Management of Aquatic Plants in Forest Lake

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Introduction

Forest Lake is located in the southeast corner of Fond du Lac County, Wisconsin, near the village of Dundee. The lake is within the boundaries of the Northern Unit of the Kettle Moraine State Forest. It has a surface area of approximately 50 acres, a maximum depth of 32 feet and a mean depth of 11 feet. Forest Lake is a classic glacial pothole lake, having no inlets or outlets. Its primary water source is groundwater seepage. There are no drive-in boat launches on the lake. However, a walk-in access is located in the State Forest frontage. Forest Lake's shores are predominantly upland hardwood forest. Its watershed covers approximately 160 acres. The main management unit for the lake is the Forest Lake Improvement Association.

Forest Lake has historically been known for its scenic beauty and good water quality. Since at least 1993 however, Forest Lake has been infested with Eurasian watermilfoil (*Myriophyllum spicatum*). By 2000, dense beds of this aggressive exotic plant had covered 25% of the littoral area. By 2002, Eurasian watermilfoil could be found in 41% of the lake (20.5 acres). Throughout much of its lakewide distribution, Eurasian watermilfoil formed dense surface mats that formed a nearly impenetrable barrier to boaters, swimmers and anglers.

Historical data

Water quality parameters and aquatic plant community characteristics have been well documented on Forest Lake over the past 35 years. Aquatic plant surveys were conducted in 1968 and 1985 by the Wisconsin Department of Natural Resources (WDNR), and in 1993 by Gerber. The results of all three surveys are presented in Aquatic plant survey for Forest Lake, Fond du Lac County, Wisconsin, USA (Gerber, 1993). Water quality monitoring was conducted by the WDNR during 1985-86 and reported in Forest Lake Update: 1986 (D. Kendziorski, 1986). Water quality monitoring was conducted by the U.S. Geological Survey from 1994 to 1996 and reported in C. Kendziorski (2001).

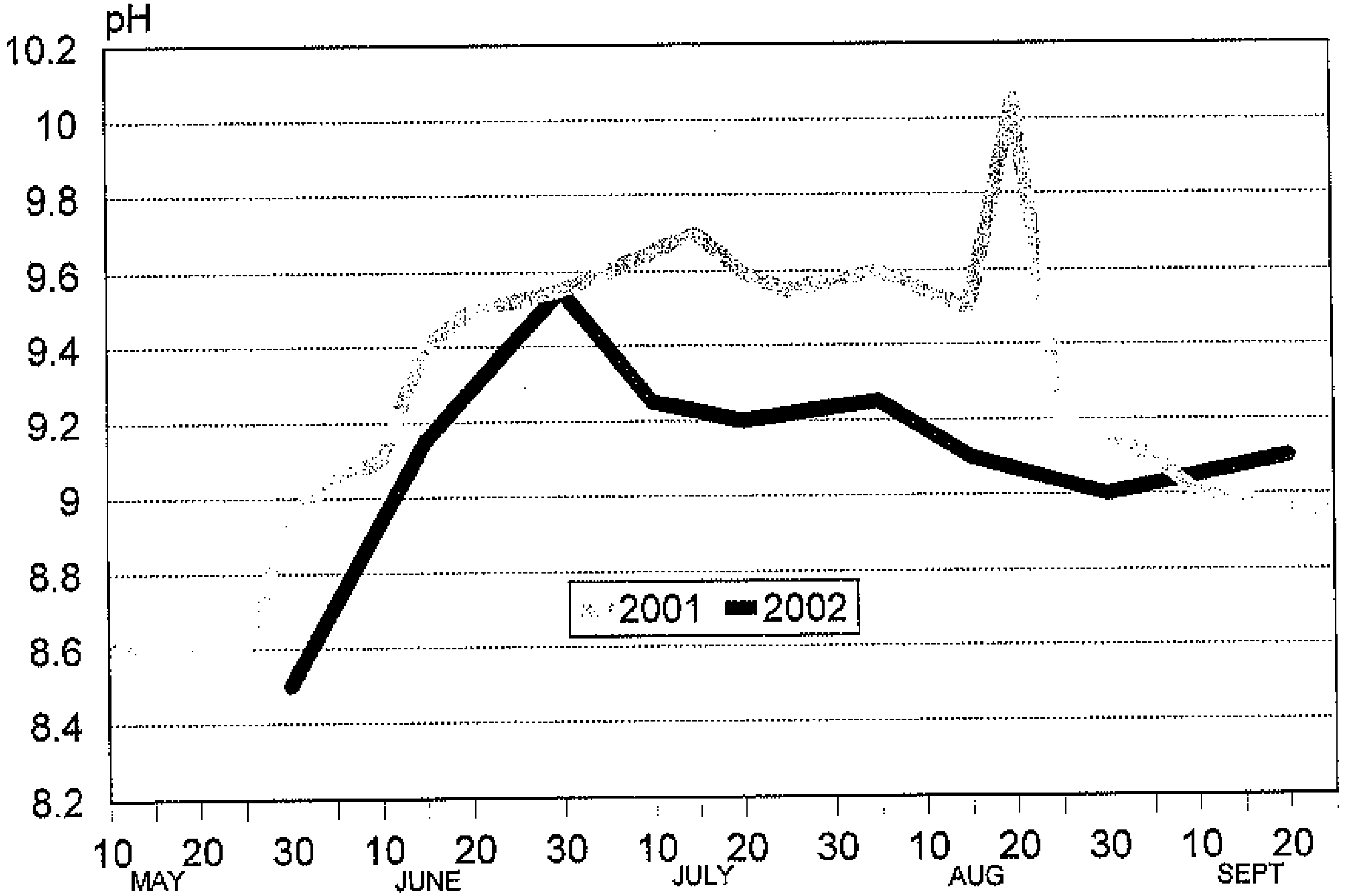
Recent management activities

During the summers of 1999 and 2000, the Forest Lake Improvement Association hired EnviroScience, Inc. to stock milfoil weevil (*Euhrychiopsis lecontei*) eggs and larvae into Forest Lake. EnviroScience, Inc. markets milfoil weevil stocking as a Eurasian watermilfoil control program. Follow-up surveys conducted by EnviroScience staff in the late summers of 1999 and 2000 found no weevil survival or damage to milfoil stems.

A report entitled Effects of sudden exposure to elevated pH on milfoil weevil *Euhrychiopsis lecontei* in Forest Lake Fond du Lac, County, Wisconsin (C. Kendziorski, 2001) studied the efficacy of weevil stocking in Forest Lake. This study hypothesized that the sudden exposure to the high pH found in Forest Lake (**Figure 1**) impacted weevil development and survival. It was calculated that the stocked weevils were exposed to a 59-fold increase in alkalinity from laboratory rearing conditions to Forest Lake waters. Laboratory experiments conducted by EnviroScience in conjunction with this study did indeed find that weevil egg-laying was significantly reduced in high pH conditions. The report recommended that weevils be gradually acclimatized to Forest Lake water in future stocking efforts. The Forest Lake Improvement Association however opted to discontinue the weevil stocking program, and to explore alternative management options.

In 2002, the Forest Lake Improvement Association retained Aquatic Biologists, Inc. to assist in the development of an aquatic plant management plan for the lake. This project involved conducting a survey of the lake's water quality and aquatic plant community, and exploring options for both short-term and long-term management of Eurasian watermilfoil and other plants. This report presents the findings of this study.

Figure 1. Forest Lake mean pH in milfoil beds 2001 - 2002.



From Kendziorski (2001)

Methods

Field studies for this project included 1) conducting a lake-wide submergent plant survey, 2) conducting a shoreline emergent plant survey, 3) mapping the distribution of Eurasian watermilfoil, 4) analyzing water quality parameters, and 5) determining temperature and oxygen profiles.

Submergent plant survey

This survey involved plotting a series of 10 transects (labeled A through J) that radiated outward from equidistant points along shore (**Figure 2**). (GPS coordinates for the starting point of each transect, and the compass direction of each transect are given in **Appendix 1**.) Four plots were sampled along each transect: at 2.5, 5, 10 and 15 foot depths in the north basin, and at 2.5, 5, 7.5 and 10 foot depths (where possible) in the south basin. Plots were established by estimating a 10-foot diameter circle around the anchored boat. The circular plot was then divided into four quarters with each quarter representing a quadrant. Plants were collected in each quadrant by making tows with a tethered short-toothed rake. A total of 160 quadrants were sampled. From each rake tow, all plants collected (including emergent and floating-leaf species) were identified to *genus* and to *species* whenever possible. Data collected included species distribution, relative abundance (% composition) and % frequency.

