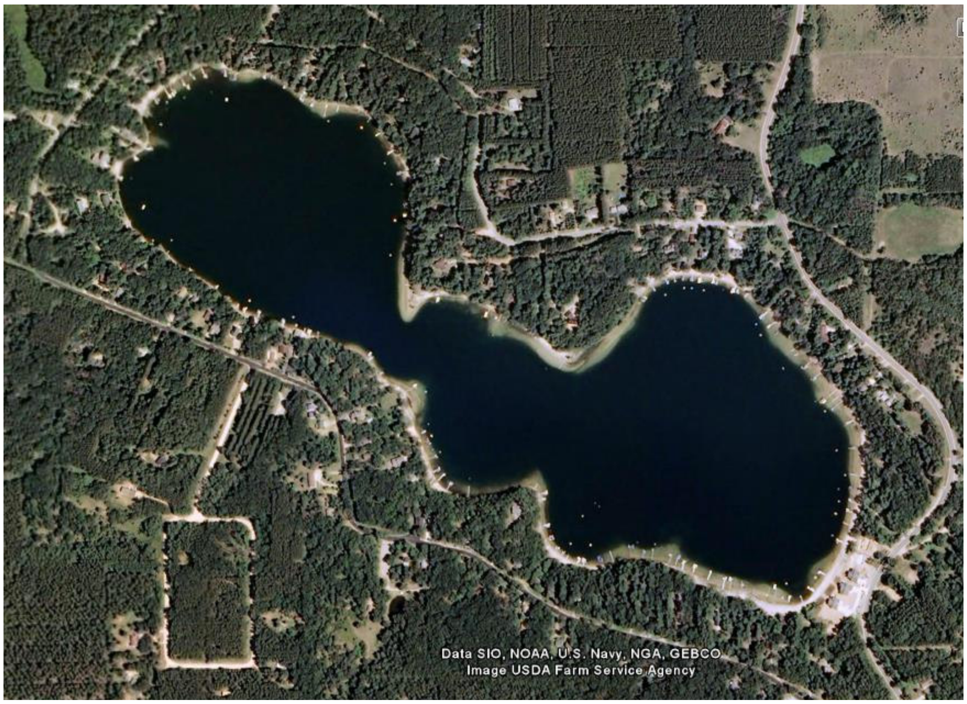
Aquatic Plant Management Plan for

Pearl Lake, Waushara County, Wisconsin

2011-2015



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Sponsored by:

Pearl Lake Protection and Rehabilitation District &
The Wisconsin Department of Natural Resources
Lake Planning Grant Program

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Executive Summary

A thorough study of Pearl Lake, Waushara County, Wisconsin was conducted in 2010. The primary goals of this project have been 1) to gather baseline information on the physical, chemical and biological aspects of Pearl Lake, 2) to identify and prioritize management concerns including water quality and the presence of exotic species, 3) to provide information needed to make informed decisions regarding the future management of the waters both ecologically and sociologically, and 4) the eventual development of an aquatic plant management plan.

Project elements focused primarily on the aquatic plant community of Pearl Lake, and water quality parameters. This project was funded by the Wisconsin DNR's Lake Planning Grant program and the property owners and members of the Pearl Lake Protection and Rehabilitation District.

Results of this study include:

- The most abundant plant species encountered in Pearl Lake were muskgrass (*Chara* sp.), slender naiad (*Najas flexilis*) and northern watermilfoil (*Myriophyllum sibiricum*).

- Eurasian watermilfoil (*Myriophyllum spicatum*) has been present for over a decade in Pearl Lake. Recent DNA analysis indicates a hybrid strain of milfoil exists in Pearl Lake. A proactive approach to management including annual surveys and small-scale herbicide treatments have been able to effectively maintain milfoil at sub-nuisance levels. Curly-leaf pondweed (*Potamogeton crispus*) has also been present for a number of years, but has not expanded to nuisance levels and has therefore not required management.

- Analysis of plant data via the Simpson Diversity Index, the Coefficient of Conservatism and the Floristic Quality Index indicated that the quality of the aquatic plant community of Pearl Lake is above average.

- Pearl Lake has very good to excellent water quality, and would be categorized as a classic mesotrophic lake. Analysis shows the water quality is greater than expected for a lake in central Wisconsin.

- Dissolved oxygen measurements indicate high levels of oxygen from the surface to a depth of more than eight meters throughout the growing season.

- Summer sampling for coliform bacteria indicated very low levels of fecal coliform including *E. coli* in Pearl Lake.

Introduction

Pearl Lake is located in central Waushara County north of the Village of Redgranite (**Figure 1**). Pearl Lake has a surface area of 101acres (**Figure 2**). The 2.2 miles of lake shoreline are predominantly upland forest that is heavily developed with summer cottages. Pearl Lake is a deep, clear lake comprised of two basins. The west basin has a maximum depth of 45 feet. The east basin has a maximum depth of 41 feet. Pearl Lake is highly prized for the recreational opportunities it has to offer. Boaters, anglers, and swimmers heavily use the lake. A public boat launch and multiple walk-in sites offer access to the lake.

With no inlets or outlets, Pearl Lake is considered a groundwater seepage lake. With little overland flow into the lake due to a relatively small watershed, Pearl Lake has historically had very good water quality. The lake also supports a healthy aquatic plant community and fishery.

Management History

Like many area lakes, Pearl Lake has experienced the invasion of Eurasian watermilfoil (*Myriophyllum spicatum*). It was first documented in Pearl Lake in 1994. A successful milfoil control program has been in place on Pearl Lake for the past 10 years. In the summer of 2000, treatments for milfoil began on a nearly annual basis. **Table 1** lists the approximate dates and acreages for milfoil treatments from 2000 to 2010. Earlier treatments were conducted with the herbicide Navigate® (granular 2,4-D herbicide) applied at a rate of 100 lbs/acre. In the past five years, the application rate was increase to 150 lbs/acre.

Table 1. Approximate data and acreage of herbicide treatments from 2000 to 2010 targeting Eurasian watermilfoil (*Myriophyllum spicatum*) in Pearl Lake, Waushara County, WI.

Date	Acreage
June, 2000	7.0
July, 2000	4.0
August, 2000	1.7
May, 2002	2.0
August, 2002	2.3
June, 2003	0.4
June, 2004	1.7
June, 2005	1.7
June, 2006	2.0
June, 2007	1.9
October, 2007	5.8
June, 2008	2.0
May, 2009	1.6
May, 2010	1.0

Figure 1. The area surrounding Pearl Lake, Waushara County, Wisconsin.

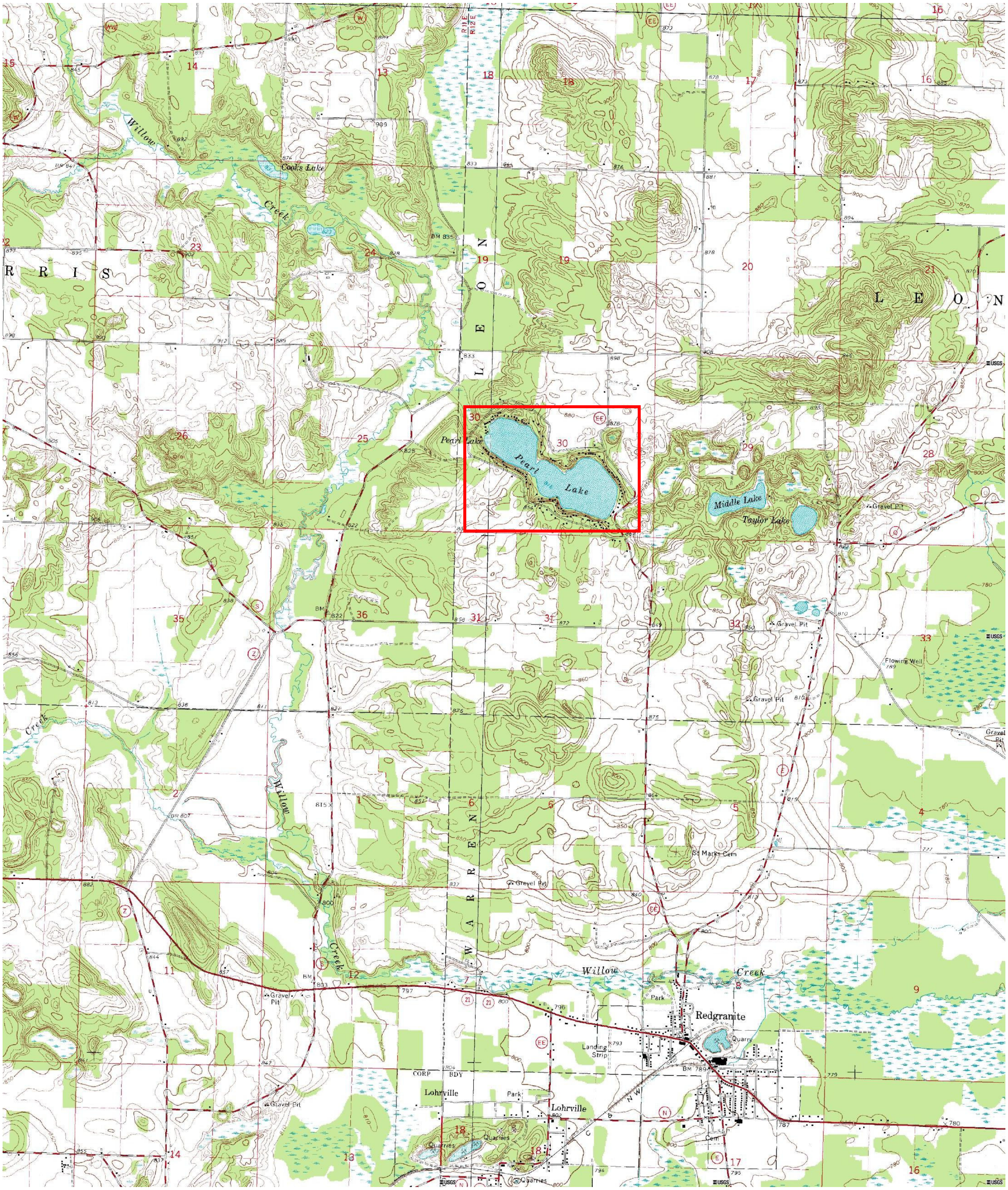
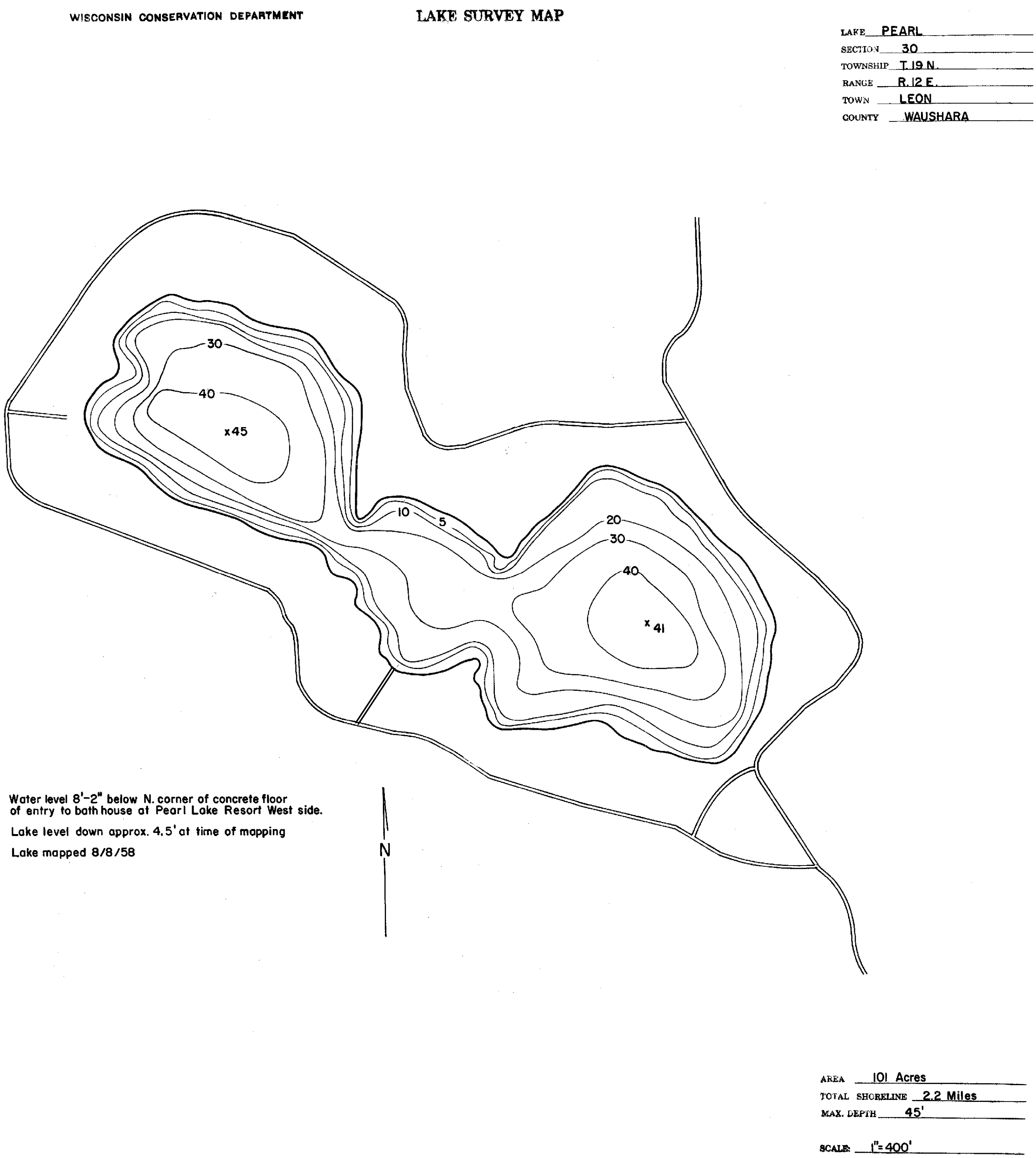


