in a lake; the Florist Quality Index was calculated from the average coefficients, and represents a measure of a plant community's closeness to an undisturbed condition.

III. RESULTS

Water Quality

The only water quality measurement collected in Lake Wissota during this study was Secchi disc readings. Water clarity is a critical factor for plants. Aquatic plants can survive with a minimum of 1 - 2% of original surface illumination. Plants vary in their tolerance to low light levels, so changes in water clarity could cause shifts in an aquatic plant community. Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color the water. Secchi disc reading measure both turbidity and color.

Lake Wissota has a characteristic reddish-brown color created by humic and tannic acids released by decomposing plants in the watershed. Water samples taken at five sites on Lake Wissota during May and November 1989 had 50-70 standard color units. Forty to 100 units are a moderate level of color in lakes (Borman, 1991).

Based on the Secchi disc readings taken during June –August in 1989 and 2005 at four different sites, the calculated maximum rooting depth in Lake Wissota changed (Table 1). Moon Bay, the Yellow River inflow had the shallowest Secchi disc reading throughout the summer and the southern end of the main lake basin had the deepest readings (Table 2). All Secchi disc readings fluctuated during the summer depending on whether there was an algae bloom occurring.

Table 1. Calculated maximum rooting depths in feet based on 1% light penetration.

	1989	2005	Change 1989 - 2005	Percent Change 1989 - 2005
Moon Bay	6.1	9.28	3.18	52.1%
South Main Basin	9	14.67	5.67	63.0%

Table 2. Secchi disc readings in feet from 1989 and 2005.

	1989	2005	Change 1989- 2005	Percent Change 1989- 2005
Little Lake Wissota	3.51	4.53	1.02	28.99%
Moon Bay	2.99	3.09	0.11	3.54%
Main Basin North	3.19	3.97	0.78	24.39%
Main Basin South	3.51	4.89	1.38	39.18%

Lake Morphometry

The morphometry of a lake has an impact on the possible areas of aquatic macrophyte distribution. The slope of the littoral zone, the zone where at least 1% of sunlight can reach the bottom of the lake, can explain about 72% of the observed variability in growth of submerged plants (Duarte and Kalff, 1986). Gentle slopes support more plant growth than steep slopes (Engel, 1985).

Lake Wissota’s main basin has very steeply sloped littoral zones offering limited environments for aquatic plant colonization. The section of Chippewa River north of Lake Wissota, also sampled, contained steeply sloping littoral zones. Only in and around the bays where inlets to the main basin occur are the littoral zones gently sloping.

Shoreline Land Use

Practices on shore can directly impact the aquatic plant community through increased sedimentation from erosion, and increased nutrient levels from fertilizer run-off, soil erosion and toxins from farmland and urban run-off.

Wooded cover accounted for the highest occurrence and mean coverage at the shoreline transects in Lake Wissota. Native herbaceous cover also commonly occurred. Disturbed shoreline was third with hard structures (boat houses, decks, and stairs) and cultivated lawns (Table 2).

Some type of natural shoreline occurred at 90 % of all transects, while some type of disturbed shoreline occurred at 75 % of transects. If the sample sites are representative of the whole lake and section of the Chippewa River north of the lake, then 67 % of natural shoreline protects the lake and disturbed shoreline impacts 33 % of the shoreline within 30 feet of the waterline (Table 3).

Table 3. Shoreline Land Use, Lake Wissota 2005

Cover Type		Frequency of Occurrence at Transects	Mean % Coverage
Natural Shoreline	Wooded	76%	48%
	Native Herbaceous	38%	13%
	Shrub	16%	5%
	Rock	11%	1%
Total		90%	67%
Disturbed Shoreline	Hard Structure	37%	7%
	Cultivated Lawn	35%	18%
	Rip-rap	19%	3%
	Erosion	12%	2%
	Other	12%	3%
Total		75%	33%

Sediment Composition

The 1989/90 survey indicated that sand was the most common substrate followed by sand gravel mix and gravel over all. Sand was the most prevalent substrate in all depth zones while, either sand gravel mix or gravel were the next common for all depth zones (Table 4).

In 2005, sand was the most dominant substrate in Lake Wissota. Sand was prevalent in all depth zones. Rock and gravel followed sand in occurrence for depth zones 1 and 2. In depth zones 3 and 4 silt was the next common substrate found (Table 5).

In the past fifteen years the sediment in Lake Wissota has shifted from muck and gravel to more sand and silt substrates.

Table 4. Sediment Occurrence in Lake Wissota, 1989/90

		Zone 1	Zone 2	Zone 3	Overall
		0-1.5ft	1.5-5ft	5-10ft	
		Depth	Depth	Depth	
Soft Sediments	Muck	4%	4%	1%	3%
	Silt	2%	4%	7%	4%
Hard Sediments	Sand	25%	44%	65%	45%
	Sand/Gravel	22%	19%	10%	17%
	Gravel	21%	15%	11%	16%
	Rock/Gravel	2%	1%	1%	1%
	Rock	16%	9%	4%	10%
	Rock/Sand	5%	3%	1%	3%
	Boulders	3%	1%	-	1%

Table 5. Sediment Occurrence in Lake Wissota, 2005

		Zone 1	Zone 2	Zone 3	Zone 4	Overall
		0-1.5ft	1.5-5ft	5-10ft	10-20ft	
		Depth	Depth	Depth	Depth	
Soft Sediments	Muck	3%	5%	-	-	2%
	Silt	2%	4%	14%	23%	11%
	Sand	33%	45%	68%	75%	54%
Hard Sediments	Sand/Gravel	4%	3%	3%	-	2%
	Gravel	18%	14%	5%	1%	10%
	Rock/Gravel	4%	2%	-	-	2%
	Rock	27%	23%	8%	1%	15%
	Rock/Sand	4%	3%	1%	-	2%
	Boulders	5%	1%	1%	-	2%

Sediment Influence

Many aquatic plants depend on the substrate in which they are rooted for stability and nutrients (Engel, 1985). The richness or sterility of the sediment can influence which plant species survive and how abundantly they grow. High-density sediments such as sand and rock are lower in nutrients and support less overall plant growth. Silt sediment is the most favorable for plant growth because of its intermediate density. Nutrient availability is greatest in sediments of intermediate density (Barko, 1988).

Sand was the dominant sediment and other hard sediments were common in Lake Wissota in 1989/90 and 2005 (Table 6).

Currently, sediment does not appear to be a limiting factor for aquatic plant growth in Lake Wissota. The number of sand and silt sites vegetated has dropped significantly since 1989/90. Granted during the 2005 study, more sediment types were vegetated than in 1989/90 (Table 6).