This survey utilized the even numbered transects from the 1993 survey and collected the same types of data so that surveys were comparable. Data collection methods for the 1993 survey utilized underwater observations, whereas rake tows were used in the 2002 survey. While the 2002 methods produced statistically stronger data, as well as allowing for easier identification of plants, the 1993 methods were more likely to document low frequency plant species.

Emergent plant survey

This survey involved establishing ten additional transects (labeled AB, BC ... ...JA) that ran parallel to shore between the starting points of the submergent transects (**Figure 2**). For each transect, all emergent and floating-leaf plants encountered were identified and recorded. Each species encountered was then given a relative abundance ranking based on the following criteria:

0	*Absent*	not found along transect
1	*Rare*	found along less than 5% of transect
2	*Present*	found along 5 – 25% of transect
3	*Common*	found along 25 – 50% of transect
4	*Abundant*	found along more than 50% of transect

From this data, percent frequency and percent composition were calculated.

Results and Discussion

Aquatic plant surveys

Species composition

The surveys conducted during 2002 found a total of 24 species, compared to 23 species in 1993, 13 species in 1985 and 10 species in 1968 (**Table 1**). The increase in plant species found may be due to more thorough surveys being conducted during 1993 and 2002. It may also be due to actual increases in species diversity. This trend has been found in other Wisconsin lakes. Increases in macrophyte diversity may be the result of increased fertility in lakes or increased human activity, such as boat trailering, or a combination of both factors.

Of the 24 species found during the 2002 survey, only five were found in all four surveys: musk grass (*Chara spp.*), northern watermilfoil (*Myriophyllum sibericum – formerly M. excelbescens*), large-leaf pondweed (*Potamogeton amplifolius*), sago pondweed (*P. pectinatus*) and flatstem pondweed (*P. zosteriformis*). Two exotic species, Eurasian watermilfoil and purple loosestrife (*Lythrum salicaria*), were encountered in 1993 and 2002 but not in the earlier surveys. One positive finding is that invasion Eurasian watermilfoil has not yet led to a decrease in species diversity.

Interestingly, the 1993 report concluded that Fries pondweed (*P. friessii*) found in the 1968 survey was misidentified small pondweed (*P. pusillus*). During the 2002 survey though, a common plant initially identified as small pondweed was later keyed out as a variant of flatstem pondweed (*P. zosteriformis*). While the true identity of the plant may remain a mystery, it is possible that all three labels have been applied to a single species.

Submergent plant survey results

Table 2 shows the results of the submergent plant survey. At 55.6% frequency, Eurasian watermilfoil dominated the plant community. Next in abundance were flatstem pondweed and bushy pondweed (*Najas flexilis*). Northern watermilfoil, Illinois pondweed (*P. illinoiensis*), and coontail (*Ceratophyllum demersum*) were also abundant. In comparison, the 1993 survey (**Table 3**) found bushy pondweed to be dominant at 47.5% frequency, followed by northern watermilfoil at 33.8% and musk grass at 27.5%. Eurasian watermilfoil was fourth in abundance at 26.3%. The most notable decline (except for small pondweed with its apparent identity crisis) occurred in musk grass, which dropped from 27.5 to 8.1% frequency. Changes in the plant community composition between 1993 and 2002 are presented in **Figure 3**. The most notable finding of these data comparisons is that Eurasian watermilfoil has expanded dramatically, but has not yet reached the point of significantly reducing the diversity and abundance of native species.

Table 1. Species found during four Forest Lake aquatic plant surveys.

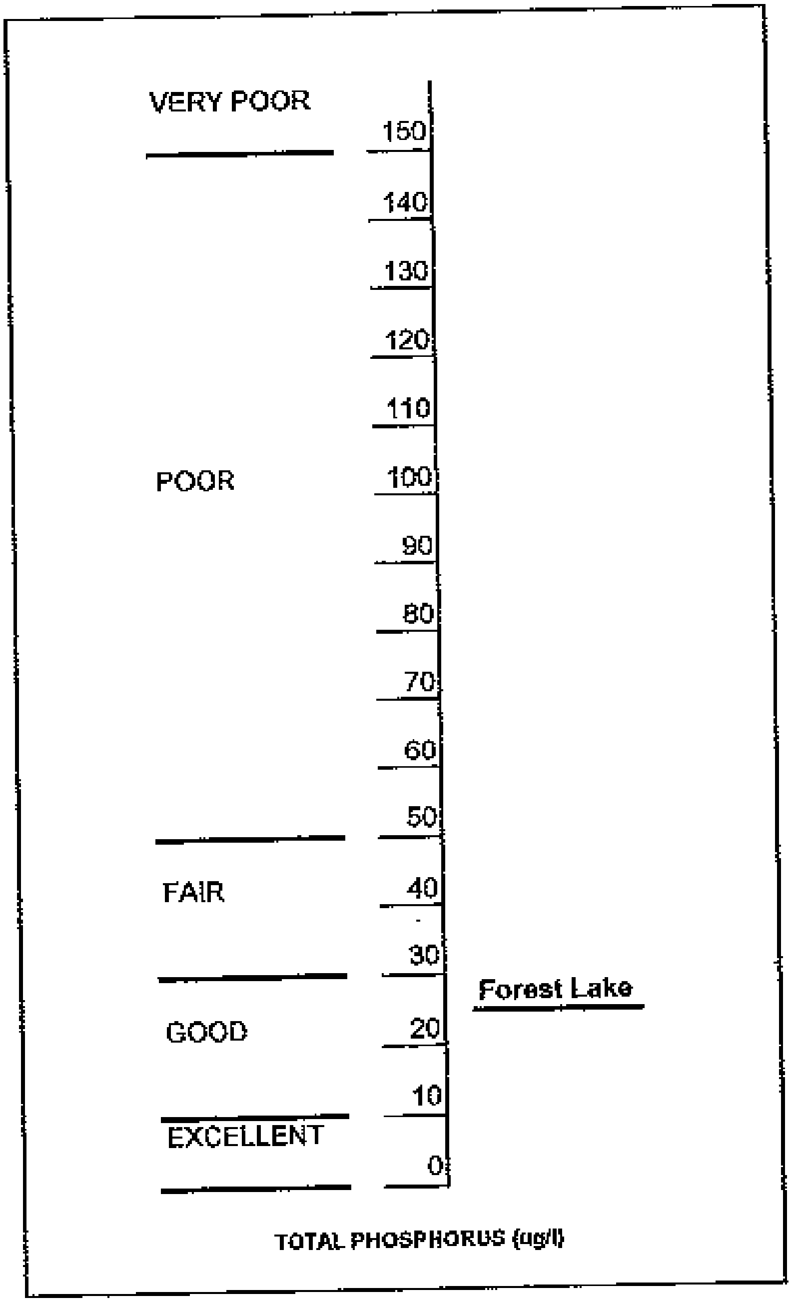
1968	1985	1993	2002
Chara sp.	Ceratophyllum demersum	Ceratophyllum demersum	Carex hystericina
Iris spp.	Chara spp.	Chara spp.	Carex spp.
Myriophyllum sibericum	Myriophyllum sibericum	Eleocharis acicularis	Ceratophyllum demersum
Potamogeton amplifolius	Najas flexilis	Eleocharis spp.	Chara spp.
P. friessii	Nuphar variegatum	Lythrum salicaria	Drepanocladus spp.
P. pectinatus	Nymphaea odorata	Myriophyllum sibericum	Eleocharis acicularis
P. zosteriformis	Potamogeton amplifolius	M. spicatum	Eleocharis palustris
Polygonum amphibium	P. natans	Najas flexilis	Lythrum salicaria
Scirpus validus	P. pectinatus	Nuphar variegata	Myriophyllum sibericum
Typha spp.	P. zosteriformis	Nymphaea odorata	M. spicatum
(10)	Polygonum amphibium	Potamogeton amplifolius	Najas flexilis
	Valisneria americana	P. foliosus	Nitella spp.
	Zosterella dubia	P. gramineus	Nuphar variegata
	(13)	P. natans	Nymphaea odorata
		P. pectinatus	Potamogeton amplifolius
		P. pusillus	P. illinoiensis
		P. zosteriformis	P. natans
		Polygonum amphibium	P. pectinatus
		Sagitaria spp.	P. zosteriformis
		Scirpus validus	Scirpus americanus
		Typha spp.	Typha latifolia
		Valisneria americana	Valisneria americana
		Zosterella dubia	Zosterella dubia
		(23)	Typha angustifolia
			(24)

Table 4 shows the submergent plant survey data by transect. Bushy pondweed and Eurasian watermilfoil were most widely distributed, having been found in every transect. Flatstem pondweed, Illinois pondweed and northern watermilfoil were also widely distributed, having been found in 9 of 10 transects. Transects I and J on the east shore had the highest diversity with 10 and 11 species, respectively. Transect A on the north shore had the lowest diversity with six species. Raw data from this survey, including transect descriptors such as depth, bottom substrate, and the presence of human disturbance (i.e. weed raking or treatment) is presented in **Appendix 1**.

