Executive Summary

Friendship Lake is a mesotrophic lake with fair water quality and clarity. Filamentous algae is abundant, especially in the 1.5-5ft depth zone.

The aquatic plant community colonized more than three-quarters of the littoral zone to a maximum depth of 10.5 feet with the most abundant plant growth in the 1.5-5ft depth zone. The community is also characterized by average quality, good species diversity, an above average tolerance to disturbance and a serious lack of emergent plant growth.

Vallisneria americana is the dominant species within the plant community, especially in the 1.5-10ft depth zone. *Elodea canadensis* was sub-dominant, especially in the 0-1.5ft depth zone.

A healthy aquatic plant community is important because it can improve water quality, provide valuable habitat resources for fish and wildlife, resist the spread of non-native species and check excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.

Management Recommendations

1) Lake District to continue monitoring water quality in Friendship Lake through the Self-Help Volunteer Lake Monitoring Program.
2) DNR should designate sensitive areas within Friendship Lake.
3) Chemical treatments for plant growth are not recommended in Friendship Lake.
4) Lake residents to restore natural shoreline around Friendship Lake.
5) Lake District to establish emergent plant beds for habitat and to stabilize the shore.
6) Lake District and DNR revise the harvesting plan to avoid beds of lily pads and large-leaf pondweed and to target Eurasian watermilfoil and common waterweed.

The Aquatic Plant Community in Friendship Lake, Adams County 2003

MWBC 1352000

Deb Konkel

I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Friendship Lake was conducted during July 2003 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR) and members of the Friendship Lake District. This was the first quantitative vegetation study of Friendship Lake by the DNR. Qualitative assessments were conducted in August 1979 and 1992.

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake ecosystem due to the important ecological role of aquatic vegetation in the lake and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

Ecological Role: All other life in the lake depends on the plant life - the beginning of the food chain. Aquatic plants and algae provide food and oxygen for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants provide habitat, improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake and impact recreation.

Characterize Water Quality: Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1993).

The present study will provide information that is important for effective management of the lake, including fish habitat improvement, protection of sensitive wildlife areas, aquatic plant management and water resource regulations. The baseline data that it provides will be compared to past and future aquatic plant inventories and offer insight into any changes occurring in the lake.

Background and History: Friendship Lake is a 115-acre impoundment on Little Roche-a-Cri Creek in central Adams County, Wisconsin. With a maximum depth of 16 feet and an average depth is 6 feet, Friendship Lake is classified as a shallow water resource.

Various projects have been conducted for the management of Friendship Lake.

In 1979, there was a winter drawdown of 8-10". In 1987, a small dredging project was carried out. Chemical control of aquatic plants has been attempted in Friendship Lake (Table 1).

Table 1. Herbicide Applied to Friendship Lake

	Arsenic Trioxide (lbs.)	Diquat (oz.)	Rodeo (oz.)
1960	7160		
1961	3240		
1995			24
1996		8	16
Total	10,400 pounds	8 ounces	40 ounces

Arsenic treatments were lake wide treatments. Arsenic stays in the sediments, resulting in the necessity to treat lake sediments as hazardous waste. The treatments in 1995-95 were conducted at a single shoreline east of the bridge on the north shore.

Friendship Lake District applied for a grant to purchase a mechanical aquatic plant harvester in 1992. Prior to mechanical harvesting, plant growth was described as solid vegetation over more than half of the lake. This heavy growth restricted the use of Friendship Lake during the summer, preventing landowners on most of the lake from accessing the open areas.

Mechanical harvesting began in 1993. Records of harvesting were sent to the DNR from 1993-1995 and 1998-2203 (Table 2). Records were not found for 1996-87. During those years for which there are records, over 1600 loads of aquatic plants, weighing more than three and a half million pounds, were removed from Friendship Lake (Table 2).

Table 2. Removal of Aquatic Vegetation by Mechanical Harvesting in Friendship Lake, 1993 - Present

	Loads removed	Weight of loads (pounds)	Total Weight (pounds)
1993	92	2000-3000	230,000
1994	78	2000-3000	195,000
1995	73	2000-3000	182,500
No records found, volunteer system breaking down			
1998	130		325,000
1999	209		522,500
2000	223		557,500
2001	299		747,500
2002	262	1500-2000	412,650
2003	300		472,500
Total	1666		3,645,150

II.METHODS

Field Methods

The study design was based primarily on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines. The shoreline was divided into 19 equal segments and a transect, perpendicular to the shoreline, was randomly placed within each segment (Appendix IV), using a random numbers table.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft and 10-20ft) along each transect. Using a long-handled, steel, thatching rake, four rake samples were taken at each sampling site. The four samples were taken from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given a density rating (0-5), the number of rake samples on which it was present at each sampling site.
A rating of 1 indicates that a species was present on one rake sample
a rating of 2 indicates that a species was present on two rake samples
a rating of 3 indicates that it was present on three rake samples
a rating of 4 indicates that it was present on all four rake samples
a rating of 5 indicates that a species was abundantly present on all rake samples.

Visual inspection and periodic samples were taken between transect lines to record the presence of any species that did not occur at the sampling sites. Specimens of all plant species present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet deep was evaluated. The percent cover of land use within this 100' x 30' rectangle was visually estimated.

Data Analysis

The percent frequency of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites) (Appendix I). Relative frequency was calculated (number of occurrences of a species/total occurrence of all species (Appendix I). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites) (Appendix II). Relative density was calculated (sum of a species density/total plant density). A "mean density where present" was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred) (Appendix II). The relative frequency and relative density was summed to obtain a dominance value (Appendix III). Species diversity was measured by Simpson's Diversity Index (Appendix I).

The Aquatic Macrophyte Community Index (AMCI) developed by Weber et. al. (1995) was applied to Friendship Lake. Measures for each of six categories that characterize a plant community are converted to values between 0 and 10 and summed.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated, as outlined by Nichols (1998), to measure disturbance in the plant community. A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the Coefficients for all species found in the lake. The Floristic Quality Index is calculated from the Coefficient of Conservatism (Nichols 1998) and is a measure of a plant community's closeness to an undisturbed condition.

III. RESULTS

PHYSICAL DATA

Many physical parameters impact the aquatic plant community. Water quality (nutrients, algae and clarity) influence the plant community as the plant community can in turn modify these parameters. Lake morphology, sediment composition and shoreline use also effect the macrophyte community.

WATER QUALITY - The trophic state of a lake is a classification of its water quality. Phosphorus concentration, chlorophyll concentration and water clarity data are collected and combined to determine the trophic state.
Eutrophic lakes are high in nutrients and therefore support a large biomass.
Oligotrophic lakes are low in nutrients and support limited plant growth and smaller fish populations.
Mesotrophic lakes have intermediate levels of nutrients and biomass.

Volunteer lake monitors in the Self-help Volunteer Lake Monitoring Program have been collecting water quality data on Friendship Lake. Lloyd and Darlene Hovorka monitored Friendship Lake 1994-1996. Tom and Eva Steiskal have been monitoring the lake since 1999.

Nutrients

Phosphorus is a limiting nutrient in many Wisconsin lakes and is measured as an indication of the amount of nutrient in a lake. Increases in phosphorus in a lake can feed algae blooms and, occasionally, excess plant growth.
1995-2002 summer mean phosphorus concentration in Friendship Lake was 30.2g/l
This concentration of phosphorus in Friendship Lake is indicative of a mesotrophic lake (Table 3).

Table 3. Trophic Status

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Disc ft.
Oligotrophic	Excellent	<1	<1	> 19
	Very Good	1-10	1-5	8-19
Mesotrophic	Good	10-30	5-10	6-8
	Fair	**30-50**	**10-15**	**5-6**
Eutrophic	Poor	50-150	15-30	3-4
Friendship Lake 1995-2002 Mean	Fair	30.2	11.2	5.5

After Lillie & Mason (1983) & Shaw et. al. (1993)

Phosphorus concentrations in Friendship Lake have varied over the years that data was collected. Phosphorus concentrations have varied close to the eutrophic / mesotrophic boundary (Figure 1).