Figure 2. Bathymetric map of Pearl Lake, Waushara County, Wisconsin (1958).



Periodic fish stocking has been done on Pearl Lake for many years to maintain a sport fishery. Questions have arisen regarding the validity and effectiveness of a stocking program. The Wisconsin Department of Natural Resources (WDNR) conducted fish surveys in 1987 and 2003. In addition to developing an aquatic plant management plan, this report reviews WDNR data regarding both fish stocking and surveys and gives recommendations for fisheries habitat improvement.

The Pearl Lake Protection and Rehabilitation (P & R) District is the principle management unit representing the interests of riparian property owners and other lake users. In 2004, the Lake District sponsored an aquatic plant survey of the lake, and the development of an aquatic plant management plan.

The current study has been intended to enhance the ability of the District to develop, promote, and implement an effective long-range plan to protect the water quality and plant and animal communities within the lake. In continues the efforts of the 2004 aquatic plant management plan. Members of the District are particularly concerned about invasive species proliferation and spread as well as water quality, fishery quality, scenic beauty and recreation. Through the update of the management plan, the District plans to address the concerns of its membership. The necessary fieldwork to update this plan was carried out in 2010. This report presents the result of these efforts. It also includes interpretation and implications of these results, as well as an analysis of management options. With the knowledge gained by this project, the District hopes to take the appropriate actions needed to best manage the aquatic plants for lake users and the biotic community alike.

Methods

Aquatic Plant Assessment

On August 19 and 20, 2010, a submergent aquatic plant survey was conducted following guidelines established by the Wisconsin Department of Natural Resources. This survey utilized the point-intercept method. A survey map for Pearl Lake was provided by the DNR (**Figure 3**). A series of grid points were mapped across the lake. At each location, aquatic plant samples were collected from a boat with a single rake tow. The rake used consisted of two short-toothed garden rake heads welded together and used to collect plant samples from the boat. At each sample point, the rake was briefly dragged along the bottom to collect plants. All plant samples collected were identified to *genus* and *species* whenever possible, and the information was recorded. An abundance rating was given for all species collected using the criteria described in **Figure 4**. In addition to the plant data, depth and bottom substrate composition were recorded for each point intercept. Data collected has been be used to determine species composition, percent frequency and relative abundance. This data has also been used to develop distribution maps of the most abundant plant species.

Exotic Plant Distribution Mapping

On June 9, 2010 and September 30, 2010, the extent and locations of exotic species in Pearl Lake were determined from surface observations and rake tows. The focus was on all possible exotic species, however curly-leaf pondweed (*Potamogeton crispus*) and Eurasian watermilfoil (*Myriophyllum spicatum*) were the primary concern. Curly-leaf pondweed is a cold-water species which dies back as the lake warms in the summer. As a result, the most opportune time to survey a lake is in the spring when the plants are actively growing. Eurasian watermilfoil, on the other hand, is typically best surveyed in the fall, because the plants often continue to grow throughout the summer. Surveys for exotic species have been conducted annually over the past ten years or more. In June 2004, curly-leaf pondweed was found at a single location. It has not been documented in subsequent surveys until 2010. In 2010, the surveys utilized the point-intercept map and corresponding coordinates provided by the Wisconsin DNR (**Figure 3**). At each location within the littoral zone of Pearl Lake, the presence or absence of exotic species was determined using surface observations and rake tows. Locations of exotic species between sample points were also noted when present and used to delineate larger plant beds where appropriate. GPS technology and modified acreage grid analysis was used to determine the total acreage of species in Pearl Lake.

In August 2010, milfoil samples were collected from Pearl Lake. Two samples were sent to Dr. Ryan Thum at Michigan's Grand Valley State University for DNA analysis. In recent years, more attention has been paid to the genetic makeup of milfoil, particularly the hybridization of Eurasian watermilfoil and the native northern watermilfoil and how hybridization may influence the efficacy of management efforts.

Figure 3. Aquatic plant survey map for Pearl Lake provided by the Wisconsin DNR.

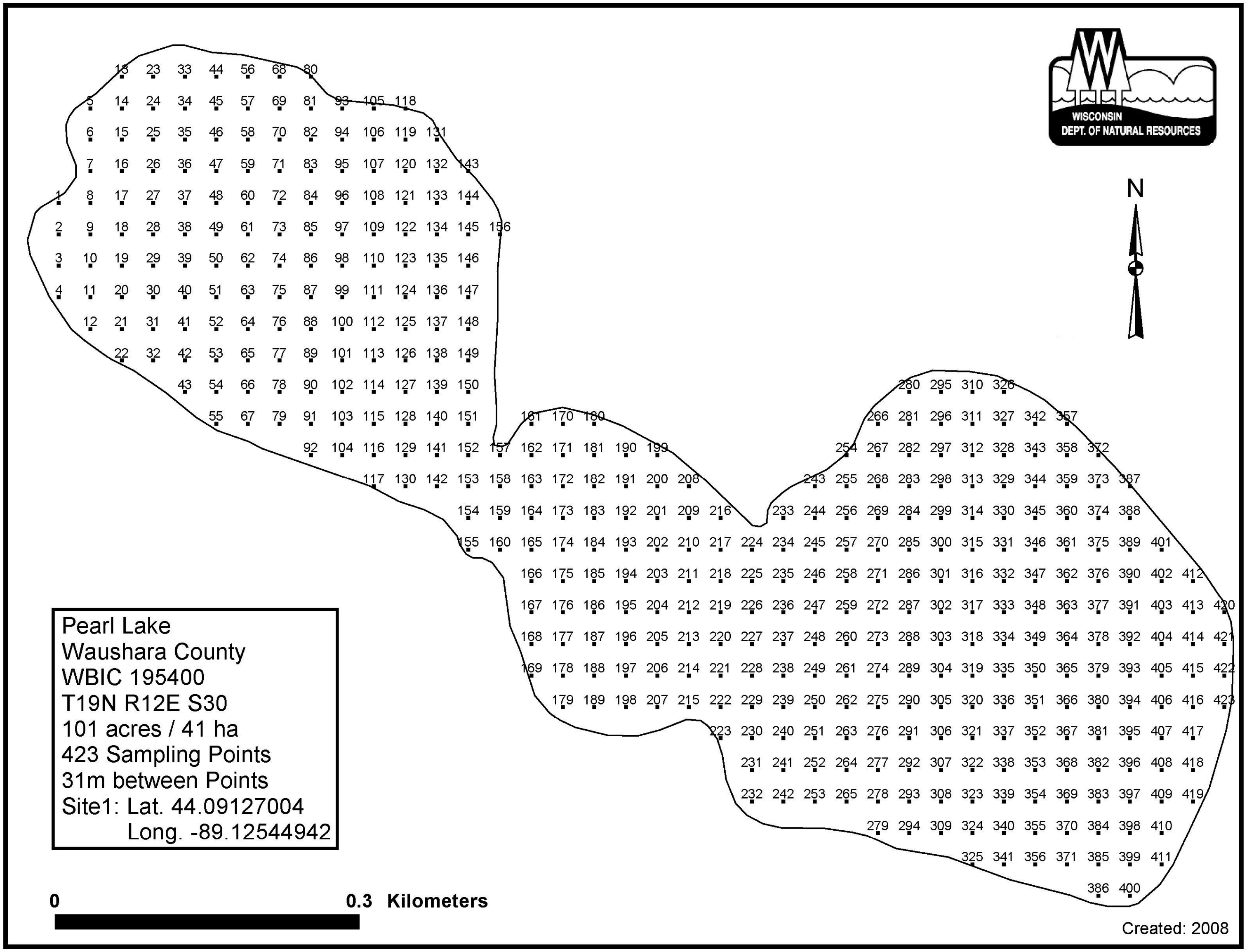
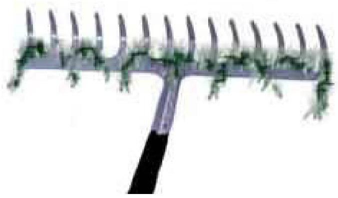


Figure 4. Plant abundance rating criteria used in submergent aquatic plant surveys.

Fullness Rating	Coverage	Description
1		Only few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines.
3		The rake is completely covered and tines are not visible.

Water Quality Assessment

Since 1986, volunteers with the Pearl Lake P & R District have collected water clarity (Secchi depth) data on Pearl Lake through the DNR's Citizen Lake Monitoring Program. Since 1997, water quality data including total phosphorus, chlorophyll and water temperature have also been collected. The following schedule reflects the current timing and parameters of each sampling event:

Spring: Secchi depth**,** total phosphorus, and water temperature
June: Secchi depth**,** total phosphorus, chlorophyll a and water temperature
July: Secchi depth**,** total phosphorus, chlorophyll a and water temperature
August: Secchi depth**,** total phosphorus, chlorophyll a and water temperature
Fall: Secchi depth**,** and water temperature

As part of this study, this sampling schedule was expanded upon. This was done at the request of Waushara County, in order to match the schedule of similar studies currently being conducted on other county lakes. Care was taken not to duplicate the current volunteer schedule with the sampling schedule requested by the County.