Table 6. Sediment Vegetation Influence

	<u>1989/90</u>		<u>2005</u>	
	% Occurrence	% Vegetated	% Occurrence	% Vegetated
Muck	3%	100%	2%	100%
Silt	4%	75%	10%	50%
Sand	45%	59%	54%	45%
Sand/Gravel	17%	31%	2%	47%
Gravel	16%	16%	10%	31%
Rock/Gravel	1%	-	2%	10%
Rock	10%	6%	15%	9%
Rock/Sand	3%	7%	2%	38%
Boulder	1%	-	2%	20%

Species Present

An aquatic plant species shift has occurred between the 1989/90 and 2005 studies. While many species found in Lake Wissota remained similar, the plant species have shifted from the majority of plants being drawdown tolerant species to more drawdown intolerant species.

In 1989/90, 31 species were present in Lake Wissota: 12 emergent species, 5 floating-leaf species, and 14 submergent species. None of these plants were listed as endangered, threatened or species of concern. Only one species was a non-native, *Potamogeton crispus* (Appendix C).

The plant community increased to 33 species present in 2005, but there were 11 emergent species, 5 floating-leaf species, and 17 submergent species. No plants were classified as endangered or threatened, but one species qualifies as a species of special concern, *Potamogeton vaseyi*. This species of special concern is at risk of state extirpation due to lack of abundance and/or distribution. Two non-native species were present in 2005, *Potamogeton crispus* and *Myriophyllum spicatum* (Appendix C).

Frequency of Occurrence

In 1989/90 aquatic plants were found growing at 30.9% of all quadrates sampled. This number increased to 38.7% in 2005. *Elodea canadensis* had the highest frequency in 1989/90 (28.03%) and 2005 (30.03%) for all depth zones and overall plant presence at sampling points.

Other species that occurred frequently in transects during 1989/90 and 2005 included: *Ceratophyllum demersum*, *Najas flexilis*, and *Vallisneria americana* (Table 7). The frequency of prevalent aquatic plants went down in 2005 with the exception of *Elodea canadensis*.

Table 7. Frequencies of Prevalent Aquatic Plant Species in Lake Wissota

Species	1989/90	2005
<i>Elodea canadensis</i>	28%	30%
<i>Ceratophyllum demersum</i>	14%	7%
<i>Najas flexilis</i>	13%	6%
<i>Vallisneria americana</i>	12%	11%
<i>Potamogeton richardsonii</i>	10%	7%
<i>Potamogeton pusillus</i>	10%	3%
<i>Zosterella dubia</i>	8%	5%

During both studies, the frequency of aquatic plant growth in Lake Wissota differed depending on the depth zone. Aquatic plants were less common in the deepest zone (10 – 20ft), than the rest of the littoral zone. The next area with minimal growth was the shallow zone (0 – 1.5ft) (Table 8). The ranking of depth zones did not change in the fifteen years between the two studies.

Table 8. Frequencies of depth zones being vegetated.

	0-1.5ft Zone 1	1.5-5ft Zone 2	5-10ft Zone 3	10-20ft Zone 4	Overall
1989/90	29%	52%	44%	0%	31%
2005	38%	56%	43%	30%	39%

Density

The “mean density where present” indicates the density or aggregation of a species growth form in Lake Wissota (Appendix B). Even though some species may not occur frequently within the lake, where they do occur, they are dense. The majority of plants have reduced in density over the 15-year period, while two of the drawdown intolerant species present in 1989/90, *Nuphar variegata*, and *Nymphaea odorata* have increased in density (Figure 1).

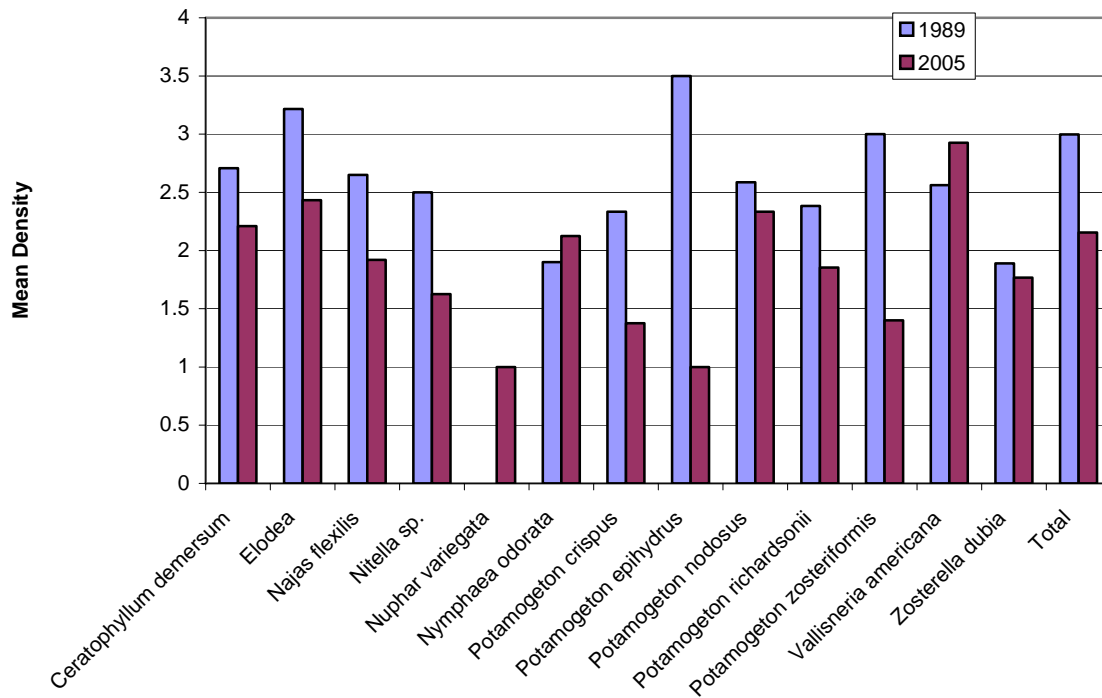


Figure 1. Density changes in common plants of Lake Wissota between 1989/90 and 2005.

Dominance

Based on the dominance value, *Elodea canadensis* was the predominant species in 1989/90 and 2005; it occurred most the frequently and with the highest density.

Ceratophyllum demersum and *Vallisneria americana* were sub-dominant both in 1989/90 and 2005, but *Ceratophyllum demersum* dropped from second-most dominant species in 1989/90 to third in 2005 switching rankings with *Vallisneria americana* as it increased in 2005 (Figure 2). The overall trend of plant dominance reduced over the 15-year period.