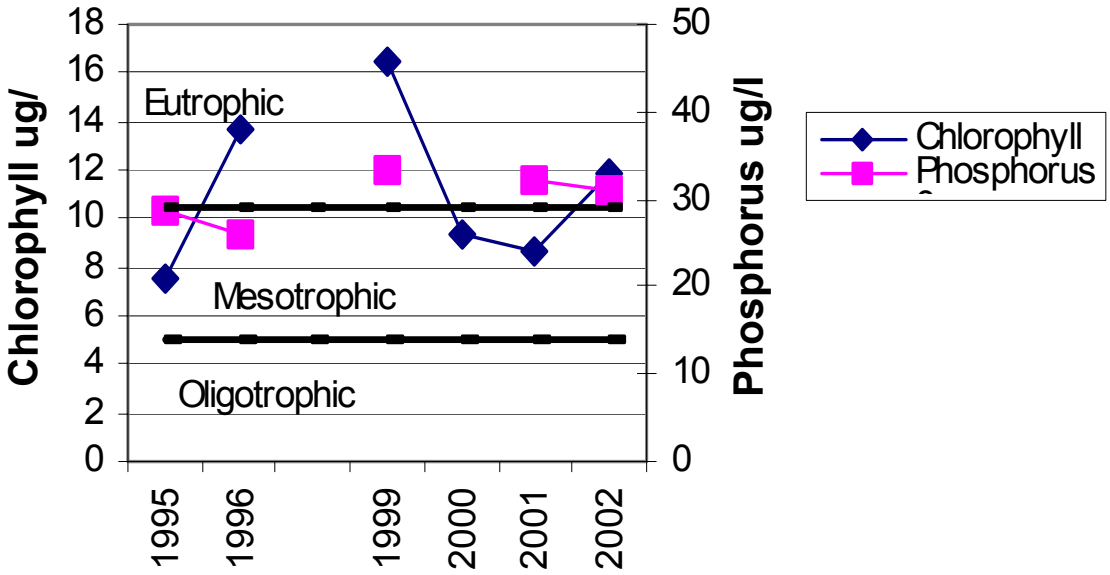


Figure 1. Variation in mean summer phosphorus and chlorophyll concentrations in Friendship Lake, 1995-2002.

Algae

Chlorophyll concentrations provide a measurement of the amount of algae in lake water. Algae are natural and essential in lakes, but high algae populations can increase turbidity and reduce the light available for plant growth.

1995-2002 summer mean chlorophyll concentration in Friendship Lake was 11.2 ug/l.

The chlorophyll concentration in Friendship Lake indicates that it was a mesotrophic lake (Table 3).

During 1995-2002, chlorophyll (algae) concentrations have varied more than phosphorus. The concentration of chlorophyll has ranged from mesotrophic, to highly europhic, to mesotrophic and lately to eutrophic (Figure 1). Variations in summer temperatures and rain events can impact algae growth.

Phosphorus and chlorophyll also vary during the growing season. Chlorophyll concentrations start in the mesotropjhic range as the growing season starts and rise quickly to eutrophic levels as the water warms; there is an unexplained decrease in mid-summer, another rise in the heat of August and a decline as the water cools in the autumn (Figure 2).

Phosphorus gradually rises to eutrophic levels in the early summer and decline to mesotrophic levels as the late summer and autumn progress (Figure 2). Rain events impact the input of phosphorus and other nutrients.

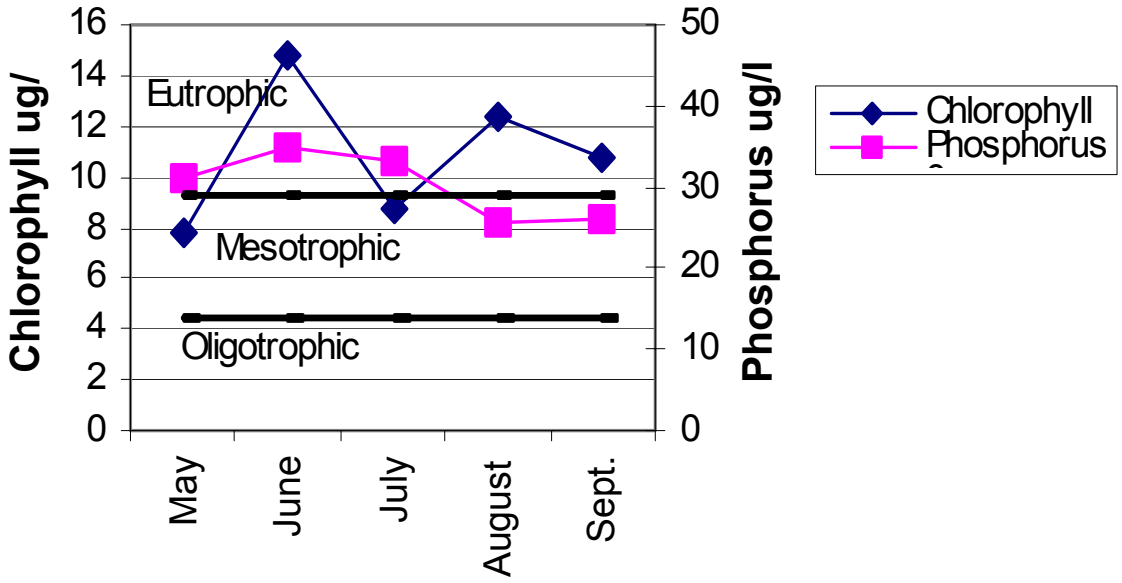


Figure 2. Variation in phosphorus and chlorophyll concentrations in Friendship Lake during the growing season, 1995-2002.

Water Clarity

Water clarity is a critical factor for plants. When plants receive less than 1 - 2% of the surface illumination, they can not survive. Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color the water. Water clarity is measured with a Secchi disc that shows the combined effect of turbidity and color

Mean summer Secchi disc clarity in Friendship Lake, 1994-2002, was 5.5 ft. Water clarity indicates (Table 3) that Friendship Lake was a mesotrophic lake with fair water clarity.

The water clarity in Friendship Lake has varied during 1994-2002, with the best mean clarity recorded in 1999 and the lowest clarity in 1996 (Figure 3). Clarity gradually increased 2000-2002. Variations in clarity can be the result of variations in algae growth in different years and turbidity after storm events.

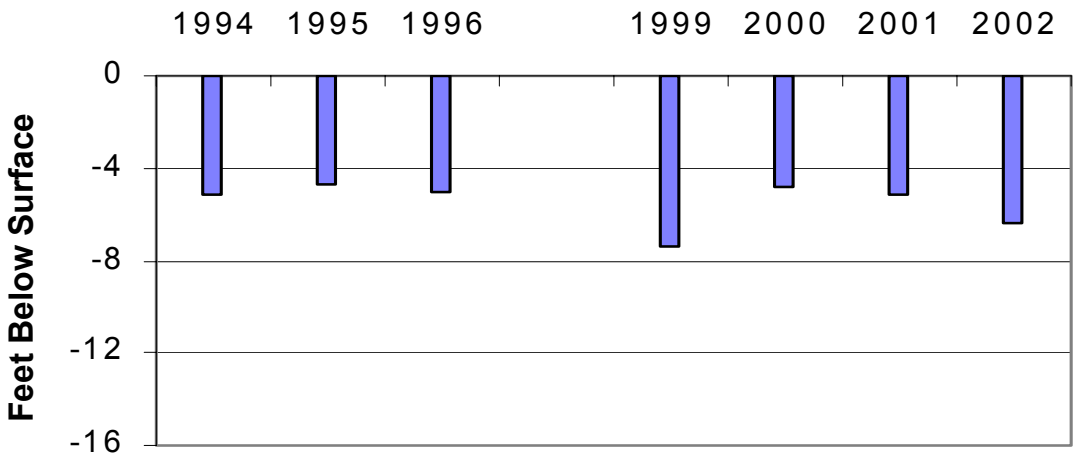


Figure 3. Variation in mean summer water clarity in Friendship Lake, 1994-2002.

Water clarity varies during the growing season also. Water clarity decreases slightly as summer progresses, likely due to algae growth (Figure 4) and increases during late summer and fall as the water cools and algae decline.