Water quality sampling took place at the deep point of Pearl Lake in the west basin seven times in 2010; spring (April), five times in the summer (June-September) and in the fall (November). During these sampling events, the following parameters were analyzed:

- pH, Conductivity, Alkalinity
- Total phosphorus
- Chlorophyll a
- Water transparency (Secchi depth)
- Dissolved oxygen profile
- Temperature profile

Cason & Associates staff and district volunteers conducted the water quality sampling as part of this study. Measurements of water transparency, dissolved oxygen and temperature were conducted in the field. Samples for the remaining parameters were collected approximately one foot below the surface and sent to the State Lab of Hygiene for analysis. Dissolved oxygen and temperature measurements were collected with a YSI 550A dissolved oxygen meter at ½ meter intervals. All subsequent data was collected from the DNR's Surface Water Integrated Monitoring System (SWIMS).

During the April and August sampling events additional samples were collected and analyzed for:

- Total nitrogen (Kjeldahl)
- Nitrate and Nitrite as N
- Ammonia as N

Chlorophyll, total phosphorus and Secchi depth data have been used to quantify the productivity of the lakes (Trophic State Index).

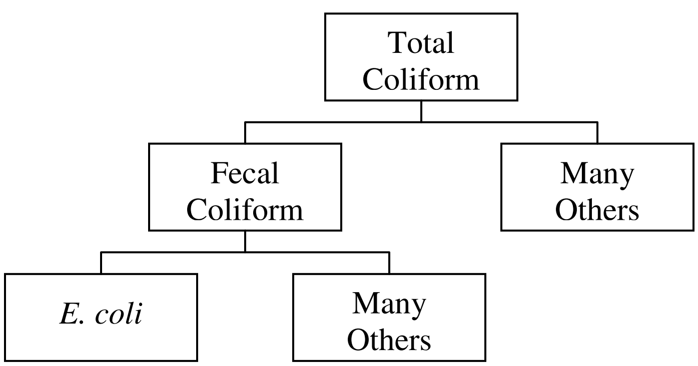
Software available from the WDNR entitled Wisconsin Lake Modeling Suite (WiLMS) was used to predict the trophic state of Pearl Lake given its size, watershed area, mean depth and eco-region. Comparisons were made between the predicted TSI values and those calculated from the phosphorus, chlorophyll and Secchi data collected during the study. The WiLMS program was also used to estimate the internal nutrient loading occurring in Pearl Lake by incorporating nutrient and dissolved oxygen data.

Coliform Bacteria

Pearl Lake residents have identified an increase in filamentous algae production which they fear is related to faulty septic systems. The Lake District is concerned that more than nutrients may be seeping into the lake from these systems. Specifically, the District requested that fecal coliform levels in the lake be assessed. Coliform testing was conducted to measure the concentration of both total coliform bacteria and *E. coli* (*Escherichia coli*). **Figure 5** shows a simplified classification of coliform bacteria. The presence of coliform bacteria in a lake can indicate the possible presence of fecal contamination. However, many species of coliform bacteria are not fecal in origin. In addition, fecal coliform bacteria can come from a number of animals including vertebrates and invertebrates. Those fecal coliform bacteria which are not mammalian in origin are not considered pathogenic to humans. *E. coli,* on the other hand, is a species of bacteria known to have the potential to cause illnesses in humans and other animal species.

Four samples were collected on August 25, 2010 (**Figure 6**). Three locations were selected by members of the lake district based on their knowledge of the human activities on the lake and the condition of the lake itself. A fourth location was chosen in the center of the east basin of the lake as a control site for comparison. Analysis of these samples was conducted by Northern Lake Service Inc. in Crandon, Wisconsin.

Figure 5. Simplified classification of coliform bacteria.



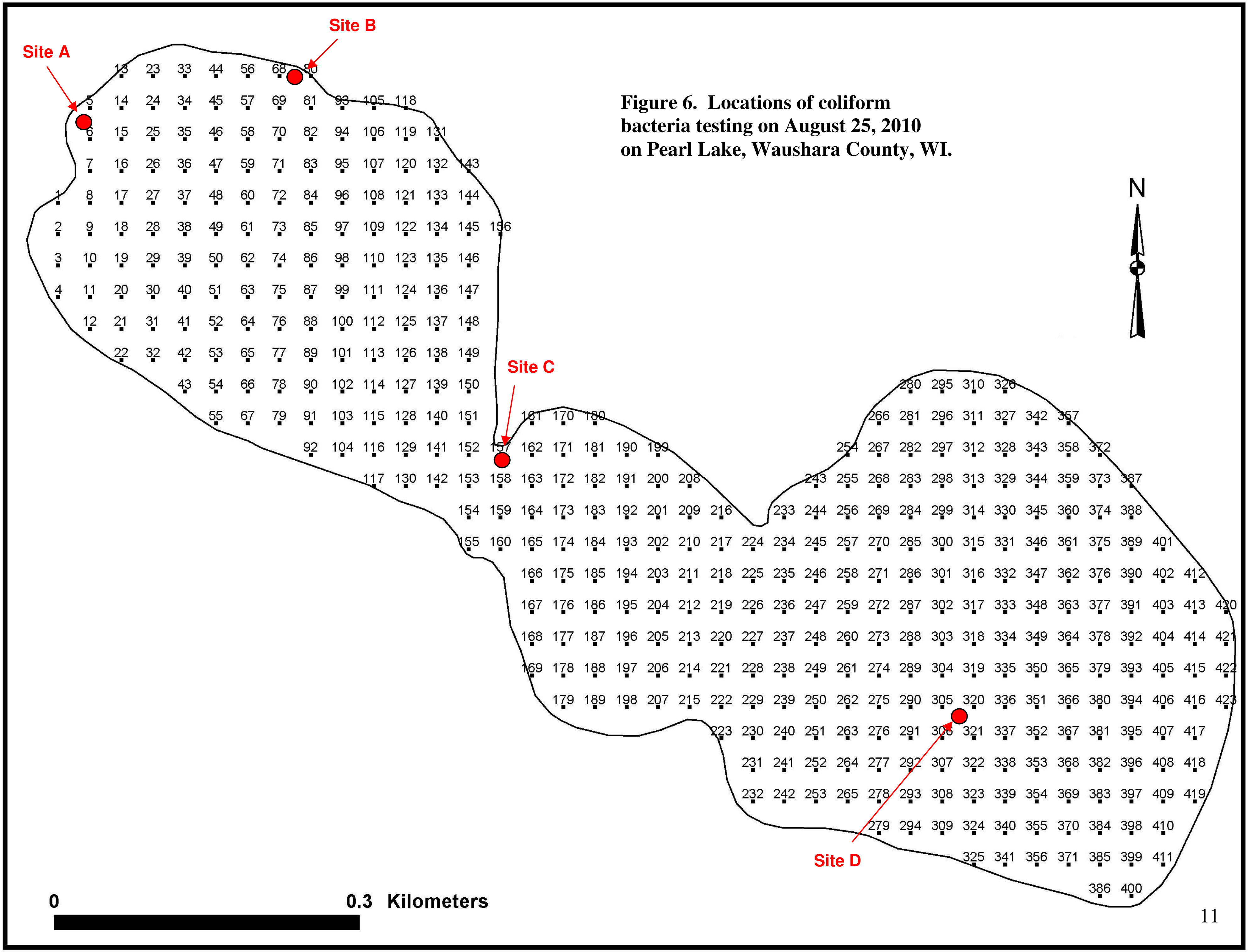


Figure 6. Locations of coliform bacteria testing on August 25, 2010 on Pearl Lake, Waushara County, WI.

Watershed Assessment

In 2009, Waushara County received a Lake Protection Classification Grant from the Wisconsin DNR to develop individual lake management plans and a County-wide plan. This project is expected to take a number of years to complete. As part of the research into this project, the County will be conducting an assessment of lake watersheds including Pearl Lake. As a result, it was decided the current study and resulting management plan would not include an additional watershed assessment.

Citizen Participation

A survey of property owners on Pearl Lake was conducted by the District Board and lake volunteers. This survey evaluated the health and usage of the lake and helped identify issues to be addressed as part of the larger project. In July, 2010, 136 survey forms were mailed to all taxpayers of record. Of these, 93 were returned, for a response rate of 68 percent. Volunteers analyzed the results and produced the report found in **Appendix A**.

Results and Discussion

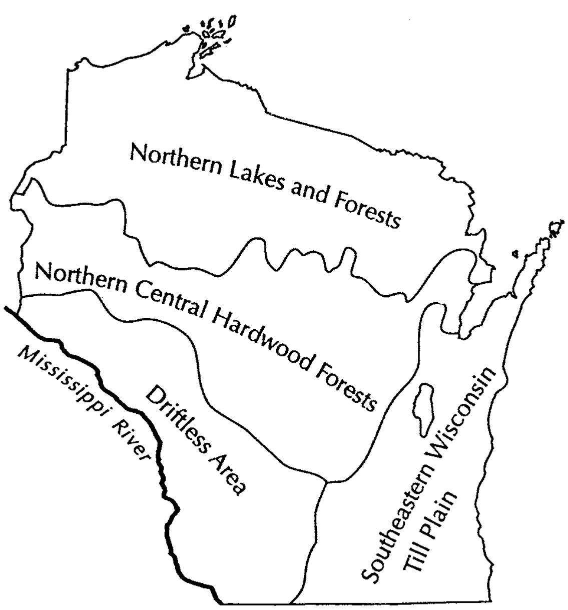
Aquatic Plant Communities

Coordinates for the sampling points on Pearl Lake can be found in **Appendix B**.

A total of 22 aquatic plant species were found during the 2010 survey (**Table 2**). This is above the state-wide average of 13 species. Pearl Lake lies near the border of the Northern Central Hardwood Forests and Southeastern Wisconsin Till Plain regions of Wisconsin (**Figure 7**). The average number of species found in lakes in these regions is 14 species (Nichols, 1999). The most abundant plant species encountered in Pearl Lake were muskgrass (*Chara* spp.), slender naiad (*Najas flexilis*) and northern watermilfoil (*Myriophyllum sibiricum*). These species were found at 80.1%, 15.6% and 11.8% of the sites within vegetated areas, respectively. **Figures 8-10** show the distribution and density of these species across Pearl Lake at the time of the survey.

Table 2 also includes a summary of the plant survey data collected on June 26, 2004. Because two different sampling techniques were used during these surveys, direct comparisons of frequency data should not be used to assume changes to the plant community. The data can be used to make some inferences regarding the numbers and relative abundance of species in the lake. As in 2010, the species with the highest frequencies of occurrence in 2004 were chara and slender naiad. Also, the species composition was largely the same in 2004 as in 2010. It should be noted, in 2004, small pondweed was identified. In 2010, small pondweed and a number of similar fine-leafed pondweed species were identified. This difference is likely a result of identification rather than changes to the plant community.

Figure 7. Ecoregions of Wisconsin (after Omernick and Gallant, 1988)



Appendix C contains the plant survey data collected for Pearl Lake in 2010. **Table 2** shows the frequency of occurrence for plant species in the lake. Percent frequency values reflect the relationship between the number of locations where a particular species was found versus the total number of locations sampled. Percent composition values reflect the abundance of a particular species in relation to all other species found.