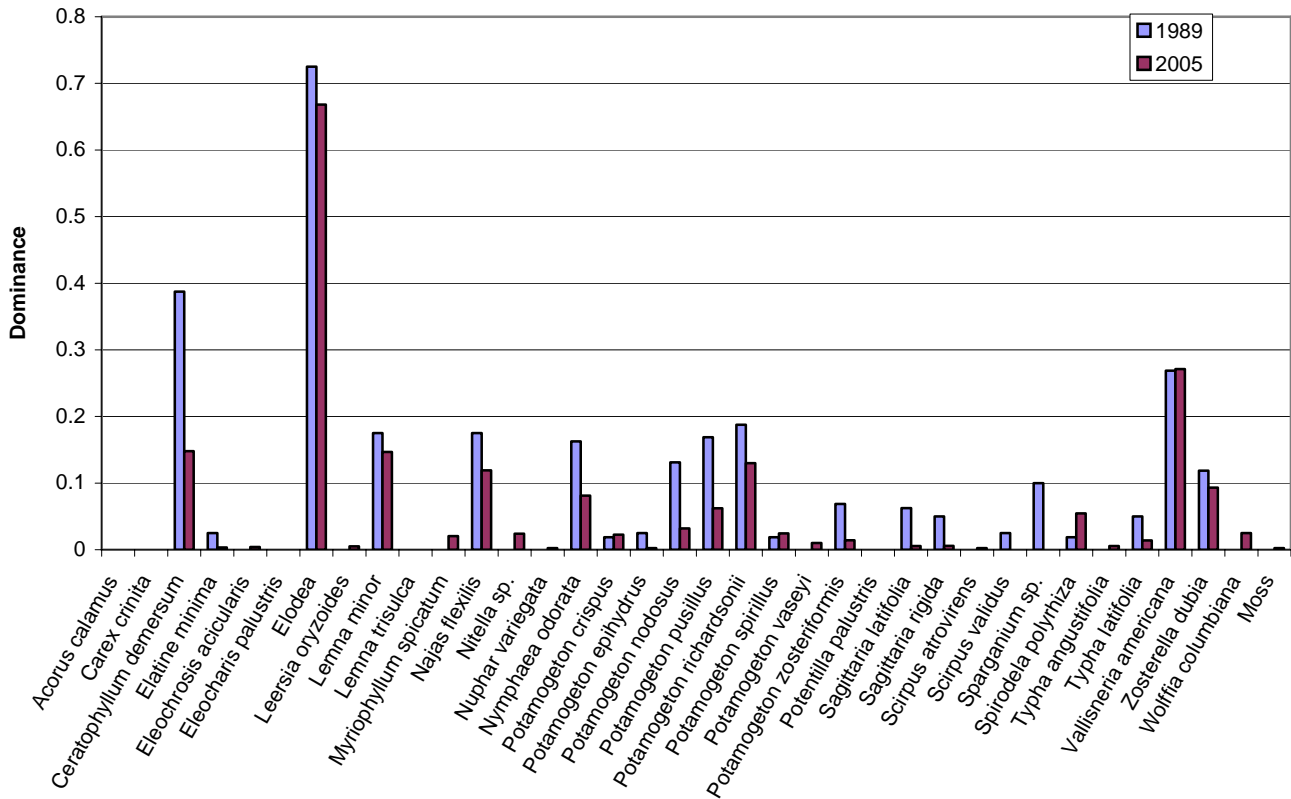


Figure 2. Dominance levels of Lake Wissota aquatic plants during 1989/90 and 2005.

Distribution

The percentage of rooted aquatic plants increased from 31 % of all quadrats vegetated in 1989/90 to 39 % of quadrats vegetated in 2005. Depth zones 1 and 2 increased in vegetation. Depth zone 4 also increased to due to plants growing in water deeper than 7ft in 2005 verses no growth in 1989/90 (Figure 3).

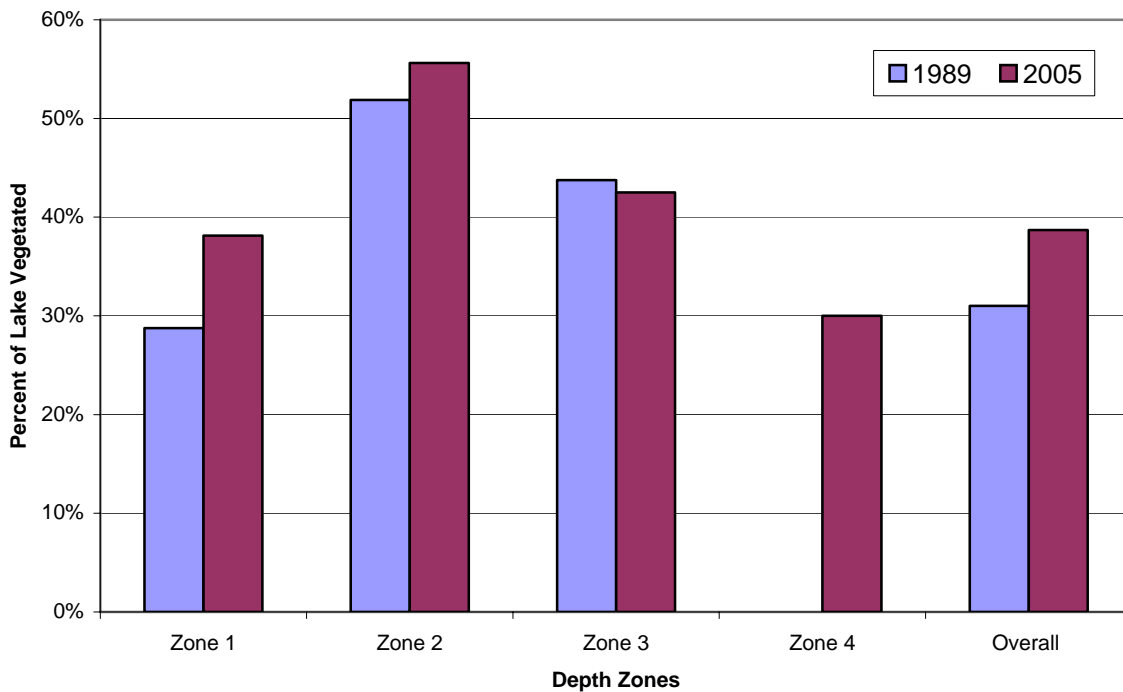


Figure 3. Percentage of vegetation in each depth zone in Lake Wissota. In 1989 no aquatic vegetation was located in depth greater than 7ft (zone 3).

Five areas were designated as high frequency and density areas of aquatic plant growth in 1989/90 and in 2005: Little Lake Wissota, O’Neil Creek, Pine Harbor Bay, State Park Bay, and Upper Moon Bay.