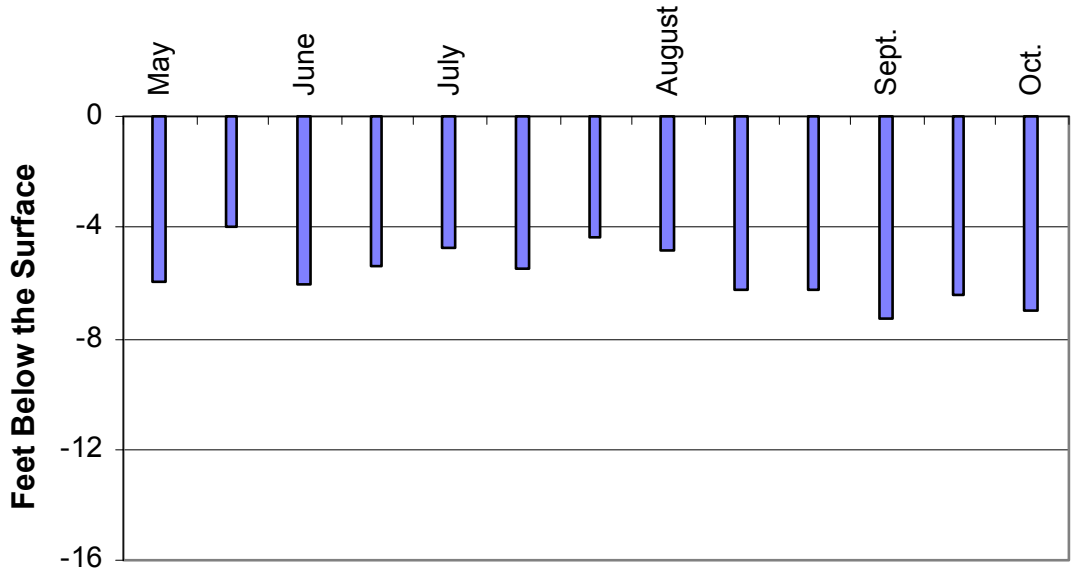


Figure 4. Variation in mean water clarity during the growing season in Friendship Lake, 1994-2002.

The combination of phosphorus concentration, chlorophyll concentration and water clarity indicates that Friendship Lake is a mesotrophic lake with fair water quality. This trophic state would favor moderate levels of plant growth and occasional algae blooms.

LAKE MORPHOMETRY - The morphometry of a lake is an important factor in determining the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support more plant growth than steep slopes (Engel 1985).

Friendship Lake has a narrow basin that is shallow and gradually sloped over most of the lake. There are small areas of more steeply-sloped littoral zones near the dam. Areas of the lake with shallow depths and gradual slopes would favor plant growth.

SEDIMENT COMPOSITION – The dominant sediment in Friendship Lake was sand, especially in the 0-5ft depth zone and in the west basin of the lake (Table 4). Sand mixed with silt was common at depths greater than 10 feet.

Silt was commonly occurring and dominant at depths greater than 5 feet. Highly organic muck sediments were commonly found in the 1.5-5ft depth zone, occurring mainly in the east basin (Table 4).

Table 4. Sediment Composition: Friendship Lake, 2003

Sediment Type		0-1.5' Depth	1.5-5' Depth	5-10' Depth	10-20' Depth	Percent of all Sample Sites
Hard	Sand	47%	47%	28%	12%	38%
Sediments	Sand/Rock	5%				2%
Mixed	Sand/Silt	10%	16%	16%	25%	17%
Sediments	Sand/Muck	5%				2%
Soft	Silt	16%	16%	50%	62%	30%
Sediments	Muck	16%	21%			12%

INFLUENCE OF SEDIMENT - Some plants depend on the sediment in which they are rooted for their nutrients. The richness or sterility and texture of the sediment will determine the type and abundance of macrophyte species that can survive in a location.

Sand was the dominant sediment found in Friendship Lake and may limit plant growth due to its high-density (Barko and Smart 1986), however 78% of the sites with sand sediment were vegetated (Table 5). Other high-density sediments, sand/rock mixtures, did not support any vegetation in Friendship Lake.

Silt sediments, which were common at the sample sites in Friendship Lake, are intermediate density sediments. The availability of mineral nutrients for growth is highest in sediments of intermediate density (Barko and Smart 1986). Silt sediments supported vegetation at 67% of the sites at which it occurred. Silt would likely have supported more vegetation, but silt was more abundant at depths greater than 5 feet, where light penetration may become a limiting factor.

Mixtures of hard and soft sediments and highly organic muck sediments supported the greatest amount of vegetation, 90-100% (Table 5).

Table 5. Influence of Sediment in Friendship Lake, 2003

Sediment Type		Percent of all Sample Sites	Percent Vegetated
Hard	Sand	38%	78%
Sediments	Sand/Rock	2%	0%
Mixed	Sand/Silt	17%	90%
Sediments	Sand/Muck	2%	100%
Soft	Silt	30%	67%
Sediments	Muck	12%	100%

SHORELINE LAND USE – Land use can strongly impact the aquatic plant community and therefore the entire aquatic community. Land use can directly impact the plant community by increased erosion and sedimentation and increased run-off of nutrients, fertilizers and toxics applied to the land. These impacts occur in both rural and residential settings.

Cultivated lawn was the most frequently encountered shoreline cover at the transects and had the highest mean coverage. Other disturbed shoreline, hard structures and rip-rap, were also commonly encountered (Table 6).

Wooded cover was commonly occurring, but covered less than one-third of the shoreline. Native herbaceous growth and shrub cover were commonly occurring but had low coverages (Table 6).

Table 6. Shoreline Land Use - Friendship Lake, 2003

Cover Type		Frequency of Occurrences at Transects	Mean % Coverage
Natural Shoreline	Wooded	63%	30%
	Native Herbaceous	37%	14%
	Shrub	26%	7%
Disturbed Shoreline	Cultivated Lawn	74%	43%
	Hard Structures	42%	3%
	Rip-rap	21%	3%

Some type of disturbed shoreline (cultivated lawn, hard structures and rip-rap) was found at 79% of the sites and had a mean coverage of 49%.

Some type of natural shoreline (wooded, shrub, native herbaceous) was found at 95% of the sites, but only had a mean coverage of 51%.

MACROPHYTE DATA

SPECIES PRESENT

Of the 15 species found in Friendship Lake, 2 were floating-leaf species and 14 were submergent species (Table 7). No emergent species were found.
No threatened or endangered species were found.
Two exotic species were found:
Myriophyllum spicatum
Potamogeton crispus

Table 7. Friendship Lake Aquatic Plant Species, 2003

Scientific Name	Common Name	I. D. Code
Emergent Species		
Floating-leaf Species		
1) *Lemna minor* L.	small duckweed	lemmi
2) *Nymphaea odorata* Aiton.	white water lily	nymod
Submergent Species		
3) *Ceratophyllum demersum* L.	coontail	cerde
4) *Elodea canadensis* Michx.	common waterweed	eloca
5) *Myriophyllum sibiricum* Komarov.	common water milfoil	myrsi
6) *Myriophyllum spicatum* L.	Eurasain water milfoil	myrsp
7) *Najas flexilis* (Willd.) Rostkov and Schmidt.	slender naiad	najfl
8) *Potamogeton amplifolius* Tuckerman.	large-leaf pondweed	potam
9) *Potamogeton crispus* L.	curly-leaf pondweed	potcr
10) *Potamogeton natans* L.	floating-leaf pondweed	potna
11) *Potamogeton pusillus* L.	small pondweed	potpu
12) *Potamogeton zosteriformis* Fern.	flatstem pondweed	potzo
13) *Ranunculus longirostris* Godron.	white watercrowfoot	ranlo
14) *Vallisneria americana* L.	water celery	valam
15) *Zosterella dubia* (Jacq.) Small	water stargrass	zosdu

FREQUENCY OF OCCURRENCE

Vallisneria americana was the most frequently occurring species in Friendship Lake in 2003, (57% of sample sites) (Figure 5). *Ceratophyllum demersum* and *Elodea canadnensis* were also a commonly occurring species, (48%, 50%).