Figure 11 presents the relative abundance of submergent aquatic plant species found in Pearl Lake at the time of the 2010 survey.

Table 2. Summary of aquatic plant survey data collected on August 19-20, 2010 and June 29, 2004 on Pearl Lake, Waushara County, WI.

		2010		2004	
Species common name	**scientific name**	**Percent Frequency**	**Percent Composition**	**Percent Frequency**	**Percent Composition**
Muskgrass	*Chara* spp.	79.68	47.3	56.6	28.6
Slender naiad	*Najas flexilis*	15.51	9.2	56.6	28.6
Northern watermilfoil	*Myriophyllum sibiricum*	11.76	7.0	1.2	0.6
moss	--	9.09	5.4	--	--
Variable pondweed	*Potamogeton gramineus*	8.02	4.8	--	--
Filamentous algae	--	7.49	4.4	27.0	13.6
Flat-stem pondweed	*Potamogeton zosteriformis*	5.88	3.5	7.0	3.6
Coontail	*Ceratophyllum demersum*	5.35	3.2	4.3	2.2
Small pondweed	*Potamogeton pusillus*	3.21	1.9	2.3	1.2
Wild celery	*Vallisneria americana*	3.21	1.9	0.8	0.4
Floating-leaf pondweed	*Potamogeton natans*	3.21	1.9	20.7	10.5
Sago pondweed	*Stuckenia pectinata*	2.67	1.6	--	--
Nitella	*Nitella* sp.	2.14	1.3	--	--
Frie's pondweed	*Potamogeton friesii*	2.14	1.3	--	--
Eurasian watermilfoil	*Myriophyllum spicatum*	1.60	1.0	0.4	0.2
Common waterweed	*Elodea canadensis*	1.60	1.0	14.8	7.5
Water stargrass	*Heteranthera dubia*	1.60	1.0	3.5	1.8
Illinois pondweed	*Potamogeton illinoensis*	1.60	1.0	1.2	0.6
Large-leaf pondweed	*Potamogeton amplifolius*	1.07	0.6	0.8	0.4
Leafy pondweed	*Potamogeton foliosus*	1.07	0.6	--	--
Three square bulrush	*Schoenoplectus pungens*	0.53	0.3	--	--
Softstem bulrush	*Schoenoplectus tabernaemontani*	visual	--	--	--
Freshwater sponge	--	visual	--	--	--
White water crowfoot	*Ranunculus longirostris*	--	--	0.4	0.2
Curly-leaf pondweed	*Potamogeton crispus*	--	--	0.4	0.2

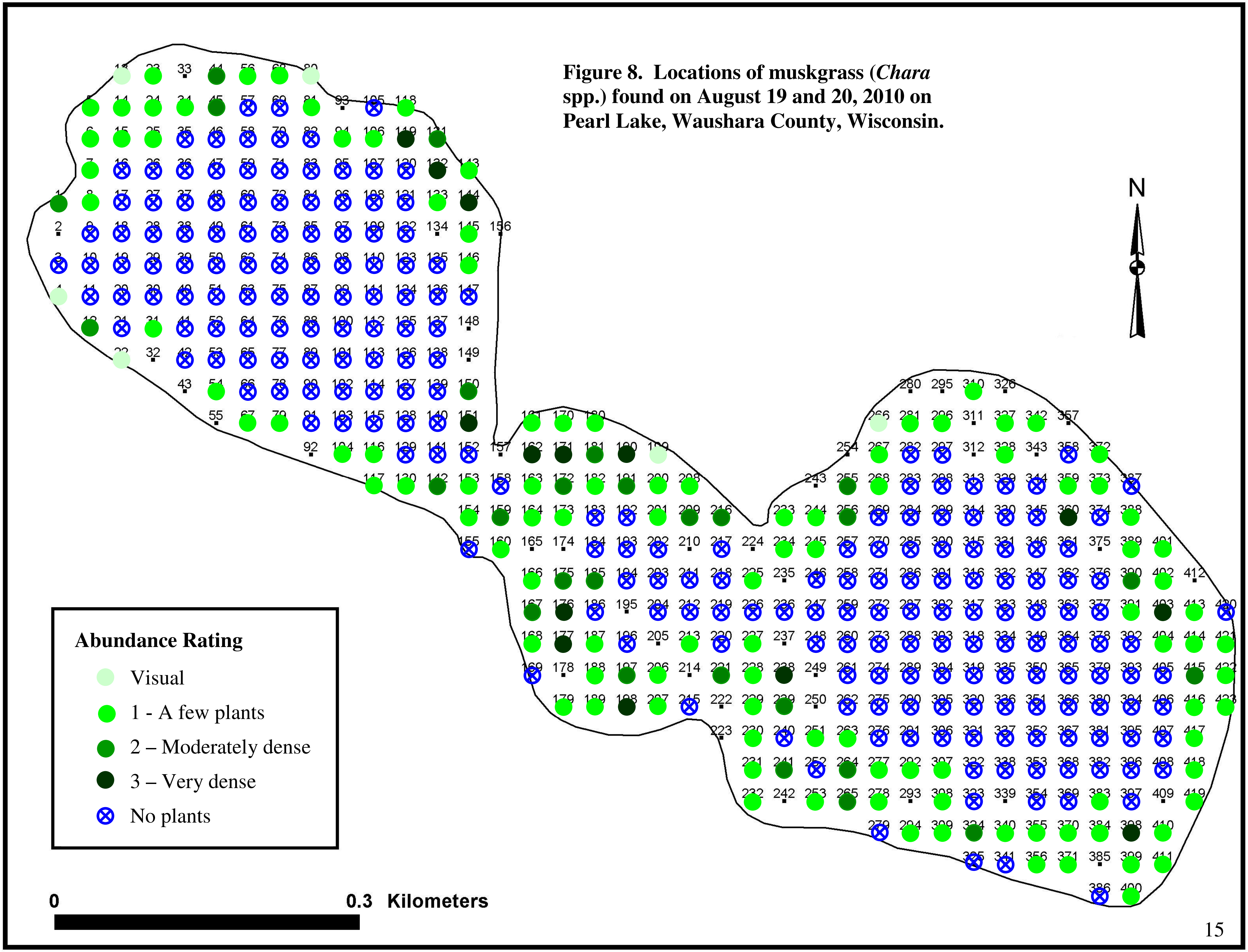


Figure 8. Locations of muskgrass (*Chara* spp.) found on August 19 and 20, 2010 on Pearl Lake, Waushara County, Wisconsin.

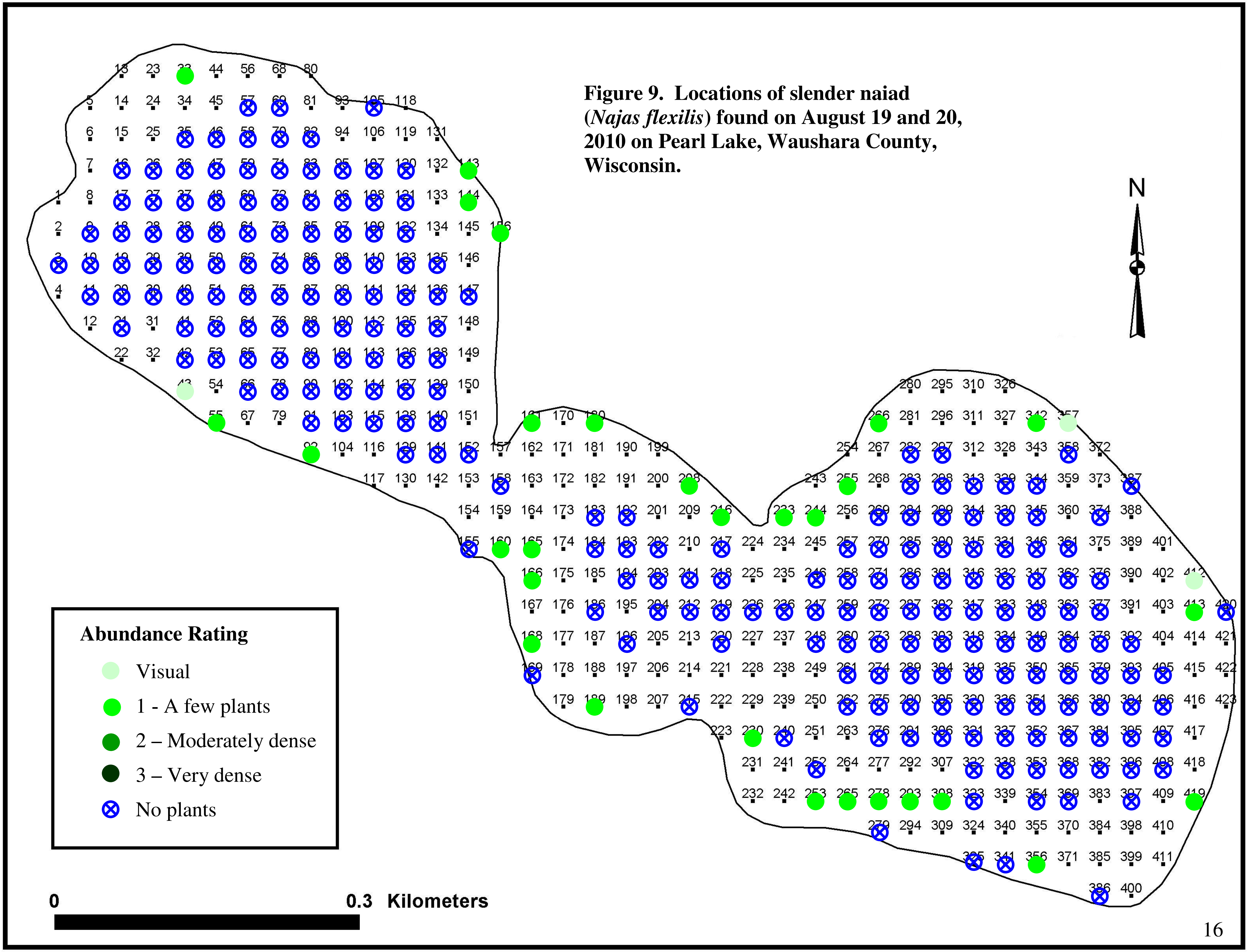


Figure 9. Locations of slender naiad (*Najas flexilis*) found on August 19 and 20, 2010 on Pearl Lake, Waushara County, Wisconsin.