Emergent plant survey data

Table 5 shows the results of the emergent and floating-leaf plant survey. A total of eleven species were found. The most commonly found plant was white water lily

Figure 6. Total phosphorus water quality index.



(*Nymphaea odorata*) at 77.5% frequency. Also abundant was the invasive exotic, purple loosestrife (*Lythrum salicaria*) at 62.5 %. The next most abundant plant was three-square bulrush (*Scirpus americanus*) at 35% frequency. While three-square bulrush is readily identifiable by its triangular-shaped stems, at a distance it resembles softstem bulrush (*Scirpus validus*). It is possible that this species was misidentified as softstem bulrush in the previous surveys.

The transect having the greatest species diversity was DE with seven species. This transect was along undeveloped State Forest land. The transects with the least diversity were AB and BC with four species each. These transects were along the north shore which is the most heavily developed (**Table 6**).

Eurasian watermilfoil distribution

Eurasian watermilfoil was found, in varying degrees of density, in approximately 20.5 acres of the lake (**Figure 4**). The largest continuous bed was found along the north shore of the lake. Eurasian watermilfoil distribution correlated most closely with depth. It was seldom found in less than two feet or greater than 15 feet of water. Dense, monotypic stands of Eurasian watermilfoil were most often found at depths of 6 to 12 feet. Eurasian watermilfoil tended to coexist with native species in shallower waters. While Eurasian watermilfoil is quite well established in Forest Lake, it is likely that it will continue to spread and become more dense.

Water quality parameters

The following water quality parameters were determined for Forest Lake from the September 20, 2002 sampling:

Chlorophyll *a*	2.9 ug/l
Ammonia (as N)	0.18 mg/l
Nitrate + Nitrite (as N)	not detectable
Kjeldahl Nitrogen	0.73 mg/l
Total Phosphorus	25 ug/l
pH	9.06
Secchi disc depth	14.0 ft.

The complete laboratory reports are found in **Appendix 2.** Explanations of these results are given in the following paragraphs.

Chlorophyll *a*

Chlorophyll is a pigment found in all plants. It is the only pigment that can convert light to chemical energy in photosynthesis. Chlorophyll *a* concentrations are often used to gauge algal abundance. Because algal abundance is often related to nutrient inputs in a lake, chlorophyll *a* can be a good indicator of water quality. **Figure 5** ranks Forest Lake on a chlorophyll *a* water quality index. Forest Lake ranked in the "very good" range.

The result found in 2002 was below historical averages and well below the average for Southeastern Wisconsin lakes (D. Kendziorski, 1986).

Nitrogen

After carbon, hydrogen and oxygen, nitrogen is the most abundant element in living cells. It is essential for most biochemical reactions. Nitrogen is always present in aquatic environments. Its most common form is gaseous; which is basically inert. Nitrogen is present in aquatic environments to a lesser extent in the forms of ammonia, nitrate, nitrite and urea. Of these, nitrate and ammonia are the most important for plant growth. Nitrogen can limit plant growth in high phosphorus environments, thus it may be an important water quality parameter. The ratio of nitrogen to phosphorus found in Forest Lake however, indicates that nitrogen is not a plant-limiting factor. The results of the 2002 nitrogen parameters tested were below historical averages and below the averages for Southeastern Wisconsin lakes (D. Kendziorski, 1986).

Phosphorus

Phosphorus is most often the element that determines, or limits, plant productivity in lakes. Results indicate that it is indeed the limiting nutrient for plant growth in Forest Lake. Forest Lake ranks in the "good" range on the total phosphorus water quality index shown in **Figure 6**. Results were comparable to 1985-86 data and below 1968 data (D. Kendziorski, 1986).

pH

pH is the negative log of the hydrogen ion concentration. It is used to measure the acidity or alkalinity of lakes. As discussed earlier in this report the pH of Forest Lake is well above average. C. Kendziorski (2001) suggested that the high pH was a result of soil types in the watershed. This is no doubt the main influence on Forest Lake's pH. However, historical data presented in D. Kendziorski (1986) indicates that mean pH has increased over time. This increase is likely due to an increase in photosynthetic activity within the lake. The likely culprit for this increased photosynthetic activity is Eurasian watermilfoil.

Secchi disc depth

Secchi disc depth is the standard measure of water clarity. It is also one of the primary indicators of water quality. Forest Lake ranks in the "good" range on the Secchi disc depth water quality index shown in **Figure 7**. Results were well above historical data and well above average for Southeastern Wisconsin Lakes (D. Kendziorski, 1986). This may be the only positive result of the dense beds of Eurasian watermilfoil.

Dissolved oxygen and temperature profiles

The saturation level of oxygen in water decreases with increased temperature. However in more productive lakes this trend is reversed when low dissolved oxygen levels are found in the cooler depths. This phenomenon is evident in the results from Forest Lake shown in **Figure 8**. A distinct oxycline was evident between 18 and 20 feet deep. Below 20 feet the lake was nearly devoid of dissolved oxygen. A thermocline was also evident between 20 and 24 feet. The anoxic conditions found in the depths are a result of bacterial decomposition of organic matter. As lake productivity increases, so does bacterial oxygen demand.

Table 2. Results of the submergent aquatic plant survey conducted on Forest Lake during September, 2002.

Species **common name**	**scientific name**	**Samples Collected**	**Percent Frequency***	**Percent Composition****
Eurasian Water Milfoil	*Myriophyllum spicatum*	89	55.6	21.3
Flatstem Pondweed	*Potamogeton zosteriformis*	73	45.6	17.5
Bushy Pondweed	*Najas flexilis*	72	45.0	17.2
Northern Water Milfoil	*Myriophyllum sibericum*	43	26.9	10.3
Illinois Pondweed	*Potamogeton illinoiensis*	35	21.9	8.4
Coontail	*Ceratophyllum demersum*	34	21.3	8.1
Water Celery	*Valisneria americana*	24	15.0	5.7
Large Leaf Pondweed	*Potamogeton amplifolius*	18	11.3	4.3
Musk Grass	*Chara spp.*	13	8.1	3.1
White Water Lily	*Nymphaea odorata*	8	5.0	1.9
Water Stargrass	*Zosterella dubia*	4	2.5	1.0
Sago Pondweed	*Potamogeton pectinatus*	2	1.3	0.5
Stonewort	*Nitella spp.*	2	1.3	0.5
Water Moss	*Drepanocladus spp.*	1	0.6	0.2