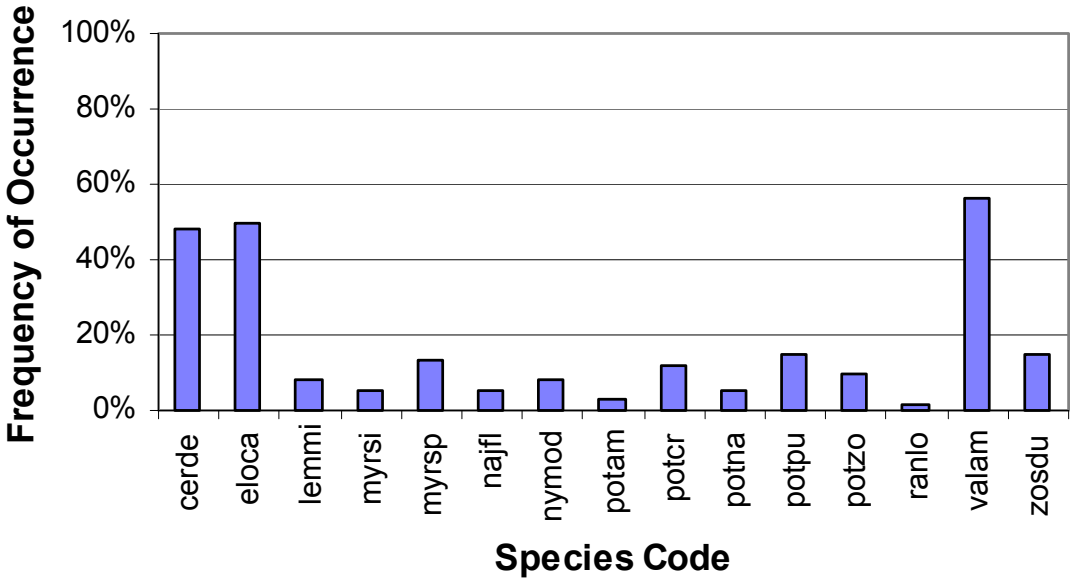


Figure 5. Frequencies of macrophyte species in Friendship Lake, 2003

Filamentous algae occurred at 48% of the sample sites. Filamentous algae occurred at:

47% of the sites in the 0-1.5ft depth zone
74% of the sites in the 1.5-5ft depth zone
43% of the sites in the 5-10ft depth zone
0% of the sites in the 10-16ft depth zone

DENSITY

Vallisneria americana was also the species with the highest mean density (1.65 on a density scale of 1-4) in Friendship Lake (Figure 6).

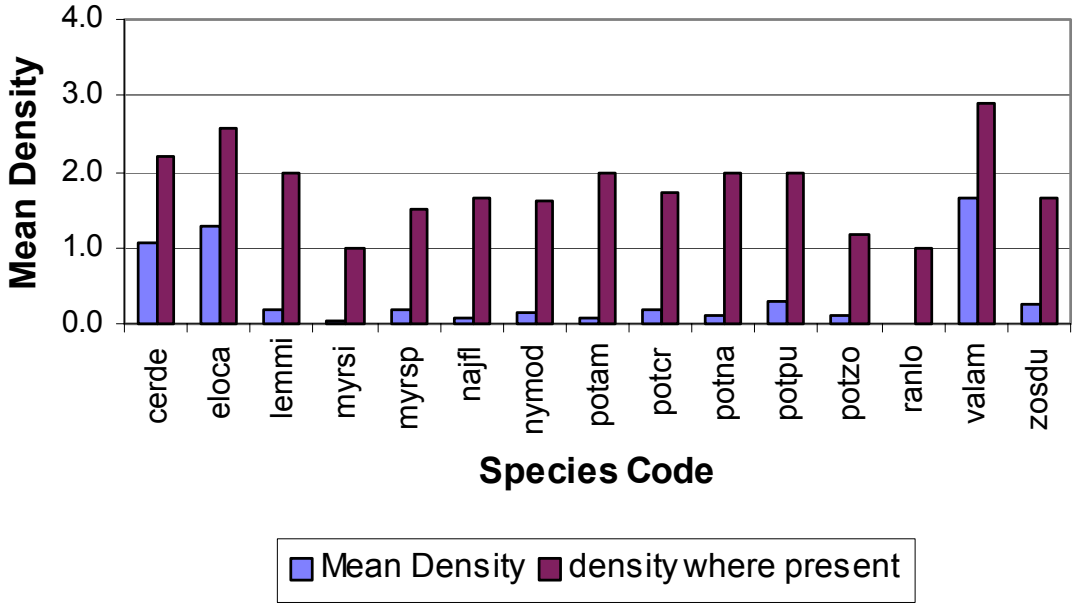


Figure 6. Densities of macrophyte species in Friendship Lake, 2003

Vallisneria americana had a "mean density where present" of 2.9. Its "mean density where present" indicates that, where *V. americana* occurred, it exhibited a growth form of above average density in Friendship Lake (Appendix II). *Elodea canadensis* also had "densities where present" of 2.5 or more, indicating that it exhibited an aggregated growth form (Appendix II).

DOMINANCE

Combining relative frequency and relative density into a Dominance Value illustrates how dominant a species is within the aquatic plant community (Appendix III). Based on the Dominance Value, *Vallisneria americana* was the dominant aquatic plant species in Friendship Lake (Figure 7). *Elodea canadensis* was sub-dominant. The exotic species, *Myriophyllum spicatum*, did not have a high dominance within the plant community.

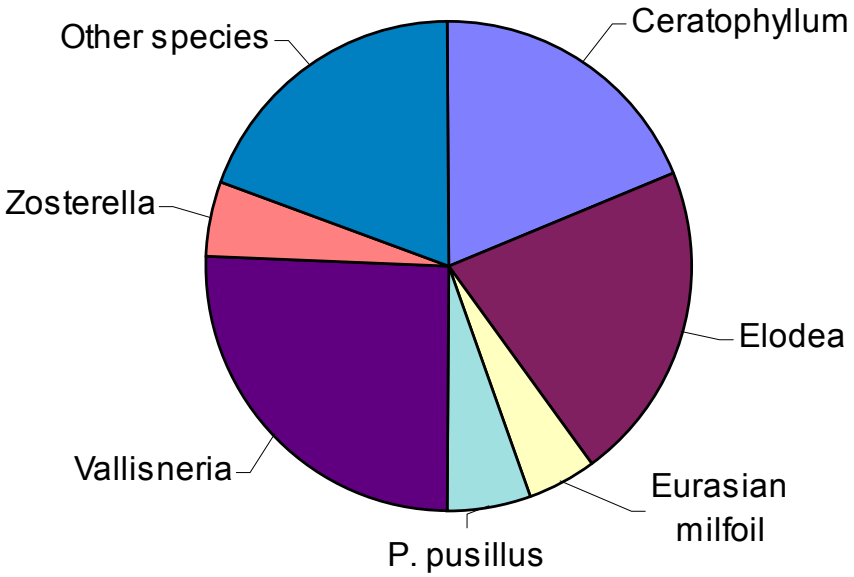


Figure 7. Dominance within the macrophyte community, of the most prevalent aquatic macrophytes in Friendship Lake, 2003.

Ceratophyllum demersum and *Elodea canandensis* were dominant in the 0-1.5ft depth zone (Figure 8, 9) although both were found at their highest frequency and density in the 1.5-5ft depth zone (Figure 8, 9). *C. demersum* was also dominant at depths greater than 10 feet. This is likely due to the ability of *C. demersum* to float in the water column, unrooted. This allows *C. demersum* to occur in water deeper than the maximum rooting depth based on water clarity.