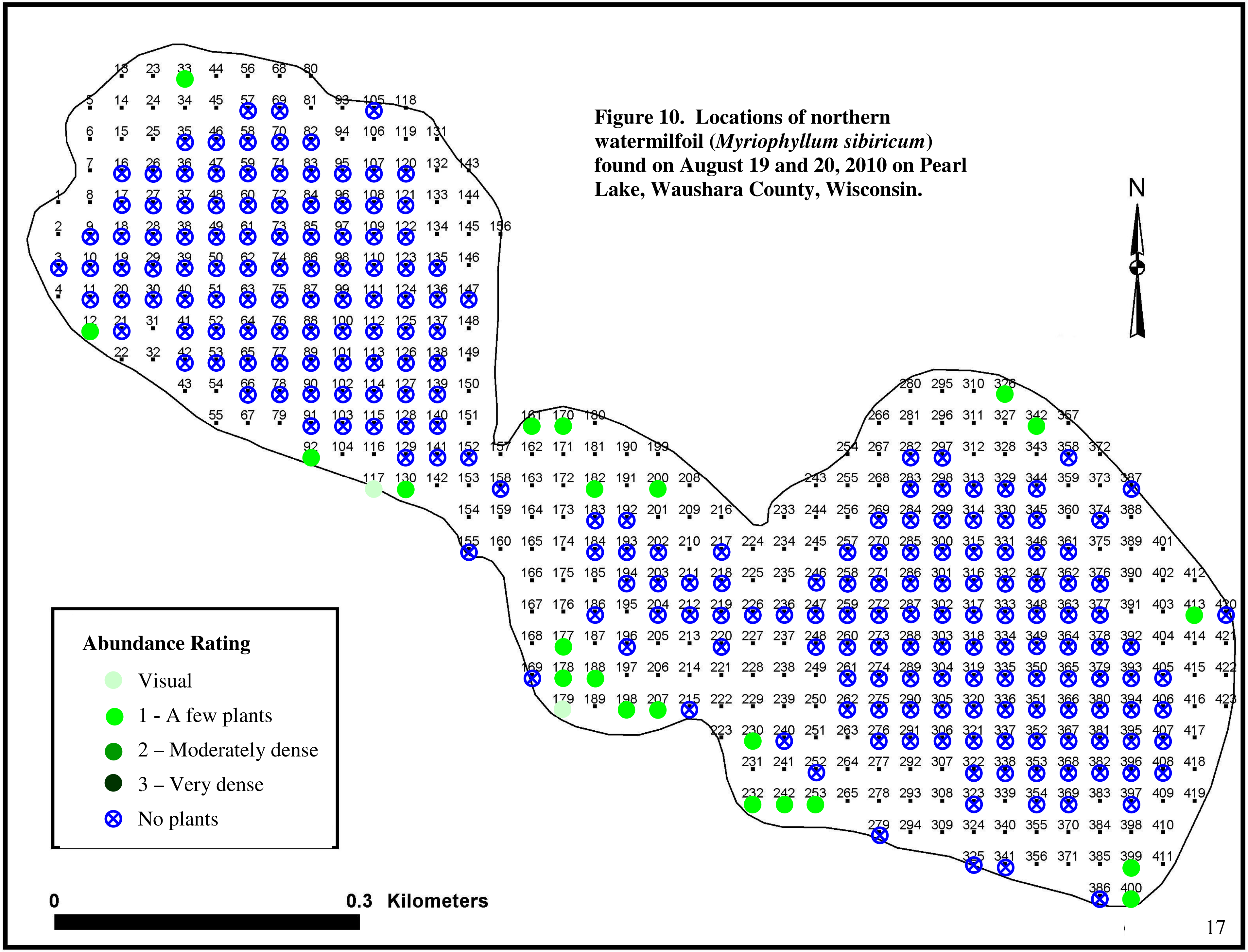
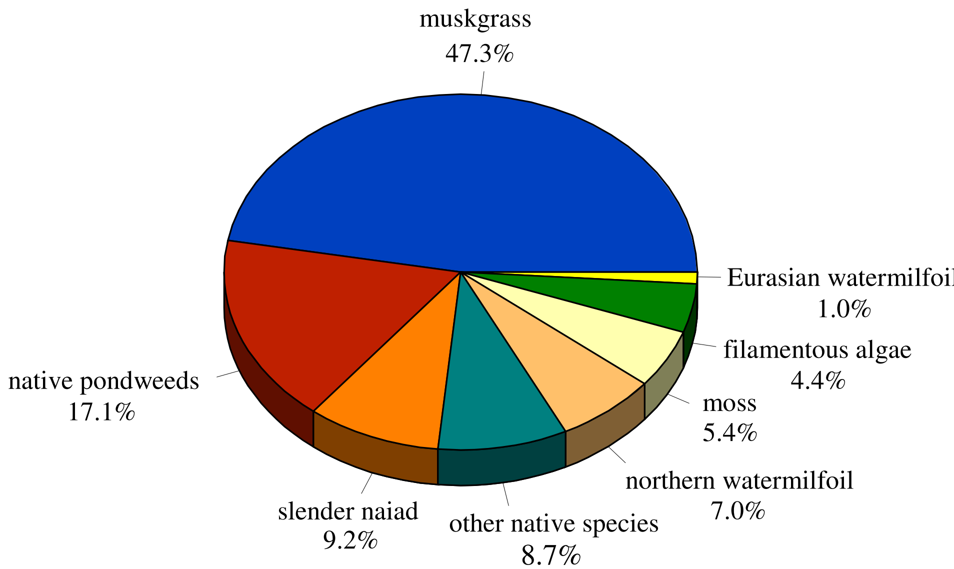


Figure 10. Locations of northern watermilfoil (*Myriophyllum sibiricum*) found on August 19 and 20, 2010 on Pearl Lake, Waushara County, Wisconsin.

Figure 11. Submergent aquatic plant community composition from August 19-20, 2010 in Pearl Lake, Waushara County, WI.



Simpson Diversity Index

The plant data collected from Pearl Lake were used to calculate the Simpson Diversity Index. In order to estimate the diversity of the aquatic plant community, this index takes in account both the number of species identified (richness) and the distribution or relative abundance of each species. As these parameters increase, so does the overall diversity. With the Simpson Diversity Index (D), 1 represents infinite diversity and 0, no diversity. That is, the bigger the value of D, the higher the diversity. The value of D calculated for Pearl Lake based on the 2010 data was 0.75. Although State-wide or regional averages for D are not available, data from lakes surveyed in neighboring counties have yielded values between 0.70 and 0.90.

Assessment of Floristic Quality

Plant survey data were also used to assess the "floristic quality" of Pearl Lake. The method used assigns a value to each *native* plant species called a Coefficient of Conservatism (C). It does not take in account the presence of exotic species, mosses, sponges, or filamentous algae. Coefficient values range from 0 - 10 and reflect a particular species' likelihood of occurring in a relatively undisturbed landscape. Species with low coefficient values, such as coontail (*Ceratophyllum demersum*) (C = 3), are likely to be found in a variety of habitat types and can tolerate high levels of human disturbance. On the other hand, species with higher coefficient values, such as Frie's pondweed (*Potamogeton friesii*) (C = 8), are much more likely to be restricted to high quality, natural areas. By averaging the coefficient values available for the submergent and emergent species found in Pearl

Table 3. Pearl Lake Floristic Quality Index (FQI) analysis table.

Species	Common Name	C
Ceratophyllum demersum	Coontail	3
Chara sp.	Muskgrass	7
Elodea canadensis	Common waterweed	3
Myriophyllum sibericum	Northern watermilfoil	7
Najas flexilis	Slender naiad	6
Nitella sp.	Stonewort	7
Potamogeton amplifolius	Large-leaf pondweed	7
Potamogeton foliosus	Leafy pondweed	6
Potamogeton friesii	Frie's pondweed	8
Potamogeton gramineus	Variable pondweed	7
Potamogeton illinoensis	Illinois pondweed	6
Potamogeton natans	Floating-leaf pondweed	5
Potamogeton pusillus	Small pondweed	7
Potamogeton zosteriformis	Flat-stem pondweed	6
Schoenoplectus pungens	Three-square	5
Schoenoplectus tabernaemontani	Softstem bulrush	4
Stuckenia pectinata	Sago pondweed	3
Vallisneria americana	Wild celery	6
Heteranthera dubia	Water stargrass	6
	N	19
	mean C	5.74
	FQI	25.0

Lake, a lake-wide value of 5.74 (**Table 3**) was calculated. The average value for lakes in Wisconsin is 6.0 while the combined average for lakes in the Northern Central Hardwood Forests and Southeastern Wisconsin Till Plain regions of Wisconsin is 5.6 (Nichols, 1999).

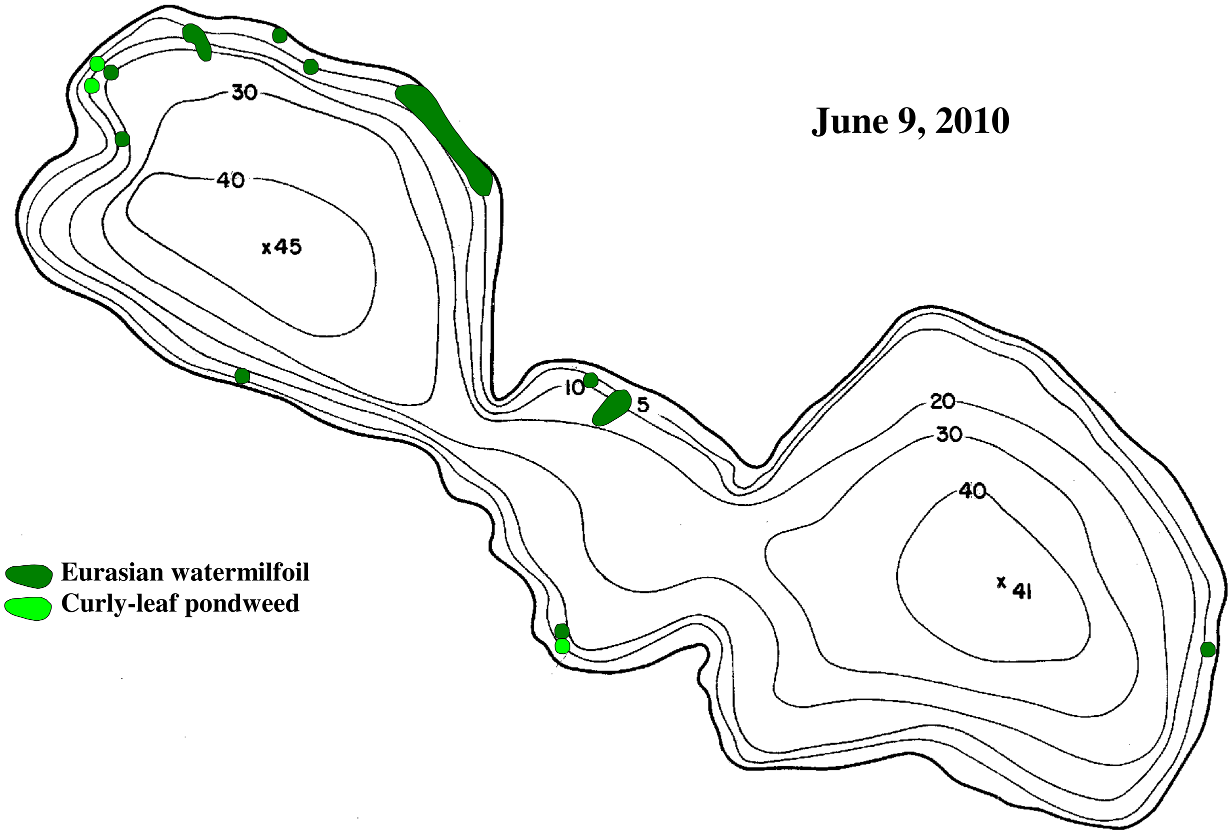
By utilizing the Coefficients of Conservatism for the plant species found in Pearl Lake, further assessment of floristic quality can be made. By multiplying the average coefficient values by the square root of the number of plant species found, a Floristic Quality Index (FQI) of 25.0 was calculated for Pearl Lake (**Table 3**). In general, higher FQI values reflect higher lake quality. The average for lakes in the Northern Central Hardwood Forests and Southeastern Wisconsin Till Plain regions is 20.9 (Nichols, 1999). Both Coefficient of Conservatism and the Floristic Quality Index values suggest the quality of the Pearl Lake, specifically in terms of the plant community, is above average.