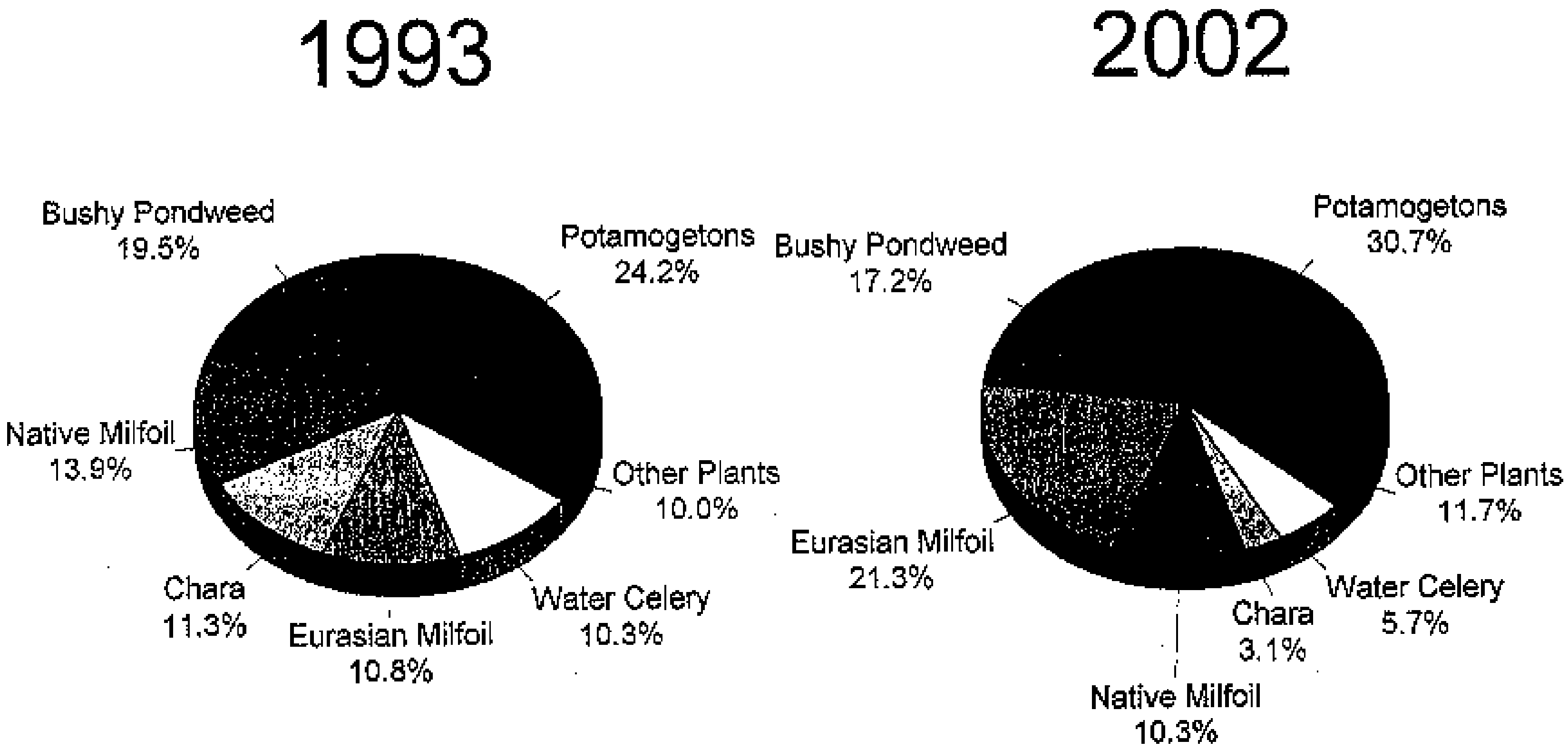
* % Frequency = number of occurences / 160 rake tows

** % Composition = individual samples collected / total samples collected (n = 418)

Table 3. A comparison of Forest Lake submergent aquatic plant survey results from 1993 and 2002.

Species common name	scientific name	1993 % Frequency	2002 % Frequency	Percent Change
Bushy Pondweed	*Najas flexilis*	47.5	45.0	(-) 2.5
Northern Water Milfoil	*Myriophyllum sibericum*	33.8	26.9	(-) 4.1
Musk Grass	*Chara spp.*	27.5	8.1	(-) 19.4
Eurasian Water Milfoil	*Myriophyllum spicatum*	26.3	55.6	(+) 29.3
Water Celery	*Valisneria americana*	25.0	15.0	(-) 10.0
Small Pondweed	*Potamogeton pusillus*	22.5	0.0	(-) 22.5
Variable Pondweed	*Potamogeton grammineus*	10.0	0.0	(-) 10.0
Flatstem Pondweed	*Potamogeton zosteriformis*	8.8	45.6	(+) 36.8
Coontail	*Ceratophyllum demersum*	6.3	21.3	(+) 15.0
Large Leaf Pondweed	*Potamogeton amplifolius*	6.3	11.3	(+) 5.0
White Water Lily	*Nymphaea odorata*	6.3	5.0	(-) 1.3
Sago Pondweed	*Potamogeton pectinatus*	6.3	1.3	(-) 5.0
Arrowhead	*Sagitaria spp.*	3.8	0.0	(-) 3.8
Water Stargrass	*Zosterella dubia*	2.6	2.5	(-) 1.0
Water Smartweed	*Polygomum amphibium*	2.5	0.0	(-) 2.5
Needle Spikerush	*Eleocharis acicularis*	1.3	0.0	(-) 1.3
Spikerush spp.	*Eleocharis spp.*	1.3	0.0	(-) 1.3
Leafy Pondweed	*Potamogeton foliosus*	1.3	0.0	(-) 1.3
Illinois Pondweed	*Potamogeton illinoiensis*	0.0	21.9	(+) 21.9
Stonewort	*Nitella spp.*	0.0	1.3	(+) 1.3
Water Moss	*Drepanocladus spp.*	0.0	0.6	(+) 0.6

Figure 3. Forest Lake submergent plant community composition.



From Gerber (1993)

Table 4. **Submergent plant transect data from the September, 2002 survey conducted on Forest lake.**

		samples collected by transect										
Species		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**total**
Bushy Pondweed	*Najas flexilis*	15	13	9	5	2	13	1	4	4	6	72
Coontail	*Ceratophyllum demersum*	2	3	4	9	3				5	8	34
Eurasian Water Milfoil	*Myriophyllum spicatum*	12	7	13	5	6	12	6	5	10	13	89
Flatstem Pondweed	*Potamogeton zosteriformis*		9	1	6	10	9	15	13	10	73	73
Illinois Pondweed	*Potamogeton illinoiensis*	6	2	5	6	8	2	1		3	2	35
Large Leaf Pondweed	*Potamogeton amplifolius*					6		7	2	1	2	18
Musk Grass	*Chara spp.*	3		4	1	2				2	1	13
Northern Water Milfoil	*Myriophyllum sibericum*		6	3	6	6	4	1	3	7	7	43
Sago Pondweed	*Potamogeton pectinatus*		1	1								2
Stonewort	*Nitella spp.*				2							2
Water Celery	*Valisneria americana*	1	5	2	2		3		2	6	3	24
Water Moss	*Drepanocladus spp.*										1	1
Water Stargrass	*Zosterella dubia*							3		1		4
White Water Lily	*Nymphaea odorata*					1	2	2	1		2	8
Species per transect	14	**6**	**8**	**9**	**9**	**9**	**7**	**8**	**7**	**10**	**11**	418

Table 5. Results of the emergent and floating-leaf aquatic plant survey conducted on Forest Lake during September, 2002.

Species **common name**	**scientific name**	**Total Rank**	**Percent Frequency***	**Percent Composition****
White Water Lily	*Nymphaea odorata*	31	77.5	30.7
Purple Loosestrife	*Lythrum salicaria*	25	62.5	24.8
Three-square Bulrush	*Scirpus americanus*	14	35.0	13.9
Porcupine Sedge	*Carex hystericina*	9	22.5	8.9
Spadderdock	*Nuphar variegata*	8	20.0	7.9
Unk. Sedge	*Carex spp.*	5	12.5	5.0
Broad-leaved Cattail	*Typha latifolia*	3	7.5	3.0
Needle Rush	*Eleocharis acicularis*	3	7.5	3.0
Creeping Spikerush	*Eleocharis palustris*	1	2.5	1.0
Floating-leaf Pondweed	*Potamogeton natans*	1	2.5	1.0
Narrow-leaved Cattail	*Typha angustifolia*	1	2.5	1.0

* % Frequency = total abundance rank / total possible rank (n = 40)