1) Little Lake Wissota (transects 39 - 63) – This southern portion of the lake is composed of two adjoining bays, Paint Creek inflow and a smaller bay fed by Frederick Creek and Stillson Creek. This section of the lake is separated from the majority of the lake by a narrow, deep channel flowing underneath a low roadway and railroad grade. The low road and railroad grade prevent some boat traffic from entering Little Lake Wissota protecting it from high impact usage. The distribution of aquatic plants has increased from 54% to 67% of all quadrats (Appendix D).

There were 14 species present in 2005 on the transect lines including 1 emergent (*Eleocharis acicularis*), 1 floating leaf species (*Lemna minor*), and 12 submergents (*Ceratophyllum demersum*, *Elatine minima*, *Elodea canadensis*, *Najas flexilis*, *Nitella*, *Potamogeton nodosus*, *Potamogeton pusillus*, *Potamogeton richardsonii*, *Potamogeton spirillus*, *Potamogeton vaseyi*, *Vallisneria americana*, *Zosterella dubia*).

In addition to plants found along transects, 1 additional emergent (*Pontederia cordata*), and 3 additional floating-leaf species (*Nuphar variegata*, *Nymphaea odorata*, *Spirodela polyrhiza*) were present in Little Lake Wissota.

2) O'Neil Creek Bay (transects 97 – 100) – This bay is located on the western side of the Chippewa River to the north of the main basin. Waters from O'Neil Creek and Jim Creek flow into this bay along with substantial sediment deposits. The distribution of aquatic plants has increased from 75% to 100% of all quadrats; this increase may be due to the increased sediment deposits in the bay (Appendix D).

There were 13 species present in 2005 along transect lines including 2 emergents (*Sagittaria rigida*, *Leersia oryzoides*), 3 floating-leaf species (*Lemna minor*, *Spriodela polyrhiza*, *Wolffia columbiana*), and 8 submergents (*Ceratophyllum demersum*, *Elodea canadensis*, *Najas flexilis*, *Nitella*, *Potamogeton crispus*, *Potamogeton pusillus*, *Potamogeton richardsonii*, *Vallisneria americana*).

In addition to plants found along transects, 2 additional floating-leaf species (*Nymphaea odorata*, *Nuphar variegata*) and 2 additional submergents (*Potamogeton nodosus*, *Zosterella dubia*) were present.

3) Pine Harbor Bay (transects 16 – 21) – This bay is located along the northeastern shoreline of the main basin of Lake Wissota. The inlet to the bay is protected from the main basin by an island with two narrow, shallow channels on each side of the island accessing the bay from the main basin. The distribution of aquatic plants has decreased from 67% to 58% of all quadrats (Appendix D).

Eight species were present in the bay along transect lines including 1 floating-leaf species (*Nymphaea odorata*) and 7 submergents (*Elodea canadensis*, *Najas flexilis*, *Nitella*, *Potamogeton spirillus*, *Potamogeton richardsonii*, *Vallisneria americana*, *Zosterella dubia*). No additional species were observed in the bay.

4) State Park Bay (transects 150 – 152) – This small bay shelters the state park boat landing. The bay is shallow filled with aquatic plants along the shoreline with only one narrow navigable channel (7 ft deep) in which to get to boat launch from the larger Moon Bay area. The amount of quadrats containing aquatic plants dropped from 80% to 70% possibly due to the center of the bay, the navigable channel, being shallow enough to have plants uprooted by boat traffic entering and leaving the launch (Appendix D).

Twelve species were present along transect lines including 3 floating-leaf species (*Lemna minor*, *Nymphaea odorata*, *Spriodela polyrhiza*) and 9 submergents (*Ceratophyllum demersum*, *Elodea canadensis*, *Myriophyllum spicatum*, *Najas flexilis*, *Potamogeton epihydrus*, *Potamogeton nodosus*, *Potamogeton zosteriformis*, *Vallisneria americana*, *Zosterella dubia*).

In addition to these species found along transect lines there were 2 additional emergents (*Scirpus validus*, *Sagittaria latifolia*) present.

5) Upper Moon Bay (transects 1 – 4) – The upper portion of Moon Bay at the mouth of Yellow River has a broad shallow area colonized by aquatic plants. There is also a

submerged island past the shallow area with a thick stand of *Elodea canadensis*. Percentage of quadrats with aquatic plants increased from 79% to 83% (Appendix D).

Nine species were present along transects including: 4 floating-leaf species (*Lemna minor*, *Nymphaea odorata*, *Nuphar variegata*, *Spirodela polyrhiza*) and 5 submergents (*Ceratophyllum demersum*, *Elodea canadensis*, *Potamogeton crispus*, *Potamogeton spirillus*, *Vallisneria americana*, *Zosterella dubia*).

In addition to species found along the transect lines, there were 3 submergents (*Myriophyllum spicatum*, *Potamogeton nodosus*, *Potamogeton zosteriformis*) present.

There are a number of smaller scattered areas of dense aquatic plant growth in Lake Wissota that offer important animal habitat (Appendix D):

Transects 15 & 16. At the mouth of Moon Bay is a very large shallow area with abundant plant growth that extends from the mouth of the bay to the island sheltering Pine Harbor Bay

Transects 26, 28, 30, 31, 32, & 36. Southeastern portions of the main basin have stands of plants in sandy sediments. These areas are largely sheltered from the majority of wave action.

Transects 75, 78, 82, & 84. The western side of the main lake basin has several inlets and small bays that shelter aquatic plant colonies from major wave action.

The Chippewa River just north of the main basin also contains inlets and small bays that protect aquatic plant colonies from waves and fast current. The largest aquatic plant beds occur in the O'Neil Creek Bay (transects 97 – 100), and the shallows upstream of Mallard Resort, which extend into a long peninsula underwater dividing the river lengthwise for more than 800 meters (transect 115).

Portions of the lake with the lowest levels of plant growth occurred on the eastern shore of the Chippewa River where there is relatively swift current and steep banks of sandstone (transects 116 – 131) and on the northern shore of the main basin where the shore is exposed to extensive wave action (transects 135 – 145). These stretches of shoreline offer unfavorable substrate for aquatic plants to root being mostly of rock or rubble sediment and a steeply sloping littoral zone.

Aquatic Plant Community

The Coefficient of Community Similarity, a measurement of the percent two communities resemble one another, indicate that the 1989/90 community and the 2005 community are statistically similar ($S_s = 0.84$). Coefficients less than $S_s = 0.75$ or 75% indicate that two communities are considered to be significantly different.