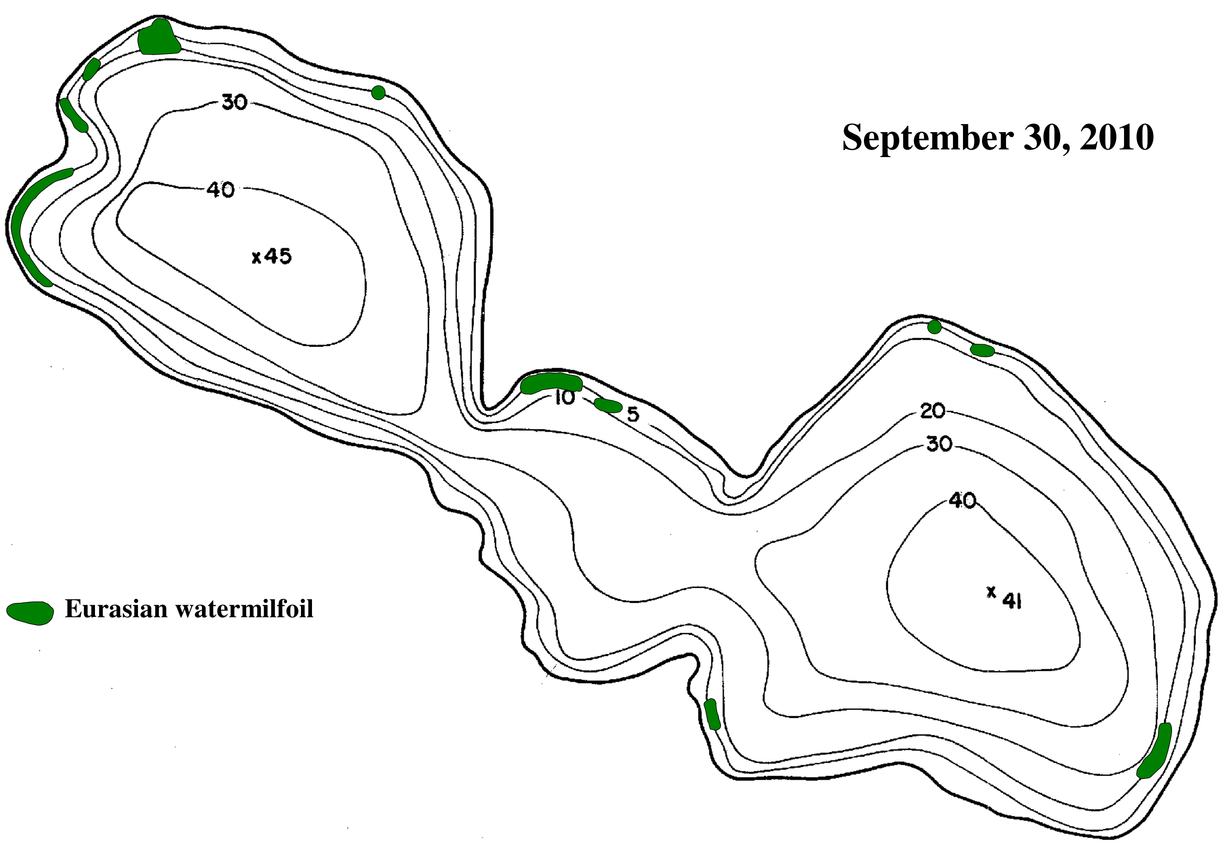
Aquatic plants serve an important purpose in the aquatic environment. They play an instrumental role in maintaining ecological balance in ponds, lakes, wetlands, rivers, and streams. Native aquatic plants have many values. They serve as buffers against nutrient loading and toxic chemicals, act as filters that capture runoff-borne sediments, stabilize lakebed sediments, protect shorelines from erosion, and provide critical fish and wildlife habitat. Therefore, it is essential that the native aquatic plant community within the District be protected. **Appendix D** provides a list of the more abundant native aquatic plant species that were found during the 2010 survey. Ecological values and a description are given for each species.

Exotic Species Surveys
Eurasian watermilfoil has been the main exotic species of concern in Pearl Lake over the past ten years or so. Although curly-leaf pondweed has occasionally been identified in Pearl Lake, it has not spread to a point of concern. According to the DNR, Eurasian watermilfoil was first reported in the lake in 1994. During the surveys conducted in 2010, Eurasian watermilfoil was found in a number of locations (**Figure 12**). A majority of the milfoil in Pearl Lake was found growing close to shore in shallow waters averaging approximately five feet in depth. The locations shown in **Figure 12** generally represent scattered growth that did not significant interfere with navigation.

Results of DNA analysis showed that the milfoil sampled from Pearl Lake was a hybrid between Eurasian watermilfoil and northern watermilfoil.

Figure 12. Locations of Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) on June 9, 2010 and September 30, 2010 on Pearl Lake, Waushara County, Wisconsin.





Water Quality Analysis

Water Chemistry

Previous water quality data available for Pearl Lake has been compiled. This includes Secchi depth (water transparency) from 1986 to present and chlorophyll and phosphorus data back to 1997. These data can be found in **Appendix E**.

Phosphorus

Phosphorus is one of the most important water quality indicators. Levels of phosphorus can determine the amount of algae growth in a lake. It can come from external sources within the watershed (fertilizers, livestock, septic systems) or to a lesser extent, from groundwater. Phosphorus can also come from within the lake through a process called internal loading. Internal loading occurs when plants and chemical reactions release phosphorus from the lake sediments into the water column.

The average phosphorus concentration for natural lakes in Wisconsin is 0.025 mg/L or 25 ppb (Shaw, et al, 2004). Values above 0.05 mg/L are indicative of poor water quality. The data available for Pearl Lake since 1997 do not contain any phosphorus levels above 0.025 mg/L (**Figure 13**). In general, these data indicate very good water quality within Pearl Lake. There appears to be a slight increase in phosphorus over the past 13 years (black trend line). However, this does not appear to be significantly affecting the water quality of the lake.

Chlorophyll

Chlorophyll is the green pigment found in all green plants and algae and is the site in plants where photosynthesis occurs. Chlorophyll absorbs sunlight to convert carbon dioxide and water to oxygen and sugars. Chlorophyll data is collected to estimate how much phytoplankton (algae) there is in a lake. Generally, the more nutrients there are in the water and the warmer the water, the higher the production of algae and consequently chlorophyll.

Chlorophyll concentrations below 10 μg/L are most desirable for lakes. The highest concentration of chlorophyll recorded since 1997 was 6.0 μg/L measured in 2001 (**Figure 14**). The remaining chlorophyll concentrations measured since 1997 have been below 6.0 μg/L. Overall, chlorophyll levels have not changed significantly, based on the data collected over the past 13 years.

Secchi Transparency

Water clarity is often used as a quick and easy test for a lake's overall water quality, especially in relation to the amount of algae present. There is an inverse relationship between Secchi depth and the amount of suspended matter, including algae, in the water column. The less suspended matter, the deeper the Secchi disc is visible. Secchi depths greater than six feet are generally indicative of good water quality. Water clarity readings collected for the Pearl Lake since 1986 have been consistently greater than 10

Figure 13. Total phosphorus data from 1997 to present for Pearl Lake, Waushara County, Wisconsin.