** % Composition = total individual rank/ total species rank (n = 101)

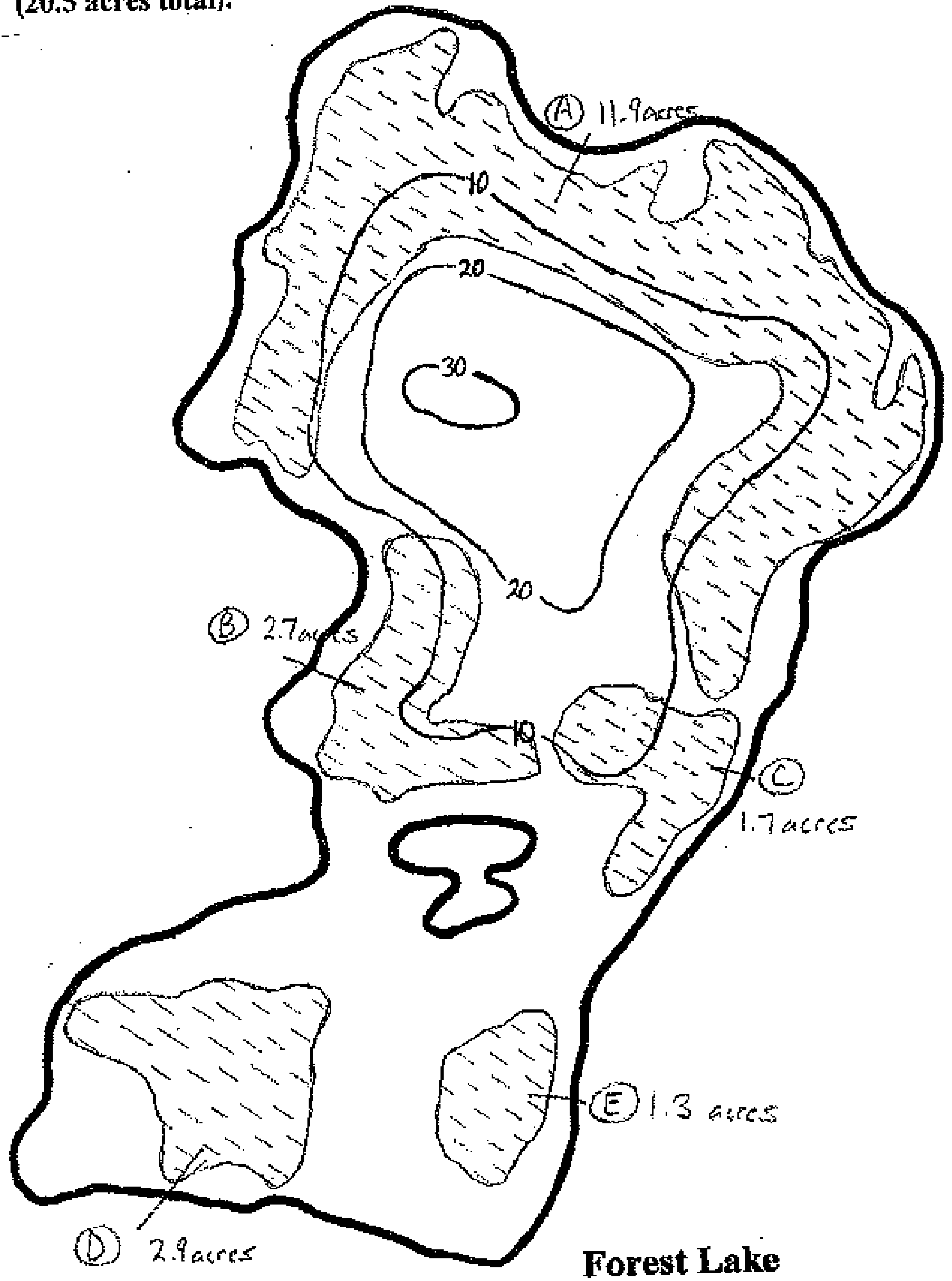
Table 6. **Shoreline aquatic plant transect data from the September, 2002 survey conducted on Forest Lake.**

Species		**Transect / Abundance Ranking**										
		AB	**BC**	**CD**	**DE**	**EF**	**FG**	**GH**	**HI**	**IJ**	**JA**	**total**
Broad-leaved Cattail	*Typha latifolia*				1		2					3
Creeping Spikerush	*Eleocharis palustris*					1						1
Floating-leaf Pondweed	*Potamogeton natans*							1				1
Narrow-leaved Cattail	*Typha angustifolia*						1					1
Needle Rush	*Eleocharis acicularis*							1		1	1	3
Porcupine Sedge	*Carex hystericina*	1	1	2	2				1	1	1	9
Purple Loosestrife	*Lythrum salicaria*	1	2	2	4	4	4	2	2	2	2	25
Spadderdock	*Nuphar variegata*			2	3			3				8
Three-square Bulrush	*Scirpus americanus*	1	1	1	4		1	1	2	1	2	14
Unk. Sedge	*Carex spp.*			1	2		1		1			5
White Water Lily	*Nymphaea odorata*	1	4	3	4	4	4	4	3	2	2	31
Species per transect		**4**	**4**	**6**	**7**	**3**	**6**	**6**	**5**	**5**	**5**	

Relative abundance ranking:

1	*Rare*	found along less than 5% of transect
2	*Present*	found along 5 -25% of transect
3	*Common*	found along 25 -50% of transect
4	*Abundant*	found along more than 50% of transect

Figure 4. Forest Lake Eurasian watermilfoil distribution – September 2002. (20.5 acres total).



Forest Lake
Fond du Lac County, Wisconsin
51 acres, maximum depth: 32 feet.

Figure 5. Chlorophyll *a* water quality index.