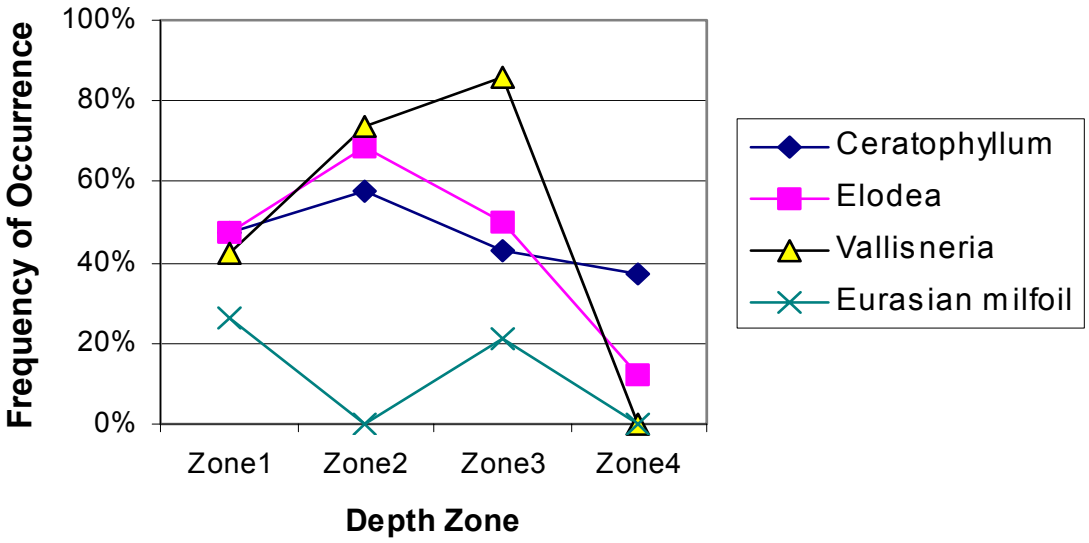


Figure 8. Frequency of occurrence of prevalent macrophytes in Friendship Lake, by depth zone, 2003.

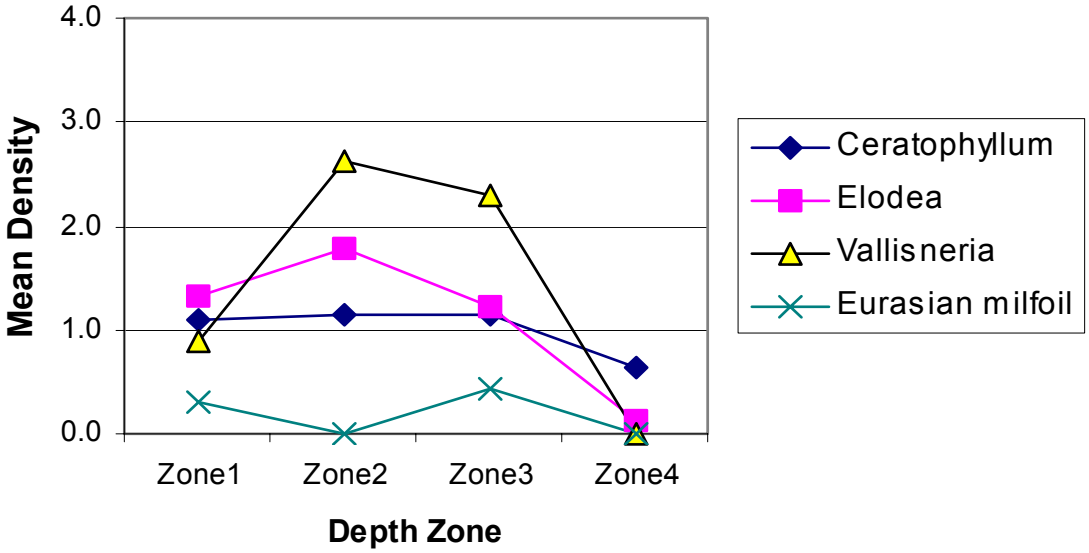


Figure 9. Density of prevalent macrophytes in Friendship Lake by depth zone, 2003.

Vallisneria americana, the dominant species, dominated the 1.5-10ft depth zone (Figure 8, 9) and was found at its highest frequency and density in this depth zone. *V. americana* was not found in the east basin.

Myriophyllum spicatum, the exotic species, only occurred in the 0-1.5ft and 5-10ft depth zone; found at its highest frequency in the shallow zone and highest density in the 5-10ft depth zone (Figure 8, 9).

DISTRIBUTION

Aquatic plants occurred throughout Friendship Lake at 83% of the sampling sites were vegetated, 78% with rooted plants, to a maximum depth of 10.5 feet. The dominant species were found throughout the lake. *Ceratophyllum demersum, Elodea canadensis, Zosterella dubia* and *Potamogeton zosteriformis* occurred at the maximum rooting depth. This maximum rooting depth is in agreement with the predicted maximum rooting depth based on water clarity (Figure 10). Secchi disc readings are used to calculate a predicted maximum rooting depth for plants in a lake (Dunst 1982).

Based on the 2002 Secchi disc clarity, the predicted maximum rooting depth in Friendship Lake would be 10.5 ft (Figure 10).

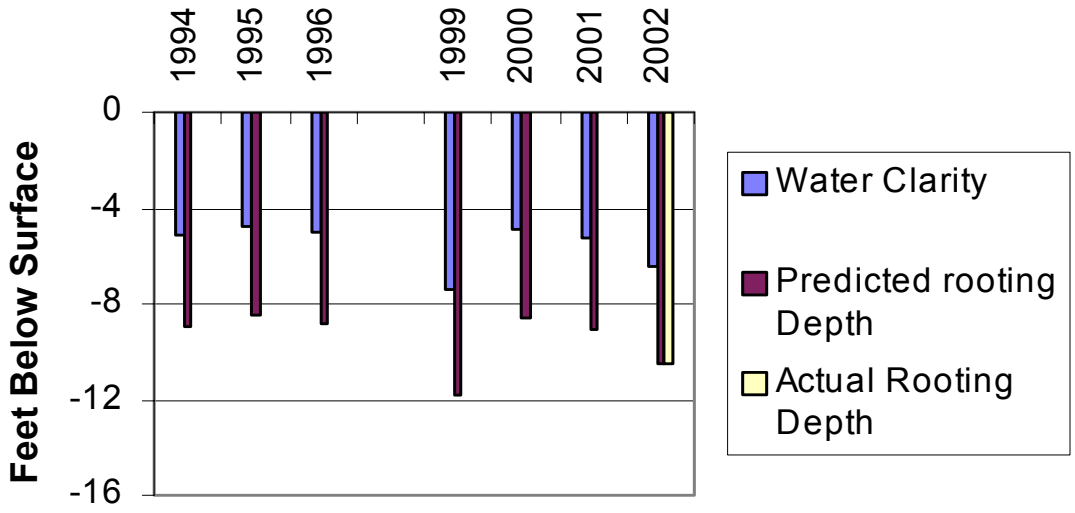


Figure 10. Predicted and actual maximum rooting depth in Friendship Lake, based on water clarity, 2003.

The 1.5-5ft depth zone supported the greatest amount of plant growth. The highest total occurrence and total density of plant growth was recorded in the 1.5-5ft depth zone (Figure 11).

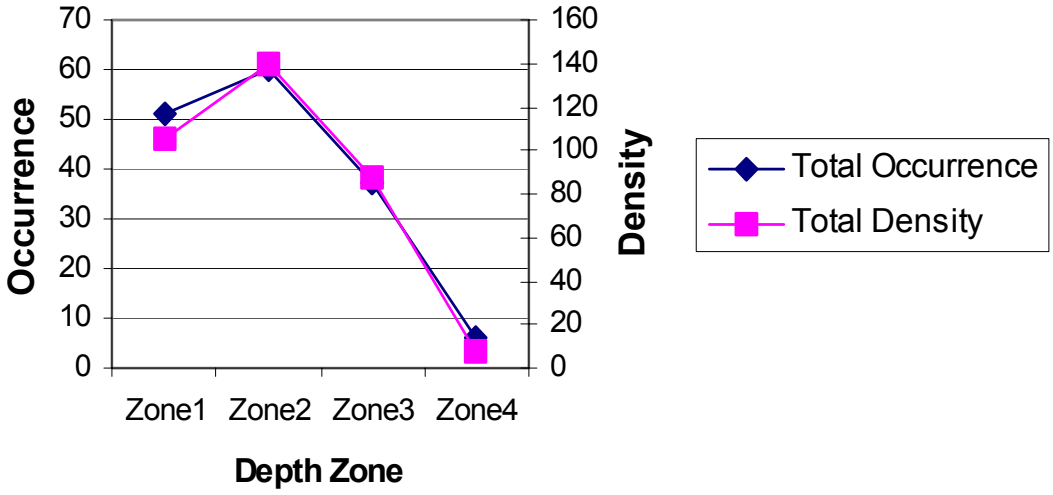


Figure 11. Total occurrence and total density of plants in Friendship Lake by depth zone.