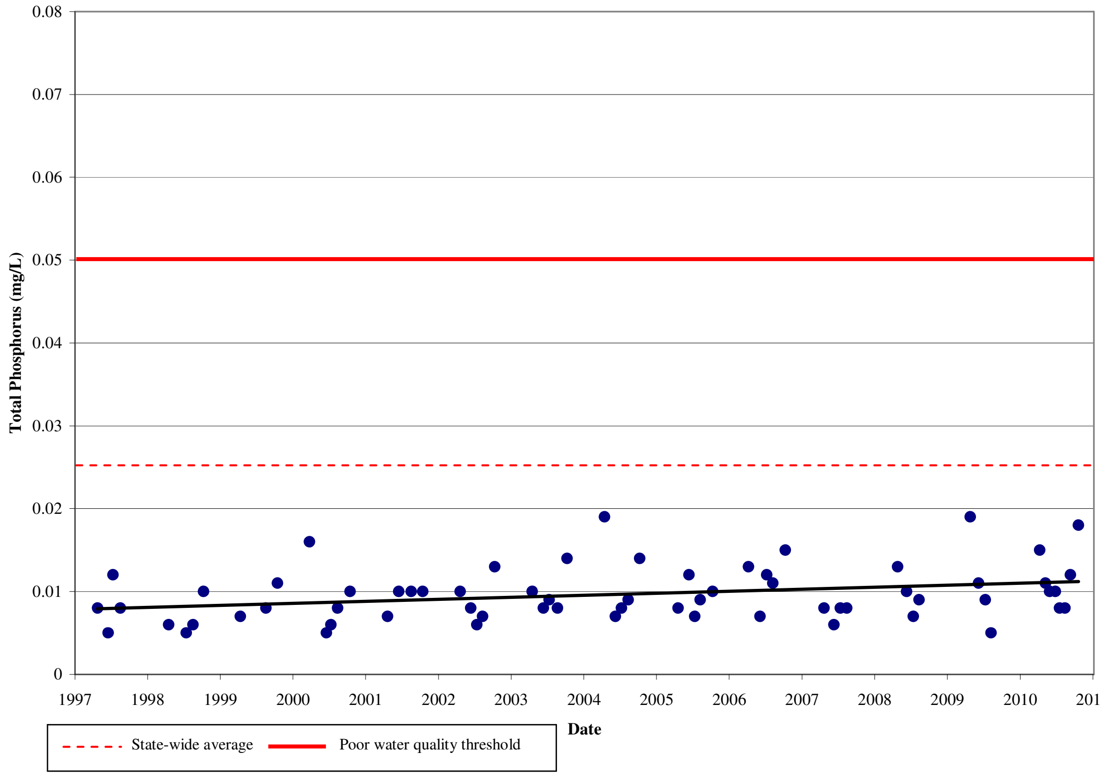
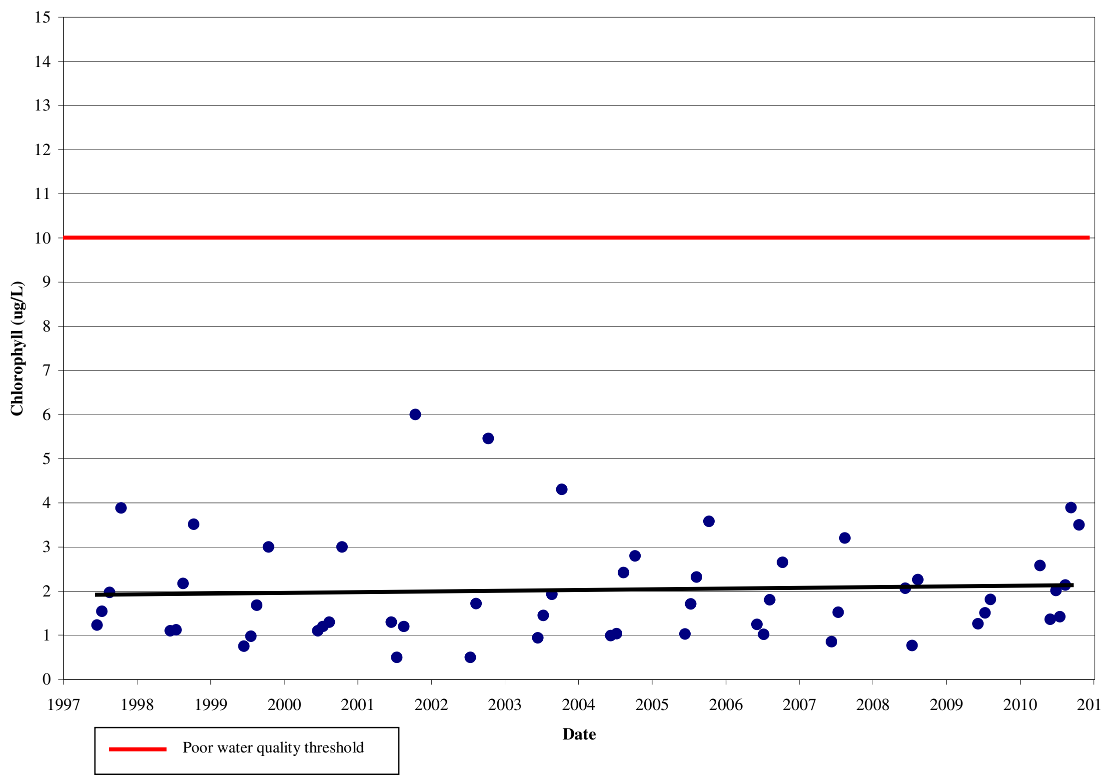
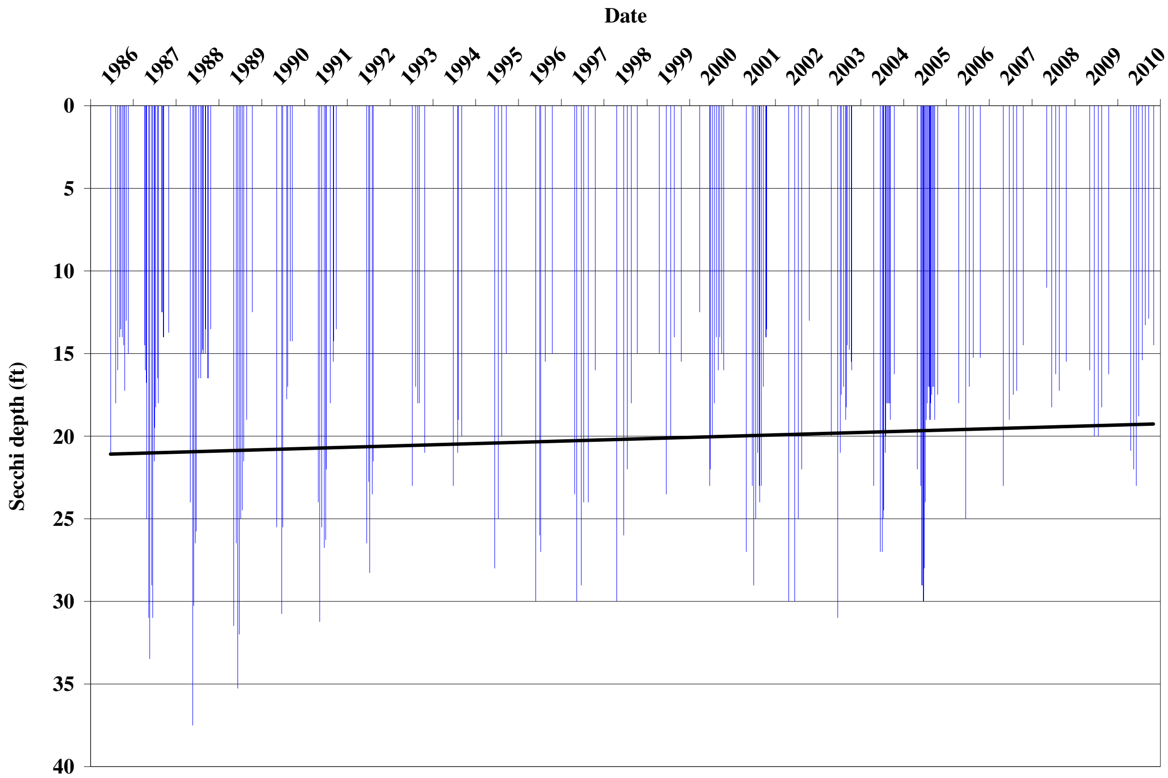


Figure 14. Chlorophyll a data from 1997 to present for Pearl Lake, Waushara County, Wisconsin.



feet (**Figure 15**). As with the previous water quality parameters, the water clarity data as a whole indicate very good to excellent water quality in Pearl Lake. As with the phosphorus data, the Secchi data show a slight decline in water quality from 1986 to present. However, this decline also does not appear to indicate a significant decline in water quality.

Figure 15. Water clarity data from 1986 to present for Pearl Lake, Waushara County, Wisconsin.



Trophic State

There is a strong relationship between levels of phosphorus, chlorophyll and water clarity in lakes. As a response to rising levels of phosphorus, chlorophyll levels increase and transparency values often decrease. The effect of this is viewed as an increase in the productivity of a lake.

Lakes can be categorized by their productivity or trophic state. When productivity is discussed, it is normally a reflection of the amount of plant and animal biomass a lake produces or has the potential to produce. The most significant and often detrimental result is elevated levels of algae and nuisance aquatic plants. Lakes can be categorized into three trophic levels:

- oligotrophic - low productivity, high water quality
- mesotrophic - medium productivity and water quality
- eutrophic - high productivity, low water quality

These trophic levels form a spectrum of water quality conditions. Oligotrophic lakes are typically deep and clear with exposed rock bottoms and limited plant growth. Eutrophic lakes are often shallow and marsh-like, typically having heavy layers of organic silt and abundant plant growth. Mesotrophic lakes are typically deeper than eutrophic lakes with significant plant growth, and areas of exposed sand, gravel or cobble-bottom substrates.

Lakes can naturally become more eutrophic with time, however the trophic state of a lake is more influenced by nutrient inputs than by time. When humans negatively influence the trophic state of a lake the process is called *cultural eutrophication*. A sudden influx of available nutrients may cause a rapid change in a lake's ecology. Opportunistic plants such as algae and nuisance plant species are able to out-compete other more desirable species of macrophytes. The resulting appearance is typical of poor water quality.

Total phosphorus, chlorophyll and Secchi depth are often used as indicators of the water quality and productivity (trophic state) in lakes. Values measured for these parameters can be used to calculate Trophic State Index (TSI) values (Carlson 1977). The formulas for calculating the TSI values for Secchi disk, chlorophyll, and total phosphorus are as follows:

$$TSI = 60 - 14.41 \ln \text{Secchi disk (meters)}$$

$$TSI = 9.81 \ln \text{Chlorophyll } (\mu g/L) + 30.6$$

$$TSI = 14.42 \ln \text{Total phosphorus } (\mu g/L) + 4.15$$

The higher the TSI calculated for a lake, the more eutrophic it is. Classic eutrophic lakes have TSI values starting around 50 (**Figure 16**). Most of the TSI values calculated from Pearl Lake's water quality data were between 30 and 50 (**Figure 17**). TSI values indicate Pearl Lake falls near the boundary between an oligotrophic and a mesotrophic lake.

Figure 16. Relationship between trophic state in lakes and parameters including Secchi transparency, chlorophyll, and total phosphorus.

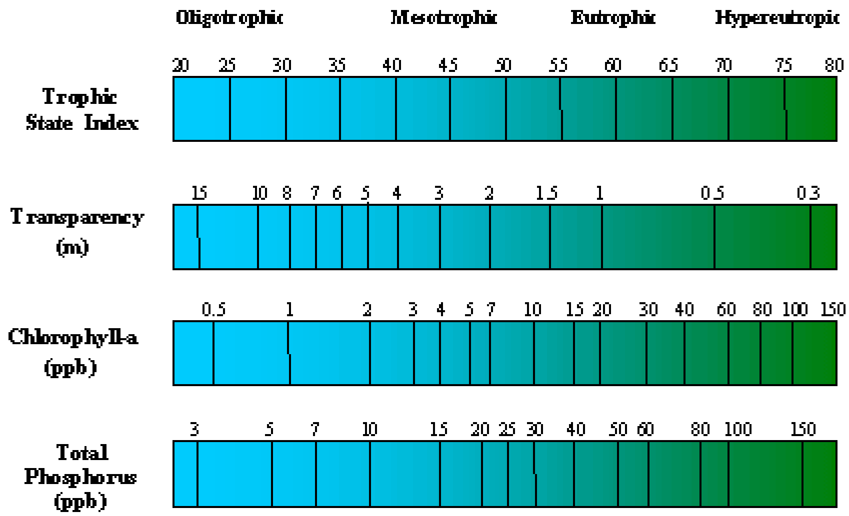
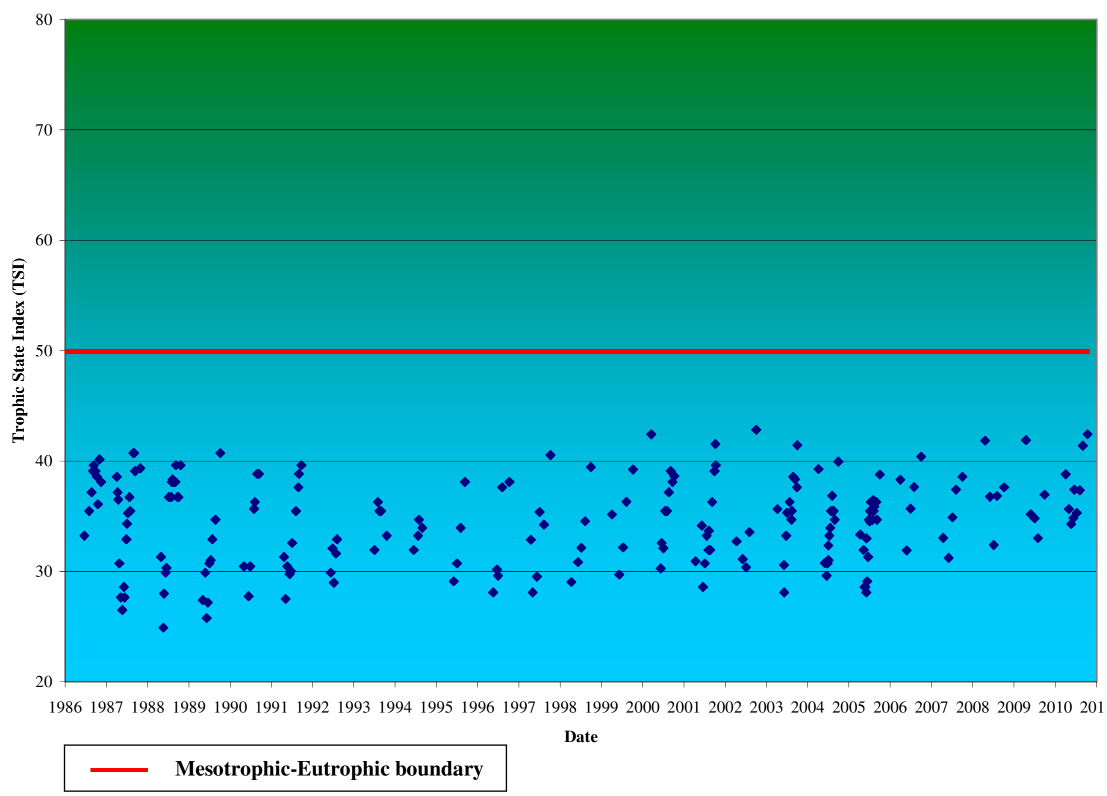
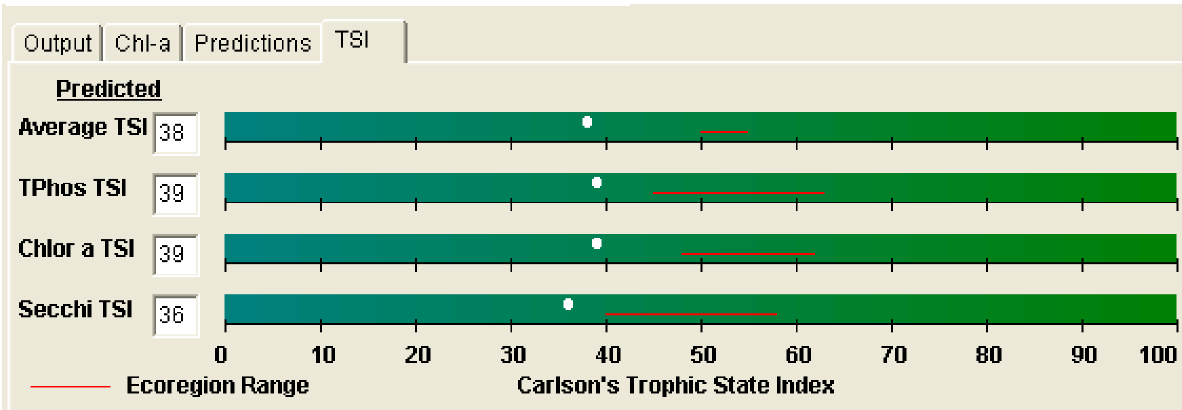