Besides significant compositional changes, various parameters can measure other types of changes or small changes in the composition of the community. Changes in the plant community from 1989/90 to 2005 (Table 9) are:

- 1) an increase in number of species
- 2) an increase in maximum rooting depth
- 3) an increase in percentage of the littoral zone vegetated
- 4) a change in the coverage of the three types of plants structure (emergent, submergent, and floating-leaf)
- 5) a decrease in Simpson's Diversity Index. Simpson's Diversity Index rates the diversity in an aquatic community. A value of 1.0 would mean that each individual plant in the community is a different species (the most diversity achievable).
- 6) a decrease in Floristic Quality (see below), the community's closeness to an undisturbed condition
- 7) an increase in the overall quality of the aquatic plant community (AMCI) (see below)

Table 9. Changes in Lake Wissota Aquatic Plant Community between 1989/90 and 2005.

	1989/90	2005	Change 1989/90- 2005	% Change 1989/90- 2005
Number of Species	31	33	2	6.5%
Maximum Rooting Depth	7	19	12	171.4%
% Littoral Zone Vegetated	31%	39%	8	25.8%
% Sites/Emergents	39%	28%	-11	-28.2%
% Sites/Submergents	45%	56%	11	24.4%
% Sites/ Floating-Leaf	16%	16%	0	0.0%
Simpson's Diversity Index	87.97	85.27	-2.70	-3.1%
Floristic Quality	28.24	28.00	-0.24	-0.9%
Average Coefficient of Conservatism	5.54	5.60	0.06	1.1%
AMCI	41	51	10	24.4%

The largest percentage change to Lake Wissota during the fifteen-year period was the percentage increase in maximum rooting depth (171.4 %). In 1989/90 the greatest maximum rooting depth found was 7ft deep in the southern part of the main basin. In 2005 the maximum rooting depth found was also in the southern part of the main basin at 19ft deep.

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols et al. (2000) was applied to Lake Wissota. Values between 0-10 are given for each of seven measures of quality of an aquatic plant community (i.e. rooting depth, % vegetated, number of submersed, exotic, and sensitive species, number of taxa, and Simpson's Diversity Index). The highest value for the index is 70. Lake Wissota's AMCI was calculated at 51 in 2005, verses 41 in 1989/90, which indicates a positive shift in the aquatic plant community.

One method for evaluating the closeness of an aquatic plant community to an undisturbed condition is the Coefficient of Conservatism (Nichols, 1999). Applied to Lake Wissota, the Coefficient of Conservatism (\hat{C}) in 1989/90 and 2005 only increased by 1.1%. During both years, Lake Wissota's conservatism values were within state (5.5-6.9) and regional (5.2-5.8) averages (Nichols, 1999).

The Floristic Quality Index values (I), a community's closeness to an undisturbed condition, for Lake Wissota were greater than state (16.9-27.5) and regional (17-24.4) averages for both years.

IV. DISCUSSION

Direct linkage between in the plant community and the elimination of late winter drawdowns is problematic because there was no aquatic plant survey conducted just prior to the elimination of winter drawdowns for direct comparison. Changes can only be said to have occurred sometime in the past 15 years between the 1989/90 survey and the 2005 survey with the high probability that changes are related to the elimination of winter drawdown.

Water Clarity

It is probable that the cessation of major late-winter drawdowns in Lake Wissota has contributed to the 63% increase of 1% light penetration through the water column. This light availability increase could in turn be linked to the 171% increase in maximum rooting depth and 25.8% increase in the aquatic plant community. Plants require phosphorus and nitrogen located in the water column and sediment for growth. Excess of either nutrient in the water column contributes to algae blooms reducing the amount of light penetration through out the water column. The increase of aquatic vascular plants in a lake reduces the amount of excess phosphorus and nitrogen available to algae (Lombardo & Cooke, 2003). This reduction in turn lowers the amount of algae growth and increases the light infiltrating greater depths. The increase in light allows the aquatic plants to spread out into deeper water increasing the littoral zone. The new plants in the new littoral zone use even more available phosphorus and nitrogen in the water column reducing even more nutrients available for algae growth thus further increasing water clarity.

Elimination of late winter drawdowns may have contributed to the reduction of excess nitrogen and phosphorus as these nutrients settled and became trapped within the sediment layer. The natural recharging of lakes after late winter drawdowns stirs up settled sediments causing nutrients and fine particles to be released into the water column and reducing water clarity (Scheffer, 1990).

Sediments

There has been an increase in the occurrence of soft sediments and sand between 1989/90 and 2005 (52% to 67%). This small particle sediment deposition could be caused by the removal of winter drawdowns, which stirs up lighter sediments and carries them

downriver. Another cause of the increase sediment deposition could be the possible increase in upstream erosion.

The lake currently has a moderate level of aquatic plant species diversity (33 species). Over the 15-year period only 32% of the species found were confined to sites with sand, silt, and/or muck sediment, the preferred sediment types for aquatic plants. Sediment type is currently not a limiting factor because as of 2005, 67% of the quadrats contained sediment conducive to aquatic plant growth, but only 39% of the quadrats were vegetated.

Aquatic Plant Community

Based on the Coefficient of Community Similarity, Lake Wissota of 1989/90 is similar to Lake Wissota of 2005 ($S_s = 0.84$). This statistical test assesses the species present during one study versus not present in the comparative study. For additional comparison four other indices were applied. Three out of the four indices had less than a 3% change.

The Simpson's Diversity Index decreased by 3% indicating that the diversity in the lake decreased over the 15-year period, yet there was an increase in the number of species found.

The average Coefficient of Conservatism increased by 1.1%, still remaining within state and regional averages for lakes in Wisconsin. The \hat{C} value does not include exotics, aquatic mosses or species found in wetland communities that are not found in lakes (Nichols, 1999).

The Floristic Quality Index (I), Lake Wissota's closeness to an undisturbed aquatic site, decreased by 1% in the past 15 years. The I value, which is derived from the average Coefficient of Conservation, is considered to be subjective. Floristic Quality Index has successfully been used to describe many terrestrial plant communities in Wisconsin (Nichols, 1999). Unfortunately, the Floristic Quality in lakes appears to be so heavily related to water quality and number of species found that it is not considered a valuable measurement to be taken alone (Nichols, 1999).

The Aquatic Macrophyte Community Index (AMCI) value increased by 24%. This index uses seven parameters to reduce subjectivity (rooting depth, % vegetated, number of submersed, exotic, and sensitive species, number of taxa, and Simpson's Diversity Index). Therefore, this index seems more reliable measure for comparison between the two studies.

The aquatic plant community changes when species within the community change (Appendix C). The species that occurred only at a few transects or were not located in any transects could change the values of the Floristic Quality Index, Coefficient of Conservatism, and the Aquatic Macrophyte Community Index if the location of the transects were shifted slightly. Those values only included plants in Lake Wissota located along the predetermined transects, while the total number of species in the lake

was collect from transects and periodic observations between transects, hence including the whole lake and not predetermine parts.