The highest percentage of vegetated sites and the greatest species richness (mean number of species per site) were also found in the 1.5-5 ft. depth zone (Figure 12).

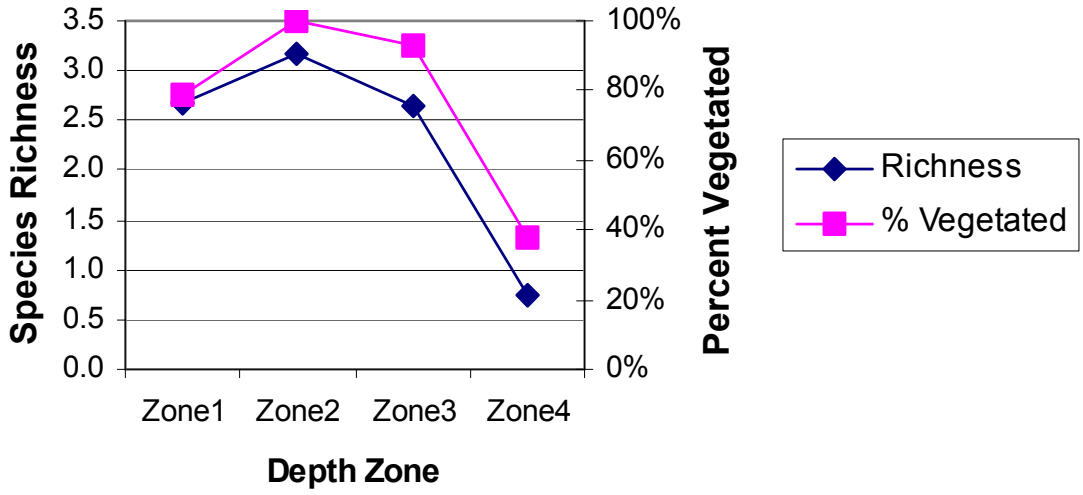


Figure 12. Percentage of vegetated site and species richness in Friendship Lake, by depth zone, 2003.

The mean number of species found at each sampling sites was 2.57

THE COMMUNITY

Simpson's Diversity Index was 0.86, indicating good species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable).

The Aquatic Macrophyte Community Index (AMCI) for Friendship Lake (Table 8) is 41. This is average quality (40) for lakes in Wisconsin. The highest value for this index is 60.

Table 8. Aquatic Macrophyte Community Index

Category		Value
Maximum Rooting Depth	3.2 meters	6
% Littoral Zone Vegetated	83%	10
Simpson's Diversity	0.86	9
# of Species	15 (2 exotics)	4
% Submergent Species	75% Rel. Freq.	10
% Sensitive Species	8% Relative Freq.	2
Totals		41

The presence of two exotic species and the lack of sensitive species are limiting the quality of Friendship Lake.

The Average Coefficient of Conservatism for Friendship Lake was in the lowest quartile for all Wisconsin lakes and lakes in the North Central Hardwood Region (Table 9). This suggests that the aquatic plant community in Friendship Lake is among the group of lakes in Wisconsin and the North Central Hardwoods Region most tolerant of disturbance. This is likely due to selection by past disturbance.

The Floristic Quality Index of the plant community in Friendship Lake was below average for Wisconsin lakes and North Central Hardwood Region lakes (Table 9). This indicates that the plant community in Friendship Lake is farther from an undisturbed condition than the average lake in Wisconsin or the North Central Hardwood Region. This suggests that the aquatic plant community in Friendship has been impacted by an above average amount of disturbance.

Table 9. Floristic Quality and Coefficient of Conservatism of Friendship Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	Average Coefficient of Conservatism †	Floristic Quality ‡	Based on Relative Frequency	Based on Dominance Value
Wisconsin Lakes	5.5, 6.0, 6.9 *	16.9, 22.2, 27.5		
NCHR	5.2, 5.6, 5.8 *	17.0, 20.9, 24.4		
Friendship Lake 2003	4.87	18.85	16.67	16.78

* - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.

† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).

‡ - lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).

These values were based on the presence or absence of tolerant and intolerant species only; their frequency or dominance within the plant community was not taken into consideration. The Floristic Quality Index was recalculated by weighting each species coefficient with its relative frequency and dominance value. The resulting values indicate that Friendship Lake was in the lowest quartile for the state and the region, in the group of lakes farthest from an undisturbed condition.

Disturbances can be of many types:

1) Physical disturbances to the plant beds result from activities such as boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures and fluctuating water levels.
2) Indirect disturbances are the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion and increased algae growth due to nutrient inputs.
3) Biological disturbances include competition from the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by a fish or wildlife population.

Major disturbances in Friendship Lake include shoreline development, invasion of exotic species and plant harvesting.

Comparison of 1979, 1992 and 2003 Aquatic Plant Assessments

The 1979 and 1992 plant surveys were not quantitative surveys using the same methods as the 2003 plant study. In the 1979 and 1992, Friendship Lake was divided into 14 areas and qualitative assessments of the plant communities were made within each area. Because of the different methods, direct comparisons

can not be made, but some observations can be compared.

The number of species recorded in each survey decline declined between 1979 and 1992 (18-14) when *Myriophyllum spicatum* was likely introduced and increased slightly between 1992 and 2003 (14-15) when aquatic plant harvesting started (Table 10). Emergent vegetation has declined the most, from 7 emergent species in 1979, to 2 emergent species in 1992 to none in 2003. The number of submergent species recorded has increased (Table 10).

Table 10. Friendship Lake Aquatic Plant Species, 1979-2003

1979	1992	2003
Emergent Species	Emergent Species	
Asclepias incarnata		
Carex spp.		
Iris versicolor		
Sagittaria latifolia		
Scirpus spp.	*Scirpus* spp	
Sparganium chlorocarpum		
Typha latifolia	*Typha latifolia*	
Floating-leaf Species	Floating-leaf Species	Floating-leaf Species
Lemna minor	*Lemna minor*	*Lemna minor*
Nymphaea odorata	*Nymphaea odorata*	*Nymphaea odorata*
Submergent Species	Submergent Species	Submergent Species
Ceratophyllum demersum	*Ceratophyllum demersum*	*Ceratophyllum demersum*
Elodea canadensis	*Elodea canadensis*	*Elodea canadensis*
Myriophyllum spp.	*Myriophyllum sibiricum*.	*Myriophyllum sibiricum*
	Myriophyllum spicatum	*Myriophyllum spicatum*
Najas flexilis		*Najas flexilis*
Potamogeton amplifolius	*Potamogeton amplifolius*	*Potamogeton amplifolius*
	Potamogeton crispus	*Potamogeton crispus*
Potamogeton natans		*Potamogeton natans*
		Potamogeton pusillus
Potamogeton zosteriformis	*Potamogeton zosteriformis*	*Potamogeton zosteriformis*
	Rannunculus spp.	*Rannunculus longirostris*
	Utricularia spp.	
Vallisneria americana	*Vallisneria americana*	*Vallisneria americana*
Zosterella dubia		*Zosterella dubia*
Filamentous algae	Filamentous algae	Filamentous algae

The disturbance tolerance of the aquatic plant community in Friendship Lake and its closeness to an undisturbed lake changed between 1979 and 2003. The Average Coefficient of Conservatism for Friendship Lake remained in the lowest quartile for all Wisconsin and region lakes (Table 11), remaining in the group of lakes most tolerant of disturbance. Although the value remained within the lowest quartile, its disturbance tolerance increased 1979-1992 and decreased

slightly 1992-2003. This suggests that some form of disturbance impacted the lake community during the time the two exotic species (Eurasian watermilfoil and curly-leaf pondweed) were introduced and disturbance decreased somewhat (though still some disturbance) during the time aquatic plant harvesting was started.

The Floristic Quality Index of the plant community in Friendship Lake was below average for Wisconsin and region lakes in 1979, dropping to the lowest quartile in 1992 and rebounding somewhat to below the mean again in 2003 (Table 11). This suggests that the plant community in Friendship Lake was farther from an undisturbed condition than the average lake in the state or region in 1979; dropped into the group of lakes farthest from an undisturbed condition during the time period that the two exotic species were introduced; improved to a condition farther from an undisturbed than the average lake during the time that the harvesting program was started.