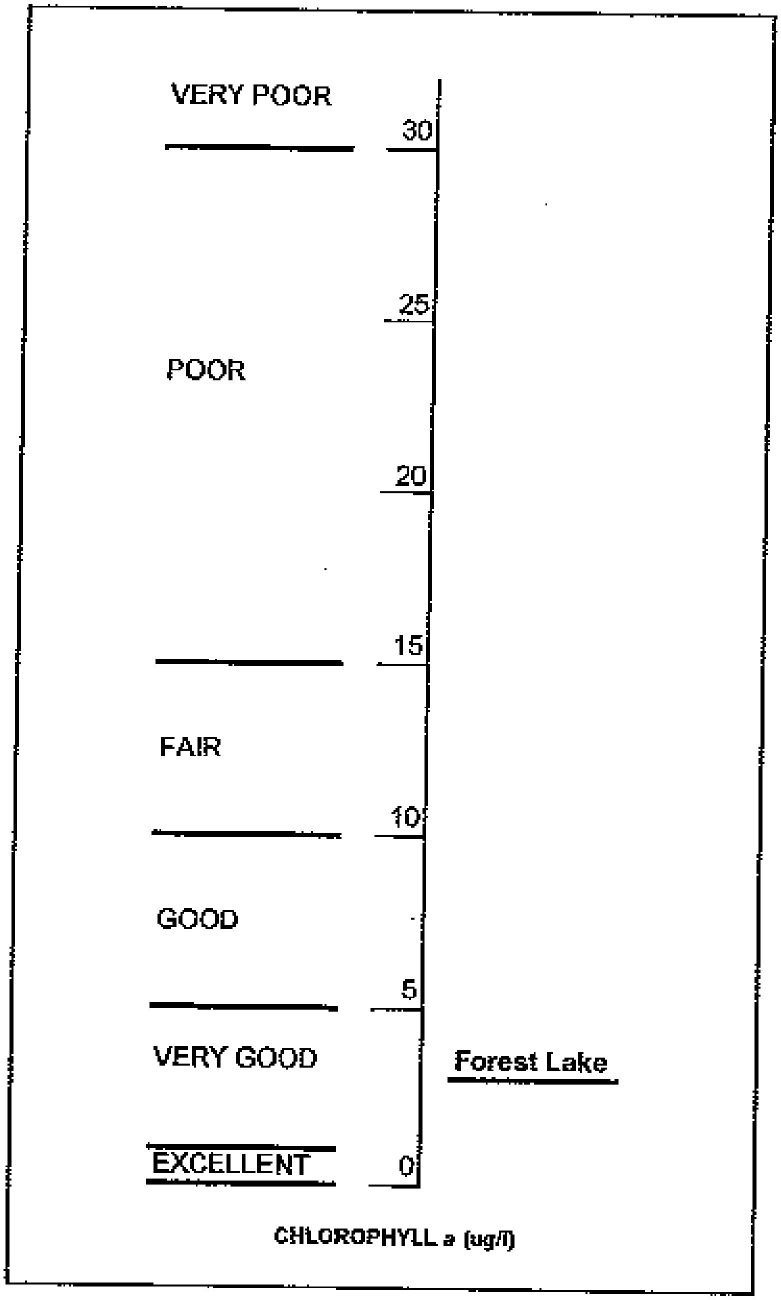
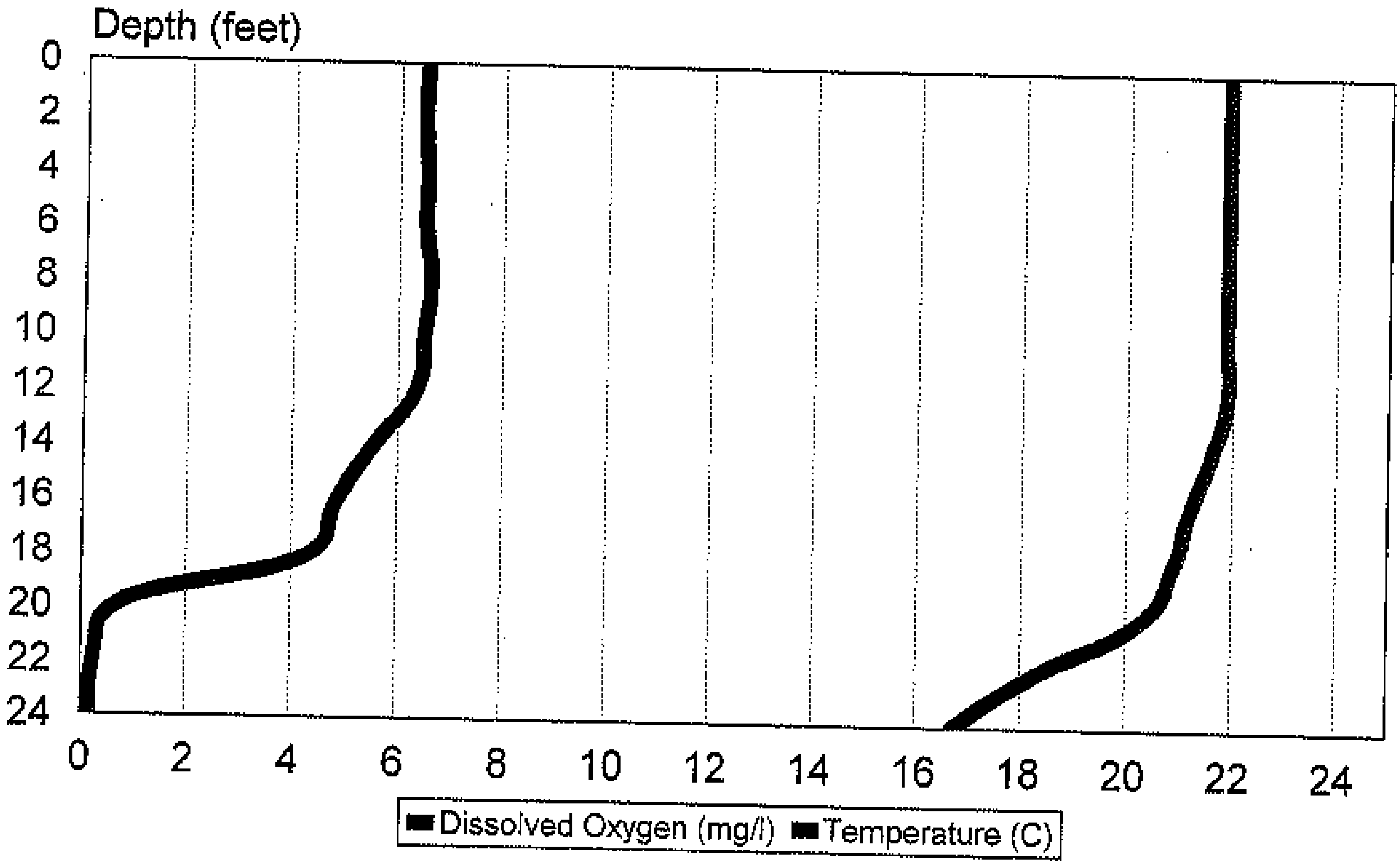


Figure 8. Forest Lake dissolved oxygen and temperature profiles
September 19, 2002



Conclusions and Recommendations

It is evident from this survey that the greatest management concerns for Forest Lake are exotic aquatic plants; in particular Eurasian watermilfoil and purple loosestrife. Due to its aggressive growth and rapid dispersal, Eurasian watermilfoil represents a substantial threat to Wisconsin's Lakes. Because Eurasian watermilfoil grows quickly to the water's surface and forms dense canopies that block sunlight, it can displace nearly all native submergent species. This has been attributed to significant declines in the habitat diversity of lakes. The dense canopy and surface mat formations of mature Eurasian watermilfoil beds can greatly inhibit recreational values such as swimming boating and fishing. Eurasian watermilfoil has also been linked to declines in fishery quality, invertebrate abundance and water quality (Pullman, 1993).

Purple loosestrife can be found in a wide variety of habitats from shallow water to moist soils. Like Eurasian watermilfoil it is a very aggressive plant that can displace many native wetland plants including cattails (*Typha spp.*). Unlike cattails, purple loosestrife has little food or cover value for wildlife (Borman, et. al. 1997). When food and cover disappear, so do the species that depend on it.

Milfoil management options

Mechanical harvesting

Boat-mounted mechanical weed harvesters have often been employed to control Eurasian watermilfoil. This method is usually used in lakes that have historically used harvesters, and is situations where lake management units have done insufficient planning to receive permits for herbicide use. Mechanical harvest is not a recommended control method for Eurasian watermilfoil, however. Eurasian watermilfoil can reproduce by fragmentation (Borman, et. al. 1997), and the free-floating plant matter left from cutting operations can accelerate dispersal of the plant. Mechanical harvest does offer several distinct advantages, though. Harvested plant matter can be removed from the lake system, eliminating the possibility of low dissolved oxygen due to bacterial decomposition. The possibility of algae blooms due to a sudden nutrient release is also greatly reduced. There are no water use restrictions following mechanical harvest either. A disadvantage of mechanical harvest is that it is not species selective. While cutting does not typically kill plants, there is little evidence to suggest that cutting can induce a shift back to native species. In the process of removing plants, weed harvesters also kill substantial numbers of fish, reptiles, amphibians and invertebrates (Shardt, 1999). Perhaps the greatest drawback of a mechanical harvest program though, is cost. Cost / benefit analysis conducted by the Florida Department of Environmental Protection found that mechanical harvest of nuisance weeds cost over 40 times as much as some herbicide treatments to achieve the same level of control (Shardt, 1999). Given these considerations, employing a mechanical weed harvester to control Eurasian watermilfoil in Forest Lake would be a poor choice.

Milfoil weevils

There has been considerable research on biological vectors, such as insects, and their ability to affect a decline in Eurasian watermilfoil populations. Of these, the milfoil weevil has received the most attention. Native milfoil weevil populations have been associated with declines in Eurasian watermilfoil in natural lakes in Vermont (Creed and Sheldon, 1995), New York (Johnson, et. al., 2000) and Wisconsin (Lilie, 2000). However there is scant evidence that *stocked* weevils can produce a decline in Eurasian watermilfoil density. A twelve lake study called "The Wisconsin Milfoil Weevil Project" (Jester, et. al. 1999) conducted by the University of Wisconsin, Stevens Point in conjunction with the Wisconsin Department of Natural Resources researched the efficacy of weevil stocking. This report concluded that milfoil weevil densities were not elevated, and that Eurasian watermilfoil was unaffected by weevil stocking in any of the study lakes.

There have been numerous reasons given for the lack of success of weevil stocking as a management option, including calcium carbonate deposits on plants (Jester, et. al. 1999), poor over-wintering habitat (Newman, et, al. 2001), high pH (C. Kendziorski, 2001) and sunfish predation (Newman, pers. comm.). Perhaps the most compelling reason why weevil stocking has been unsuccessful may be that weevil populations are already at carrying capacity in many lakes. Recent studies in Wisconsin indicate that milfoil weevils are widely distributed throughout Wisconsin's lakes (Jester, et. al. 1997). In fact this may have been the case in Forest Lake, as numerous weevils were observed during the 2002 plant survey, despite weevils not having been stocked in 2002. One reason that native weevil populations may be able to impact Eurasian watermilfoil in some lakes but not others may have to do with a lake's surface are and its wind fetch. Recent studies conducted by Aquatic Biologists, Inc. staff (as yet unpublished) concluded that a relationship may exist between wind energy and the ability of milfoil weevils to affect a decline in Eurasian watermilfoil. It appears that lakes must be large enough (300 acres +) to generate sufficient wave action before milfoil stems burrowed by weevils will collapse.