Even though the aquatic plant communities were not significantly different, there were changes in the community. The species composition has shifted in the past 15 years. Lake Wissota has new species sensitive to water level fluctuations and an increased frequency of water fluctuation sensitive species that were present in 1989/90. The elimination or reduction of water fluctuations (i.e. late winter drawdowns) is likely the cause for this change in community dynamics.

The number of species found in Lake Wissota has increased from 31 to 33 species. The quantity of emergents was reduced by 28%; most of these plants are tolerant to water fluctuations and without the yearly water fluctuation may not be able to compete with other plant species. There was a drought during the summer of 2005 and the water level of Lake Wissota was below normal. The summer water fluctuations could have allowed for certain emergents to not be counted because they appeared to be on shore verses in the water due to low water levels at the time of the survey. The number of floating-leaf plants found did not change, but *Lemna trisulca* was not present in 2005 whereas *Wolffia columbiana* was found. The frequency of two floating-leaf plants sensitive to water fluctuations, *Nymphaea odorata*, *Nuphar variegata*, increased in 2005. Submergents increased by 24%; while some species are annuals and tolerant to water fluctuations others are perennials that are more sensitive. These sensitive species have increased in frequency since 1989/90 including one exotic aquatic plant, *Myriophyllum spicatum*.

During the 1989/90 study the actual maximum rooting depth (7 ft) was less than the calculated rooting depth (9 ft). Only annuals and perennials with large seed producing ability could survive frozen sediment conditions caused by ice being directly dropped onto the sediment and freezing it through the transfer of energy. The majority of the adult plants are killed during the winter by ice crystals forming in the root systems and breaking the roots apart; only the seeds are sturdy enough to survive and perpetuate the given species (Engel, 1985 & 1990). During the 2005 survey not only was calculated maximum rooting depth greater than 1989/90 (14.5 ft), but the actual maximum rooting depth (19 ft) was greater than the calculated rooting depth (14.5 ft). The species found at depths greater than 14 ft were a moss and *Elodea canadensis*, which are both tolerant of low light levels. The 2005 actual maximum rooting depth for Lake Wissota was in the upper quartile for state and regional averages.

Lake Wissota's overall mean aquatic plant density decreased between 1989/90 and 2005 (3.0 to 2.16). This decreased density could be related to the additional plant competition for resources at each sampling point. The shift in the aquatic community's composition from pioneer species (annuals and high seed producing perennials) to more competitor species (perennials with better resource uptake abilities) could cause the density levels to shift. Pioneer species produce many offspring in high densities to ensure species survival, whereas competitor species produce less offspring to prevent competition with the parent plant during the next growing season. Hence, a less dense stand of diverse plants would be found in an area where competitor plants exist (Grime, 2002).

V. CONCLUSION

Based on the calculated Aquatic Macrophyte Community Index, Lake Wissota rates as an average impoundment in the North Central Hardwood Forest region of Wisconsin.

Lake Wissota is characterized by a moderately diverse community for the North Central Hardwood Forest region of Wisconsin. This community has only 39% of its littoral zone vegetated compared to the regional average of 78%, but has higher than average number of species located in the lake. The community resembles more of an undisturbed condition than most lakes in the North Central Hardwood Forest region. The 1.5 – 5ft depth zone supports most of the plant growth in the lake.

Elodea canadensis was the dominant aquatic plant species, dominating all depth zones; *Vallisneria americana* and *Ceratophyllum demersum* were the sub-dominant species. Only 39% of sites were vegetated making Lake Wissota an under-vegetated lake, but portions of the lake are uninhabitable to aquatic plants due to lake morphology.

There was not a significant change in the aquatic plant community between 1998/90 and 2005, but there have been some small changes that affect lake health. The positive changes are:

- 1) An increase in the percentage of sites with submergent vegetation.
- 2) An increase in the water clarity.
- 3) An increase in maximum rooting depth.
- 4) An increase in sensitive species present.
- 5) An increase in drawdown intolerant species.
- 6) An increase in the number of plant species present.
- 7) A decrease in the frequency of the exotic species *Potamogeton crispus*.

Some changes have occurred that are of concern and should be monitored to ensure that they are not the beginning of a negative trend:

- 1) A decrease in overall plant density of sampling plots.
- 2) The appearance of the exotic species *Myriophyllum spicatum*.

Healthy aquatic plant communities play a vital role within lake communities. Plants provide improved water quality by removing nutrients that would otherwise be available for algae blooms (Engel, 1985). Plants also provide cover and food for fish and invertebrates (Engel, 1985 & 1990). Lakes with a healthy and diverse community of native aquatic plants are more resistant to invasions of non-native species and excessive growth of more competitive species.

Based on comparisons between the 1989/90 and 2005 surveys, Lake Wissota's aquatic plant community appears to be moving toward a more natural state with a healthy and a diverse plant community.

VI. REFERENCES

- Barko J. 1988. Interactions between macrophyte growth and sediment nutrient availability. U.S. Army Corps of Engineers Waterways Experiment Station. 28 pp.
- Borman S. 1991. The distribution and density of aquatic plants in Lake Wissota, Chippewa County, Wisconsin. Wisconsin Department of Natural Resources. Eau Claire, Wisconsin.
- Chippewa River Settlement Team. 2001. Lower Chippewa River Settlement Agreement. FERC #1982; 2567; 2670; 2639; 2491; 2440
- Crow G. & B. Hellquist. 2000. *Aquatic and wetland plants of northeastern North America*. University of Wisconsin Press. Madison, Wisconsin.
- Deppe E. R. & R. C. Lathrop. 1992. A comparison of two rake sampling techniques for sampling aquatic macrophytes. Wisconsin Department of Natural Resources – Bureau of Research Bulletin No. 32. 4 pp.
- Duarte C. M. & J. Kalff. 1986. Littoral slope as a predictor of the maximum biomass of submerged macrophyte communities. *Limnology Oceanographic*. 31(5): 1072-1080
- Dunst R. 1982. Sediment problems and lake restoration in Wisconsin. *Environment International*. 7: 82-92
- Engel S. 1985. Aquatic community interactions of submerged macrophytes. Wisconsin Department of Natural Resources Tech. Bulletin No. 156. 79pp.
- Engel S. 1990. Ecosystem response to growth and control of submerged macrophytes: A literature review. Wisconsin Department of Natural Resources Tech. Bulletin No. 170. 20 pp.
- Gleason H. & A. Cronquist. 1991. *Manual of vascular plants of northeastern United States and adjacent Canada*. Willard Grant Press. Boston, Massachusetts.
- Grime J.P. 2002. *Plant strategies and vegetative processes*. John Wiley and Sons Ltd. Hoboken, New Jersey.
- Jessen R. & R. Lound. 1962. An evaluation of a survey technique for submerged aquatic plants. Minnesota Department of Conservation Game Investigation Rep. No. 6. 10 pp.
- Lombardo P. & P.G. Cooke. 2003. Ceratophyllum demersum - phosphorus interactions in nutrient enriched aquaria. *Hydrobiologia*. 497(1-3): 79-90
- Nichols S. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. *Journal of Lake and Reservoir Management*. 15(2): 133-141
- Nichols S., S. Weber, & B. Shaw. 2000. A proposed aquatic plant community biotic index for Wisconsin lakes. *Environmental Management*. 26(5): 491-502
- Scheffer M. 1990. Multiplicity of stable states in freshwater systems. *Hydrobiologia*. 200 475-486