Table 11. Floristic Quality and Coefficient of Conservatism of Friendship Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes, 1979-2003.

	Average Coefficient of Conservatism †	Floristic Quality ‡
Wisconsin Lakes *	5.5, 6.0, 6.9	16.9, 22.2, 27.5
NCHR *	5.2, 5.6, 5.8	17.0, 20.9, 24.4
Friendship Lake - 1979	5.06	20.86
Friendship Lake - 1992	4.15	14.98
Friendship Lake - 2003	4.87	18.85

* - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.

† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).

‡ - lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).

The number of species recorded in each area varied among the three years. There were many variations of increase and/or decrease from year-to-year, but, on average, the mean number of species per site decreased slightly after the introduction of the two exotic species and declined further after the harvesting program started (Figure 13).

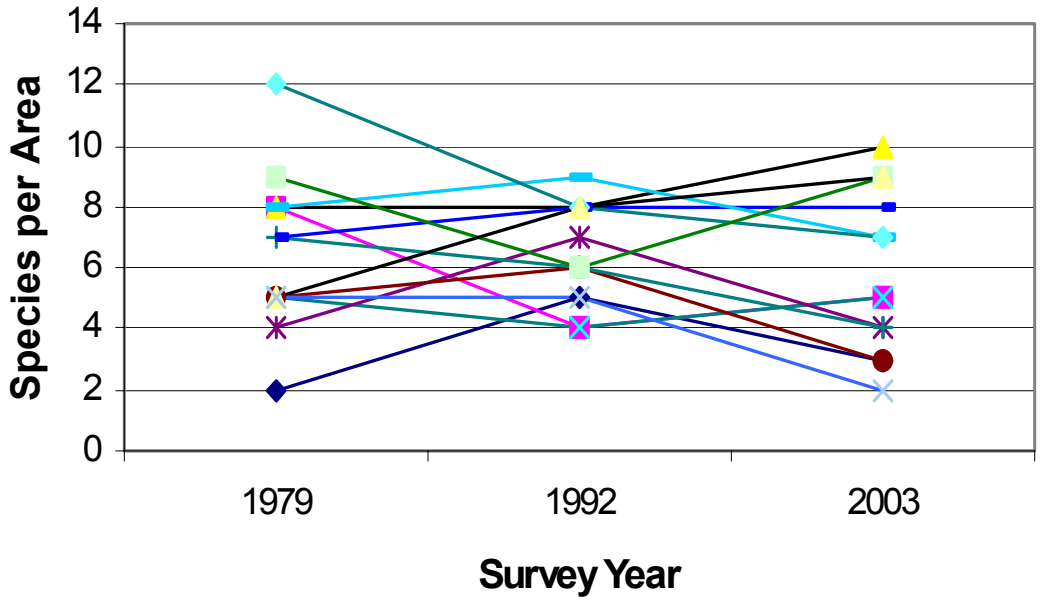


Figure 13. Variations in mean species richness between aquatic plant survey years.

Since a quantitative survey was not conducted in 1979 and 1992, the only comparison that can be made is in the qualitative assessments of each species in each of the areas delineated in 1979 (Appendix V).

The 2003 dominant species, *Vallisneria americana*, has decreased in 10 of the 13 areas since harvesting programs was started. *Potamogeton amplifoilius* has decreased in nearly all areas it has been found (10 areas) since harvesting began.

Potamogeton zosteriformis decreased in all areas, 4 since Eurasian milfoil was introduced and 7 since harvesting began. *Nymphaea odorata* has also decreased in all areas, 3 since Eurasian water milfoil and 10 since harvesting. *Najas flexilis* has decreased , 4 since Eurasian watermilfoil and 2 since harvesting. *Myriophyllum sibiricum* has declined in 6 areas since Eurasian watermilfoil was introduced and 6 areas since harvesting began.

Elodea canadensis has increased, after the invasion of Eurasian watermilfoil in 4

areas and in 4 more areas since harvesting and has decreased in 3 areas since harvesting.
Ceratophyllum demersum increased in all areas when Eurasian watermilfoil was introduced, but has decreased in all areas since harvesting began. *Lemna minor* also increased after the Eurasian watermilfoil invasion and decreased after harvesting began in 5 of the 7 areas in which it has been found.

Potamogeton pusillus has appeared since the harvesting program began; *Zosterella dubia* has increased since harvesting began.

Myriophyllum spicatum has decreased in all areas since harvesting began. *Potamogeton crispus* has decreased in 7 of the 10 areas in which it has been found since harvesting began.

Since harvesting began, the abundance of filamentous algae has decreased in more areas than it has increased.

V. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Friendship Lake is a mesotrophic lake with fair water clarity and quality. This trophic state should support moderate plant growth and occasional algae blooms. Filamentous algae was abundant (48% of sites), especially in 1.5-5ft depth zone.

Adequate nutrients (trophic state) and the shallow depth and gradually sloped littoral zone in Friendship Lake favor plant growth. The dominance of high-density sand and sand/gravel sediments in Friendship Lake may limit the density of plant growth. Favorable silt sediments are more abundant in the deeper water, where light penetration is less.

Since 1993, mechanical harvesting has been conducted in Friendship Lake and has removed more than 3.5 million pounds of plant material. This removal of vegetation would help somewhat with nutrient reduction although impoundments have continuous nutrient input from the river and watershed.

Aquatic plants occurred at 83% of the sites (78% with rooted vegetation), to a maximum depth of 10.5 feet. This maximum rooting depth is in agreement with the predicted maximum rooting depth of 10.5 feet, based on water clarity.

The highest total occurrence of plants, highest total density of plants, the greatest percentage of vegetated sites and the largest mean number of species per sample site occurred in the 1.5-5ft depth zone.

Fifteen species were recorded in Friendship Lake in 2003, none of the species were emergent species. *Vallisneria americana* was the dominant plant species in Friendship Lake, especially in the 1.5-10ft depth zone, occurring at more than half of the sample sites. *Elodea canadensis* was sub-dominant. Both the dominant and sub-dominant species exhibited a growth form of above average density in Friendship Lake. *Ceratophyllum demersum* and *Elodea canadensis* dominated the 0-1.5ft depth zone; *C. demersum* dominated the >10ft depth zone.

Myriophyllum spicatum, Eurasian watermilfoil, occurs in Friendship Lake but does not have a high frequency (13% of the sites) or density in Friendship Lake. *M. spicatum* only ranks sixth in dominance in the Friendship Lake plant community.

The Aquatic Macrophyte Community Index (AMCI) for Friendship Lake was 41, indicating that the quality of the plant community in Friendship Lake is average (40) for Wisconsin lakes. Simpson's Diversity Index (0.86) indicates that the plant community had a good diversity of species. The mean number of species per sample site was 2.57.

The Average Coefficient of Conservatism and the Floristic Quality Index

suggests that Friendship Lake has been impacted by an above average amount of disturbance as compared to lakes in Wisconsin and in the North Central Hardwoods Region of Wisconsin. Disturbances to Friendship Lake could include past arsenic treatments, development of the shorelines, the invasion of exotic species (*Myriophyllum spicatum, Potamogeton crispus*) and the present mechanical harvesting. Small-scale dredging projects and limited drawdowns in the past may have had localized impacts.

Qualitative comparisons of the 1979, 1992 and 2003 aquatic plant communities were used to determine the history of the plant community.

A. INTRODUCTION OF EURASIAN WATERMILFOIL INTO FRIENDSHIP LAKE BETWEEN 1979 AND 1992

Some changes were seen in the aquatic plant community:

1) the lake moved closer to a disturbed condition
2) there was a decline in species diversity (number of species)
3) there was a decline in species richness (species per area)
4) there was an increase in the abundance of some species that can become overabundant with disturbance: *Ceratophyllum demersum, Elodea canadensis* and *Lemna minor.*

Like many exotic species, Eurasian watermilfoil is able to out-compete native species when introduced into a new area that does not support the diseases and herbivores that kept it in check in its natural habitat.

The greatest decline in species has been the emergent species. However this decline in number of emergent species has continued from 1979 to present and is not likely due to exotic species invasions. As the shoreline becomes developed, emergents have likely been removed in an attempt to "clean up" the shoreline.