Given the findings of this literature review and the results of past weevil stocking efforts, it seems prudent that weevil stocking be discontinued in Forest Lake.

Herbicides

Herbicides have been the most widely used and most successful tools for controlling Eurasian watermilfoil. The two herbicide groups most commonly employed are fluridone (Avast®, Sonar®) and 2,4D (Aquacide®, Aquakleen®, Navigate®, Weedar 64®). Whole-lake Sonar® treatments have been done on several Wisconsin Lakes. While initial results were encouraging (species selectivity, 95-100% initial control), continued monitoring found that desired long-term control was not achieved (Cason, 2002). 2,4D herbicides, on the other hand, have been used on hundreds of Wisconsin Lakes with good success. Before any treatment plan is adopted for a lake though, the following concerns should be addressed:

Is it safe for humans? The E.P.A. lists 2,4D as a Class D herbicide; which means that there is no data to support that it is harmful to humans. The E.P.A. product label lists no water use restrictions for swimming or fish consumption following treatment with 2,4D (**Appendix 3**). The University of Michigan School of Public Health recently concluded a review of more than 160 toxicological and epidemiological studies on 2,4D and concluded that there was no adequate evidence to link 2,4D exposure to any forms of cancer. Nor does 2,4D from treated lakes appear to be able to contaminate well water. The Michigan Department of Environmental Quality recently released results of a 4-year study of drinking water wells surrounding twelve lakes heavily treated with 2,4D. To date, no traces of 2,4D have been found in any of the test wells (Bondra, 2002). While no one will guarantee that any herbicide is 100% safe, the overwhelming body of evidence suggests that 2,4D poses minimal risks to humans.

Is it safe for the environment? 2,4D is a biodegradable organic herbicide that does not persist in the environment in any form. 2,4D does not bioaccumulate. Even if fish consume 2,4D pellets, the chemical passes through the gut without entering muscle tissues. Hence, the reasons there are no label restrictions on fish consumption.

Will it affect desirable plants? Applied correctly at prescribed rates, 2,4D is highly selective to Eurasian watermilfoil. According the product label (**Appendix 3**), the following plants found in Forest Lake are susceptible to 2,4D at higher rates: water stargrass, white water lily, spadderdock, and coontail. At lower rates (100 lbs / acre) these and other native plants typically respond positively to treatments.

Is it effective? 2,4D has been used on thousands of lakes throughout North America. To date 2,4D treatments have been the single most effective Eurasian watermilfoil control program. In fact, the number of lakes in Michigan having Eurasian watermilfoil problems has actually declined as a result of 2,4D use (Pullman, 1993).

Is it economical? While no control method could be considered cheap, 2,4D treatments are among the least costly of methods. Perhaps the greatest consideration is that 2,4D typically produces long-term milfoil control. This means that lake management units seldom need to spend as much in the long term as they do for the initial treatment. Once Eurasian watermilfoil is brought under control, the costs of annual maintenance treatments, if needed, are minimal.

What are the disadvantages? The greatest disadvantage of 2,4D treatments is that they rarely produce 100% control. As a granular formulation, the product tends to work only where applied. Unnoticed and untreated plants may eventually grow to dense beds if left unchecked. Factors such as pH and plant maturity may also reduce treatment efficacy. Several follow-up treatments, in-season or on subsequent years, may be needed to reduce Eurasian watermilfoil to target levels.

Purple loosestrife management options

There are several methods that are commonly used for purple loosestrife control: digging and hand pulling, cutting, herbicide treatments and biological controls. Digging and hand pulling are most effective for small infestations. Individual property owners are encouraged to use this method if they are able. Cutting involves removal and destruction of flowers and seed heads to inhibit plant propagation. Since cut plants tend to re-grow and since seeds present in the soils can sprout new plants, this method will need to be done for a number of years before desired control is achieved. Herbicide treatments are the easiest and most economical of methods. The preferred herbicide is glyphosate (Eagre®, Rodeo®). This product rapidly biodegrades upon contact with soil or water. There are no water use restrictions following treatment. Because it is non-selective, each individual plant must be sprayed, as opposed to broadcast applications. Glyphosate is extremely effective in controlling purple loosestrife. It is also a very low cost treatment. The biggest disadvantage is that seeds in the soil will sprout new plants, requiring annual treatments for a number of years before desired control is achieved. Biological controls using several species of beetles and a weevil from Europe, by far show the most promise for long-term control of purple loosestrife (WDNR PUB-WT-276 2001). However this method is generally not recommended for small infestations such as found on Forest Lake because of the labor, time and expense involved.

Plant management plans for Forest Lake

If volunteers are willing to donate the time and labor require for rearing beetles to control purple loosestrife, this would be the best management option for the lake. Started kits are available from the DNR. Contact:

Brock Woods
DNR Research Center
1350 Femrite Dr.
Monona, WI 53716
(608) 221-6349

If herbicide treatments are deemed a more reasonable course of action for purple loosestrife, they should be scheduled for 2003. A treatment for the entire lake should cost less than $600. This amount would need to be budgeted for several years though. A DNR permit is required for treatment; however the fee is waived. With either method, full cooperation will be required from all lakeshore property owners, as purple loosestrife occurs on private property.

Based on the considerations presented in this report, the best course of action for controlling Eurasian watermilfoil in Forest Lake will be to develop a 2,4D treatment program. The Forest Lake Improvement Association should seek permits to conduct large-scale 2,4D treatments in 2003. Given the seasonal pH profiles of the lake (**Figure 1**) treatments should be conducted in April or May to increase effectiveness. While dissolved oxygen levels do not appear to be a major concern (**Figure 8**) treatments should none-the-less be conducted in early season as soon as plants are visible to reduce the biological oxygen demand, as well as the threat of algae blooms from nutrient release.

Because Forest Lake contains non-target species that are moderately to slightly susceptible to 2,4D (**Appendix 3**), treatment rates should be 100 lbs / acre or less. Treatments should be made with properly calibrated equipment and with GPS tracking to ensure that application rates are both even and thorough.

Ideally all of the Eurasian watermilfoil found in the lake should be treated at once. Past experience has shown that this will produce the greatest long-term control. 2003 treatment prices should be around $400 / acre. A twenty-acre treatment then, would cost $8000. The Lake Association should budget at least 10% of this amount for in-season follow-up treatments, and at least 25% of this amount for 2004 follow up treatments. A realistic goal for Forest Lake will be to reduce Eurasian watermilfoil to less than 10% of its 2002 distribution (as measured by % frequency). The success of this program will rest upon the Lake Association's ability to develop an active monitoring program. After Eurasian watermilfoil has been reduced to target levels, volunteers will be needed to regularly monitor the lake for the purpose of identifying and mapping and recurring Eurasian watermilfoil. This will facilitate timely retreatments, and prevent Eurasian watermilfoil from again becoming the dominant plant in the lake. In this manner Eurasian watermilfoil should be kept under control for a minimal annual cost.

Formal aquatic plant surveys should be done in 2003 and 2004 to monitor program effectiveness and to provide information that will direct future management efforts. Conducting these surveys will likely be a condition of a DNR permit. The Lake Association can seek financial assistance from the DNR's Lake Planning Grant Program to complete this work.

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Appendix 1. Aquatic plant survey raw data.

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/13/2002
TRANSECT: A (corresponds to 1993 transect: 2)

Starting GPS Loc. N 43 36.612' **Compass direction:** 220 SW
W 88 9.924'

		QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth	feet	2.5	5	10	15
Substrate		sand	unk	unk	unk
Disturbed?		yes	dredged	dredged	no
Species / Occurrence					
musk grass		3			
coontail		1			
Eurasian watermilfoil		4	4	2	2
bushy pondweed		3	4	4	4
illinois pondweed			3	3	
water celery		1			

Observations: EWM is loaded with milfoil weevils - many appear newly hatched. Little apparent damage to stems though.