Appendix A
Summary Of Lake Wissota Drawdowns From 1966 To 2004. *

2004	No drawdown
2003	No drawdown
2002	No drawdown
2001	Lowered 3 ft. beginning March 15 and refilled on April 5
2000	No drawdown
1999	Lowered 9.2 ft. beginning March 16 and refilled on April 1 (for entrainment study)
1998	Lake drawdown did not occur due to the lack of snow in upstream watershed.
1997	Lowered 12 ft. beginning 2/17/97 and refilled on 3/31/97 (high flood threat).
1996	Lowered 10 ft. between 2/12/96 and 4/17/96 (high flood threat).
1995	Lowered 5 ft. between 3/1/95 and 3/18/95; (early runoff)
1994	Lowered 10 ft. between 2/14/94 and 4/9/94 (macroinvertebrates/drawdown assessment study)
1993	Lowered 12 ft. between 2/16/93 and 4/5/93 for inspection of spillway gates.
1992	Lowered 5 ft. between 2/19/92 and 3/8/92. Lowered 5 ft. again on 3/17/93 to 4/9/92.
1991	Lowered 5 ft. between 3/6/91 and 3/23/91.
1990	Lowered 8 ft. between 12/14/89 and 1/10/90 for dam repairs; began refilling on 1/22/90.
1989	Lowered 8 ft. between 1/30/89 and 2/17/89 for dam repairs.
1988	Lowered 5 ft. beginning first week of March (6"/day)
1987	Lowered 5 ft. beginning 2/23/87 (6"/day)
1986	Lowered 15 ft. throughout the period 1/1/86 to 3/17/86 (construction drawdown).
1985	Began 15 ft. construction drawdown on 12/15/85 at rate of 6"/day. Began 15 ft. spring drawdown on 3/1/85.
1984	Began 14.5 ft. spring drawdown on 2/13/84 and completed about 3/25/84.
1983	Drawdown information is not available.
1982	Drawdown information is not available.
1981	Drawdown information is not available.
1980	15 ft. drawdown *
1979	15 ft. drawdown; 2/26/79 - 4/1/79 **
1978	Began 15 ft. spring drawdown on 2/10/78; drawdown was terminated on 4/6/78 (55 days).
1977	Began 4 ft. spring drawdown on 3/1/77; drawdown was completed on 3/30/77 (4 days).
1976	Began 15 ft. spring drawdown on 1/21/76; drawdown was completed on 3/30/76 (68 days).
1975	15 ft. drawdown; 2/10/75 - 3/27/75. **
1974	15 ft. drawdown; 2/11/74 - 3/27/74. **
1973	14 ft. drawdown; 2/12/73 - 3/27/73. **
1972	15 ft. drawdown; 2/14/72 - 3/27/72. **
1971	15 ft. drawdown; 2/11/71 - 3/27/71. **
1970	15 ft. drawdown; 2/9/70 - 3/27/70. **
1969	15 ft. drawdown (actual)
1968	7.4 ft. drawdown (actual)
1967	Began 15 ft. drawdown on 2/1/67 for concrete work on piers of spillway. Drawdown continued until 3/27/67. **
1966	7.8 ft. drawdown (actual).

* The dates indicate the time that the pond was reduced from below the normal low water level (897.0) until the pond was refilled to the normal low water level at the conclusion of the drawdown.

** The dates and the extent of drawdown performed on Lake Wissota was dependent upon snow conditions in the Chippewa and Flambeau River Basins and the timing of spring runoff.

Appendix B
Individual Plant Data Analysis for 1989/90 and 2005

1989/90 Survey

Species	%Freq.	%Freq. w. veg.	Relative Freq.	Mean Density	Mean Dens. w. pres.	Relative Density
<i>Acorus calamus</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Carex crinita</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Ceratophyllum demersum</i>	13.60%	32.83%	0.12	0.37	2.71	0.12
<i>Elatine minima</i>	0.21%	0.51%	0.00	0.01	3.00	0.00
<i>Eleocharis palustris</i>	0.21%	0.51%	0.00	0.01	4.00	0.00
<i>Elodea canadensis</i>	28.03%	67.68%	0.24	0.90	3.22	0.30
<i>Zosterella dubia</i>	7.53%	18.18%	0.07	0.14	1.89	0.05
<i>Leersia oryzoides</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Lemna minor</i>	2.51%	6.06%	0.02	0.05	2.08	0.02
<i>Lemna trisulca</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Najas flexilis</i>	12.55%	30.30%	0.11	0.33	2.65	0.11
<i>Nitella sp.</i>	1.26%	3.03%	0.01	0.03	2.50	0.01
<i>Nuphar variegata</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Nymphaea odorata</i>	4.18%	10.10%	0.04	0.08	1.90	0.03
<i>Potamogeton crispus</i>	0.63%	1.52%	0.01	0.01	2.33	0.00
<i>Potamogeton epihydrus</i>	0.84%	2.02%	0.01	0.03	3.50	0.01
<i>Potamogeton nodosus</i>	6.07%	14.65%	0.05	0.16	2.59	0.05
<i>Potamogeton pusillus</i>	9.62%	23.23%	0.08	0.17	1.80	0.06
<i>Potamogeton richardsonii</i>	9.83%	23.74%	0.09	0.23	2.38	0.08
<i>Potamogeton spirillus</i>	1.05%	2.53%	0.01	0.02	1.80	0.01
<i>Potamogeton zosteriformis</i>	2.09%	5.05%	0.02	0.06	3.00	0.02
<i>Potentilla palustris</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Sagittaria latifolia</i>	0.42%	1.01%	0.00	0.02	4.00	0.01
<i>Sagittaria rigida</i>	0.42%	1.01%	0.00	0.01	3.00	0.00
<i>Scirpus atrovirens</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Scirpus validus</i>	0.21%	0.51%	0.00	0.01	3.00	0.00
<i>Sparganium sp.</i>	0.84%	2.02%	0.01	0.03	3.00	0.01
<i>Spriodela polyrhiza</i>	0.42%	1.01%	0.00	0.01	1.50	0.00
<i>Typha angustifolia</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Typha latifolia</i>	0.42%	1.01%	0.00	0.01	3.00	0.00
<i>Vallisneria americana</i>	11.92%	28.79%	0.10	0.31	2.56	0.10
	114.85%		1.00	3.00		1.00