B. IMPLEMENTATION OF MECHANICAL HARVESTING BETWEEN 1992 AND 2003

Changes seen in the aquatic plant community:

1) filamentous algae abundance has declined slightly
2) species diversity (number of species) has recovered slightly but species richness (number of species per area) has continued to decline
3) the lake community shifted partly back to a less disturbed condition
4) the abundance of Eurasian watermilfoil has declined
5) the abundance of the other exotic species, curly-leaf pondweed, has declined
6) two of the species that can become overabundant with disturbance (*Ceratophyllum demersum, Lemna minor)* have declined.

Harvesting opens up the top canopy of Eurasian milfoil growth and allows light to penetrate farther into the water where the native species are trying to grow. Harvesting also removes the nutrients found in the plant tissue.

The disturbance caused by the invasion of Eurasian watermilfoil appears to be greater than the disturbance caused by mechanical harvesting. However, there were some disturbing discoveries during the comparison of the plant communities, 1979-2003.

1) Species richness has continues to decline since harvesting began
2) Species that are considered premier habitat have declined more dramatically since harvesting began: *Nymphaea odorata* and *Potamogeton amplifoilus.* These species have declined in spite of the directive to avoid harvesting areas these species colonized.

Friendship Lake has some protection by natural shoreline cover (wooded, shrub, native herbaceous growth), but disturbed shoreline covered 49% of the shore. One type of disturbed cover, cultivated lawn, occurred at 74% of the sample sites and covered 45% of the shoreline. Areas with cultivated lawn could be impacted by increased run-off of lawn fertilizers, pesticides and pet wastes into the lake. Expanding the buffer of natural vegetation along the shore will help prevent shoreline erosion and reduce additional nutrient/chemical run-off that can add to algae growth and sedimentation of the lake bottom.

VI. CONCLUSIONS

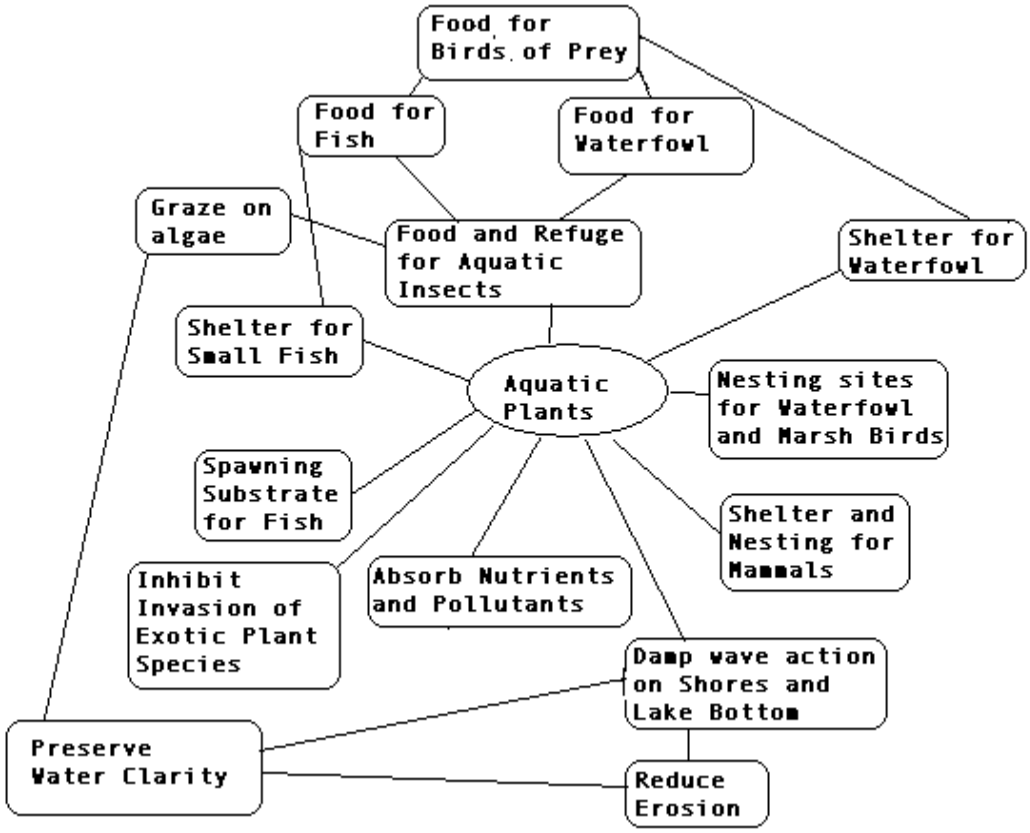
Friendship Lake is a mesotrophic lake with fair water quality and clarity. Filamentous algae is abundant, especially in the 1.5-5ft depth zone.

The aquatic plant community is characterized by average quality for Wisconsin lakes, good species diversity and an above average amount of disturbance. Friendship Lake lacks emergent plant growth.

The aquatic plant community colonized more than three-quarters of the littoral zone to a maximum depth of 10.5 feet. The 1.5-5ft depth zone supported the most abundant aquatic plant growth.

Vallisneria americana is the dominant species within the plant community, especially in the 1.5-10ft depth zone. *Elodea canadensis* was sub-dominant, especially in the 0-1.5ft depth zone.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in
1) improving water quality 2) providing valuable habitat resources for fish and wildlife 3) resisting invasions of non-native species and 4) checking excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.



1) Aquatic plant communities improve water quality in many ways:
   they trap nutrients, debris, and pollutants entering a water body;
   they absorb and break down some pollutants;
   they reduce erosion by damping wave action and stabilizing shorelines and lake bottoms;
   they remove nutrients that would otherwise be available for algae blooms (Engel 1985).

2) Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish (Table 12). Plant cover within the littoral zone of Friendship Lake is 83% and is appropriate but on the high side of ideal (25-85%) to support a balanced fishery.

Compared to non-vegetated lake bottoms, macrophyte beds support larger, more diverse invertebrate populations that in turn will support larger and more diverse fish and wildlife populations (Engel 1985). Additionally, mixed stands of macrophytes support 3-8 times as many invertebrates and fish as monocultural stands (Engel 1990). Diversity in the plant community creates more microhabitats for the preferences of more species. Macrophyte beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990).

Management Recommendations

1) Continue monitoring the water quality through the Self-Help Volunteer Lake Monitoring Program.
2) DNR should designate sensitive areas within Friendship Lake. These are areas that are most important for habitat and maintaining water quality.
3) Chemical treatments for plant growth are not recommended in Friendship Lake due to the undesirable side-effects of chemical treatments. The decaying plant material releases nutrients that feed algae growth that further reduce water clarity. Broad-spectrum treatments would open up areas that would be vulnerable to the spread of the exotic species. Mechanical harvesting appears to be keeping the Eurasian watermifoil in control while removing nutrients from the lake.
4) Natural shoreline restoration is needed. Disturbed shoreline covers nearly half of the shore and mowed lawn alone covers 45% of the shore. Unmowed native vegetation reduces shoreline erosion and run-off into the lake and filters the run-off that does enter the lake. Shoreline restoration could be a as simple as leaving a band of natural vegetation around the shore by discontinuing mowing or as ambitious as planting native grasses, flowers, shrubs and trees would be the ideal.
5) Establish emergent plant beds for habitat and to stabilize the shore. These were likely lost with shoreline development as residents removed this

valuable habitat in an attempt to "clean up the shore".

6) Revise the harvesting plan. Mechanical harvesting appears to have had beneficial impacts in reducing filamentous algae and controlling both of the exotic species, Eurasian watermilfoil and curly-leaf pondweed. In 2003, Eurasian watermifloil was found at only 13% of the sites and was 6th in dominance. Removing the milfoil canopy allows light to penetrate the water to other native species. The decline in the number of species that started with the milfoil invasion seems to have been stopped. The plant community has moved back to a less disturbed condition. Harvesting has removed significant plant biomass and its nutrients, especially some species that can become overabundant with disturbance. On the negative side, since harvesting began, there has been a significant decline in two valuable habitat species and an additional native pondweed species; there has been a decline in species richness; there has been an increase in one species that can become overabundant with disturbance. The plan should be revised to avoid beds of lily pads and large-leaf pondweed and to target Eurasian watermilfoil and common waterweed.