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/13/2002
TRANSECT: B (corresponds to 1993 transect: 4)

Starting GPS Loc. N 43 36.662' **Compass direction:** 210 S
W 88 10.006'

		QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth	feet	2.5	5	10	15
Substrate		muck	muck	unk	unk
Disturbed?		yes	dredged	dredged	no
Species / Occurrence					
coontail					3
Eurasian watermilfoil		2		4	1
northern watermilfoil		4	2		
bushy pondweed		4	2	4	3
sago pondweed			1		
illinois pondweed			1	1	
flatstem pondweed		4	3	1	1
water celery		4	1		

Observations:

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/13/2002
TRANSECT: C (corresponds to 1993 transect: 6)

Starting GPS Loc. N 43 36.612' **Compass direction:** 140 SE
W 88 10.111'

		QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth	feet	2.5	5	10	15
Substrate		sand	sand	muck	unk
Disturbed?		yes	yes	dredged	no
Species / Occurrence					
musk grass		1	3		
coontail				1	3
Eurasian watermilfoil		4	2	4	3
bushy pondweed		4	3		2
Illinois pondweed		1	3		1
water celery		2			
northern watermilfoil			3		
sago pondweed			1		
flatstem pondweed		1			

Observations: Milfoil weevils are near surface- they are even clinging to the boat.

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/13/2002
TRANSECT: D (corresponds to 1993 transect: 8)

Starting GPS Loc. N 43 36.490' **Compass direction:** 60 NE
W 88 10.093'

		QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth	feet	2.5	5	10	15
Substrate		sand	muck	muck	muck
Disturbed?		no	no	no	no
Species / Occurrence					
coontail			2	3	4
Eurasian watermilfoil		1		4	
northern watermilfoil		1	4	1	
bushy pondweed			3	2	
Illinois pondweed		3	3		
flatstem pondweed		4	1		1
water celery		2			
musk grass		1			
nitella					2

Observations: undeveloped shore

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/13/2002
TRANSECT: E (corresponds to 1993 transect: 10)

Starting GPS Loc. N 43 36.397' **Compass direction:** 90 E
W 88 10.098'

	QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth feet	2.5	5	7.5	10
Substrate	muck	muck	muck	muck
Disturbed?	no	no	no	no
Species / Occurrence				
coontail				3
bushy pondweed	1		1	
Eurasian watermilfoil	2			4
flatstem pondweed	4	3	3	
Illinois pondweed	2	3	2	1
largeleaf pondweed		4	2	
musk grass		1	1	
northern watermilfoil	3	2	1	
white water lily	1			

Observations:

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/13/2002
TRANSECT: F (corresponds to 1993 transect: 12)

Starting GPS Loc. N 43 36.365' **Compass direction:** 130 SE
W 88 10.193'

	QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth feet	2.5	5	10	15
Substrate	sand	muck	muck	muck
Disturbed?	yes	dredged	dredged	dredged
Species / Occurrence				
bushy pondweed	4	4	4	1
Eurasian watermilfoil	2	4	2	4
flatstem pondweed	3	3	1	1
Illinois pondweed		1	1	
northern watermilfoil	2	1	1	
water celery	2	1		
white water lily	2			

Observations:

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/19/2002
TRANSECT: G (corresponds to 1993 transect: 14)

Starting GPS Loc. N 43 36.296' **Compass direction:** 340 NW
W 88 10.119'

		QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth	feet	2.5	5	6	7
Substrate		muck	muck	muck	muck
Disturbed?		no	no	no	no
Species / Occurrence					
water stargrass					3
Eurasian watermilfoil		3	1	2	
northern watermilfoil		1			
bushy pondweed				1	
largeleaf pondweed		4	3		
illinois pondweed		1			
flatstem pondweed		4	4	3	4
white water lily		2			

Observations: Lots of CaCO3 buildup on plants.

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/19/2002
TRANSECT: H (corresponds to 1993 transect: 16)

Starting GPS Loc. N 43 36.325' **Compass direction:** 280 NW
W 88 09.984'

		QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth	feet	2.5	5	7.5	10
Substrate		sand	muck	muck	muck
Disturbed?		no	no	no	dredged
Species / Occurrence					
bushy pondweed				1	3
Eurasian watermilfoil		2			3
flatstem pondweed		3	4	4	2
largeleaf pondweed					2
northern watermilfoil		1			2
water celery		2			
white water lily		1			

Observations:

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/19/2002
TRANSECT: I (corresponds to 1993 transect: 18)

Starting GPS Loc. N 43 36.420' W 88 09.917' **Compass direction:** 270 W

	QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth feet	2.5	5	10	15
Substrate	sand	muck	muck	muck
Disturbed?	no	no	no	no
Species / Occurrence				
coontail		1		4
muskgrass	2			
northern watermilfoil	3	2	2	
bushy pondweed	1		3	
largeleaf pondweed		1		
illinois pondweed	1	1	1	
flatstem pondweed	3	4	2	1
water celery	4	1	1	
Eurasian watermilfoil	4	1	3	2

Observations:

Waterbody: Forest Lake **Collectors:** C. Cason C. Zickert
Date: 9/19/2002
TRANSECT: J (corresponds to 1993 transect: 20)

Starting GPS Loc. N 43 36.533' W 88 09.848' **Compass direction:** 270 W

	QUAD 1	QUAD 2	QUAD 3	QUAD 4
Depth feet	2.5	5	10	15
Substrate	sand	unk	unk	unk
Disturbed?	no	no	no	no
Species / Occurrence				
coontail	2	2	1	3
musk grass	1			
Eurasian watermilfoil	4	4	4	1
northern watermilfoil	3	2	2	
bushy pondweed		3	3	
largeleaf pondweed	2			
illinois pondweed	2			
water celery	3			
white water lily	2			
water moss				2

Observations:

Appendix 2. Water quality monitoring analytical reports.

NORTHERN LAKE SERVICE, INC.
Analytical Laboratory and Environmental Services
400 North Lake Avenue - Crandon, WI 54520
Ph: (715)-478-2777 Fax: (715)-478-3060

ANALYTICAL REPORT

WDNR Laboratory ID No. 721026460
WDATCP Laboratory Certification No. 105 000330
EPA Laboratory ID No. WI00034

Printed: 10/10/02 Code: S Page 1 of 1

Client: Aquatic Biologists Inc
Attn: Chad Cason
426 NW Cumberland Street
Berlin, WI 54923

Project: Forest Lake

NLS Project: 69238

NLS Customer: 90182

FOR0902 NLS ID: 292247
Ref. Line 1 COC 51503 FOR0902 Matrix: SW
Collected: 09/20/02 12:30 Received: 09/26/02
Notes: Noncompliance: Sample(s) received at 11.1 degrees C, which is above EPA protocol of 4 degrees C.

Parameter	Result	Units	Dilution	LOD	LOQ	Analyzed	Method	Lab
Chlorophyll, all species	see attached		-			10/09/02	SM 10200H	721026460
Nitrogen, ammonia as N (unfiltered)	0.18	mg/L	1	0.025	0.075	10/04/02	EPA 350.1	721026460
Nitrogen, NO2 + NO3 as N (unfiltered)	ND	mg/L	1	0.075*	0.075*	10/03/02	EPA 353.2	721026460
Nitrogen, Kjeldahl as N (unfiltered)	0.73	mg/L	1	0.10	0.37	10/08/02	EPA 351.2	721026460
Phosphorus, tot. as P	0.025	mg/L	1	0.0070*	0.0070*	10/01/02	EPA 365.2	721026460

Values in brackets represent results greater than the LOD but less than or equal to the LOQ and are within a region of "Less-Certain Quantitation". Results greater than the LOQ are considered to be in the region of "Certain Quantitation". LOD and LOQ tagged with an asterisk(*) are considered Reporting Limits.

LOD = Limit of Detection
DWB = Dry Weight Basis
MCL = Maximum Contaminant Levels for Drinking Water Samples
LOQ = Limit of Quantitation
NA = Not Applicable
ND = Not Detected
%DWB = (mg/kg DWB) / 10000
1000 ug/L = 1 mg/L

Reviewed by: ______

Authorized by:
R. T. Krueger
President

Northern Lake Service, Inc.
Chlorophyll Results

Customer: Aquatic Biologists Inc
Project: Forest Lake

Sample	Description	CC a	Pheo a	TC a	TC b	TC c
292247	FOR0902	2.9	0.49	3.3	0.24	0.4

CC a = Corrected Chlorophyll a
Pheo a = Pheophytin a
TC a = Trichromatic Chlorophyll a
TC b = Trichromatic Chlorophyll b
TC c = Trichromatic Chlorophyll c
Units = ug/l.

*: The complex calculations used to differentiate the various chlorophyll species magnify error at low concentrations and sometimes produce negative values, which are reported as 0.0 on this report.