2005 Survey

Species	%Freq.	%Freq. w. veg.	Relative Freq.	Mean Density	Mean Dens. w. pres.	Relative Density
<i>Ceratophyllum demersum</i>	7.05%	18.22%	0.08	0.16	2.21	0.07
<i>Elatine</i>	0.16%	0.42%	0.00	0.00	2.00	0.00
<i>Eleocharis acicularis</i>	0.16%	0.42%	0.00	0.00	3.00	0.00
<i>Elodea canadensis</i>	30.33%	78.39%	0.33	0.74	2.43	0.34
<i>Leersia oryzoides</i>	0.33%	0.85%	0.00	0.00	1.00	0.00
<i>Lemna minor</i>	5.74%	14.83%	0.06	0.18	3.20	0.09
<i>Myriophyllum spicatum</i>	0.98%	2.54%	0.01	0.02	2.17	0.01
<i>Najas flexilis</i>	6.07%	15.68%	0.07	0.12	1.92	0.05
<i>Nitella sp.</i>	1.31%	3.39%	0.01	0.02	1.63	0.01
<i>Nuphar variegata</i>	0.16%	0.42%	0.00	0.00	1.00	0.00
<i>Nymphaea odorata</i>	3.93%	10.17%	0.04	0.08	2.13	0.04
<i>Potamogeton crispus</i>	1.31%	3.39%	0.01	0.02	1.38	0.01
<i>Potamogeton epihydrus</i>	0.16%	0.42%	0.00	0.00	1.00	0.00
<i>Potamogeton nodosus</i>	1.48%	3.81%	0.02	0.03	2.33	0.02
<i>Potamogeton pusillus</i>	3.44%	8.90%	0.04	0.05	1.57	0.03
<i>Potamogeton richardsonii</i>	6.72%	17.37%	0.07	0.12	1.85	0.06
<i>Potamogeton spirillus</i>	1.15%	2.97%	0.01	0.03	2.29	0.01
<i>Potamogeton vaseyi</i>	0.66%	1.69%	0.01	0.01	1.00	0.00
<i>Potamogeton zosteriformis</i>	0.82%	2.12%	0.01	0.01	1.40	0.01
<i>Sagittaria latifolia</i>	0.16%	0.42%	0.00	0.01	5.00	0.00
<i>Sagittaria rigida</i>	0.33%	0.85%	0.00	0.00	1.50	0.00
<i>Scirpus atrovirens</i>	0.16%	0.42%	0.00	0.00	1.00	0.00
<i>Scirpus validus</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Sparganium eurycarpum</i>	0.00%	0.00%	0.00	0.00	0.00	0.00
<i>Spriodela polyrhiza</i>	2.46%	6.36%	0.03	0.06	2.47	0.03
<i>Typha angustifolia</i>	0.16%	0.42%	0.00	0.01	5.00	0.00
<i>Typha latifolia</i>	0.66%	1.69%	0.01	0.01	2.25	0.01
<i>Vallisneria americana</i>	11.15%	28.81%	0.12	0.33	2.93	0.15
<i>Zosterella dubia</i>	4.92%	12.71%	0.05	0.09	1.77	0.04
<i>Wolffia columbiana</i>	0.98%	2.54%	0.01	0.03	3.17	0.01
Moss	0.16%	0.42%	0.00	0.00	1.00	0.00
	93.11%		1.00	2.16		1.00

Appendix C
Plants present in 1989/90 and 2005

1989/90 Study

Emergents (12)

Acorus calamus
Carex crinita
Eleocharis palustris
Leersia oryzoides
Potentilla palustris
Sagittaria latifolia
Sagittaria rigida
Scirpus atrovirens
Scirpus validus
Sparganium eurycarpum
Typha angustifolia
Typha latifolia

Floating-Leaf (5)

Lemna minor
Lemna trisulca
Nuphar variegata
Nymphaea odorata
Spriodela polyrhiza

Submergents (14)

Ceratophyllum demersum
Elatine minima
Elodea canadensis
Najas flexilis
Nitella sp.
Potamogeton crispus
Potamogeton epihydrus
Potamogeton nodosus
Potamogeton pusillus
Potamogeton richardsonii
Potamogeton spirillus
Potamogeton zosteriformis
Vallisneria americana
Zosterella dubia

2005 Study

Emergents (11)

Carex crinita
Eleocharis palustris
Leersia oryzoides
Pontederia cordata
Sagittaria latifolia
Sagittaria rigida
Scirpus atrovirens
Scirpus validus
Sparganium eurycarpum
Typha angustifolia
Typha latifolia

Floating-Leaf (5)

Lemna minor
Nuphar variegata
Nymphaea odorata
Spriodela polyrhiza
Wolffia columbiana

Submergents (17)

Ceratophyllum demersum
Elatine minima
Eleocharis acicularis
Elodea canadensis
Myriophyllum spicatum
Najas flexilis
Nitella sp.
Potamogeton crispus
Potamogeton epihydrus
Potamogeton nodosus
Potamogeton pusillus
Potamogeton richardsonii
Potamogeton spirillus
Potamogeton vaseyi
Potamogeton zosteriformis
Vallisneria americana
Zosterella dubia

Appendix D
Lake Wissota Maps

- 1) Lake Wissota
- 2) Chippewa River, Aquatic Plant Survey
- 3) Chippewa River, Transect Lines and Depth Zones
- 4) Northern Shoreline, Aquatic Plant Survey
- 5) Northern Shoreline, Transect Lines and Depth Zones
- 6) Southern Shoreline, Aquatic Plant Survey
- 7) Southern Shoreline, Transect Lines and Depth Zones
- 8) Moon Bay, Aquatic Plant Survey
- 9) Moon Bay, Transect Lines and Depth Zones
- 10) Little Lake Wissota, Aquatic Plant Survey
- 11) Little Lake Wissota, Transect Line and Depth Zones

Appendix E
Lake Wissota Shoreline Pictures

- 12) Chippewa River North of Lake Wissota (Transects 85-134)
- 13) North Shore of Lake Wissota (Transects 15-23, 76-84, and 135-145)
- 14) Southern Shoreline of Lake Wissota (Transects 24-38 and 64-75)
- 15) Moon Bay (Transects 1-14 and 146-160)
- 16) Little Lake Wissota (Transects 39-63)