Figure 17. Trophic State Index values from 1986 to present for Pearl Lake, Waushara County, Wisconsin.



Results of the WiLMS modeling (**Figure 18**) found that the observed trophic state index values for Pearl Lake fell below the range of expected values given the ecoregion where the lake exists. In other words, the water quality of Pearl Lake based on the three parameters tested is better than expected for a lake in central Wisconsin.

Figure 18. Results of Wisconsin Lake Modeling Suite (WiLMS) analysis in 2010 for Pearl Lake, Waushara County, Wisconsin.



Additional water quality data

Table 4 contains the pH, conductivity and alkalinity data collected on Pearl Lake in 2010.

Table 4. Additional water quality data collected in 2010 on Pearl Lake, Waushara County, WI.

Date	pH SU	Conductivity mmhos/cm	Alkalinity mg/L	Ammonia mg/L	Nitrates & Nitrites mg/L	Total Kjeldahl Nitrogen mg/L	N:P
4/20/2010	8.58	253	122	ND	0.041	0.45	45
6/9/2010	8.73	243	115	--	--	--	--
7/7/2010	8.72	232	111	--	--	--	--
7/28/2010	8.72	223	107	--	--	--	--
8/24/2010	8.67	227	108	ND	ND	0.48	60
9/21/2010	8.46	245	115	--	--	--	--
11/1/2010	8.07	256	120	--	--	--	--

Nitrogen

Excess nitrogen can also be a threat to overall water quality. Nitrogen is an important nutrient for plants and algae. It can enter lakes from groundwater, surface runoff (livestock manure and agricultural fertilizers) and precipitation. In addition, decomposing organic matter releases nitrogen.

Nitrogen can exist in a number of forms in aquatic systems. Samples collected in April and August 2010 from Pearl Lake were tested for ammonia, nitrates and nitrites and total Kjeldahl nitrogen (**Table 4**). Nitrates and nitrites (along with ammonia) are inorganic forms of nitrogen which can be readily used by plants and algae. Kjeldahl nitrogen is the sum of organic and ammonia forms of nitrogen. By adding the results of these two tests, the total amount of nitrogen in all forms can be determined. Decomposing organic matter releases ammonia, which is converted to nitrate if oxygen is present. This conversion occurs more rapidly at higher water temperatures. Water naturally contains less than 1 ppm of nitrogen. If the inorganic forms of nitrogen exceed 0.3 mg/l, there is sufficient nitrogen to support summer algae blooms and negatively affect water quality. Results from Pearl Lake in 2010 show relatively low nitrogen levels. Ammonia was undetectable during the two sampling events. Total nitrogen levels were less than 1 mg/L nitrogen, and inorganic forms of nitrogen were well below 0.3 mg/L.

The ratio of total nitrogen to total phosphorus can tell us more about the nutrient dynamics in a lake. When the ratio of nitrogen to phosphorus is less than 10:1, nitrogen (rather than phosphorus) limits algae growth. Values between 10:1 and 15:1 are considered transitional, while lakes with values greater than 15:1 are considered phosphorus limited. Freshwater systems tend to be phosphorus limited. Nitrogen: phosphorus ratios for Pearl Lake in 2010 were 45 and 60. As a phosphorus limited system, the severity of algae blooms will be determined by or in relation to excess phosphorus available.

pH

pH is a measure of a lake's acidity or alkalinity. It is the negative log of the hydrogen ion concentration in the water. Many factors influence pH including geology, productivity, pollution, etc. pH levels between seven and nine are not uncommon for lakes in Wisconsin. The 2010 data for Pearl Lake fell between 8.00 and 8.75.

Conductivity

Conductivity is the measure of the inorganic compounds in a body of water as determined by how well an electrical current is carried through a water sample. Conductivity is dependant upon the concentration of inorganic compounds suspended in the water column. High conductivity values may indicate contamination from septic systems, fertilizers, animal wastes or road salts. As a result, conductivity can be used to determine if human activities are influencing water quality. The recommended value for conductivity in lake samples is below 300 µmhos/cm. The data from Pearl Lake in 2010, were below 300 µmhos/cm, in the range of 220-260 µmhos/cm.

Alkalinity

Alkalinity is a measure of the amount of carbonates, bicarbonates and hydroxide present in water. Alkalinity is predominantly determined by soil and bedrock characteristics. Lakes and ponds fed by groundwater from limestone aquifers tend to have high alkalinity. High alkalinity can also be a result of high algae and aquatic plant production.

Low alkalinity (< 25 mg/L) waters are susceptible to acid rain. Alkalinity levels above 25 mg/L in Pearl Lake are indicative of a hard water system able to withstand acid rain conditions. These levels do not warrant concern.

Dissolved oxygen and temperature

Dissolved oxygen, temperature, and percent saturation data collected from Pearl Lake in 2010 are presented in **Appendix E** and **Figures 19 and 20**. Dissolved oxygen data show that surface levels of dissolved oxygen have consistently remained high in the lake throughout the season. The ideal level of oxygen needed for fish, such as bass, perch, and sunfish to survive and grow, is 5 mg/L or greater. Even at the warmest times of the year, sufficient levels of oxygen were present down to over 7 meters in Pearl Lake.

Table 5. Oxygen solubility in water at different temperatures.

Temperature ºC	ºF	Oxygen solubility (mg/L)
0	32	15
5	41	13
10	50	11
15	59	10
20	68	9
25	77	8

To better understand this data, it is important to first understand the relationship between dissolved oxygen and temperature. As a rule, colder water can hold more oxygen than warmer water. **Table 5** illustrates this point. By utilizing this relationship, the level (or percent) of saturation of oxygen can be determined at a given temperature. Saturation levels from sampling at Pearl Lake in 2010 can also be found in **Appendix E**. A number of the oxygen saturation profiles in **Figure 20** appear to exceed the oxygen solubility given. For these data the dissolved oxygen levels were higher than solubility levels at the corresponding temperatures. As a result, the percent saturation levels recorded in the field were above 100%. This is referred to as supersaturation and is due to factors such as wind and wave action and biological processes. This also commonly occurs under warm sunny conditions. Percent saturation values of 80-120% are considered to be excellent and values less than 60% or over 125% are of concern. A majority of the data collected in 2010 fell within this range. A fair number of data indicated very high oxygen concentrations and correspondingly high saturation levels. During sampling events in June and July a spike in oxygen levels was recorded at depths around four to six meters. The cause of this is unknown, however, it is a phenomenon witnessed on other similar lakes in the area and does not appear to cause any negative impacts to life in Pearl Lake. During the November sampling event lower oxygen concentrations and saturation levels were recorded. The data and profile indicate that the lake had recently undergone fall turnover in which the entire lake destratisfies and a mixing of the lake water occurs. This is driven by changes in water temperature. This typically results in uniform temperature and oxygen levels throughout the water column and lowered saturation levels. This is a natural process and the data should not be of concern.

Figure 19. Dissolved oxygen data from 2010 for Pearl Lake, Waushara County, WI.

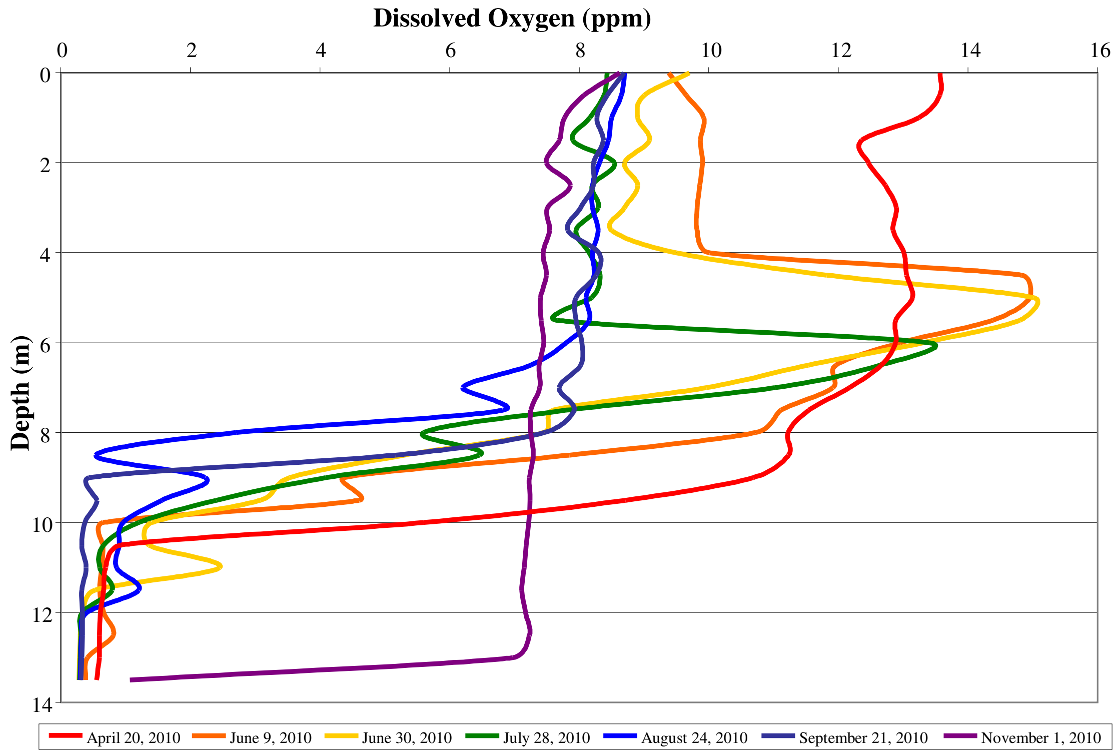
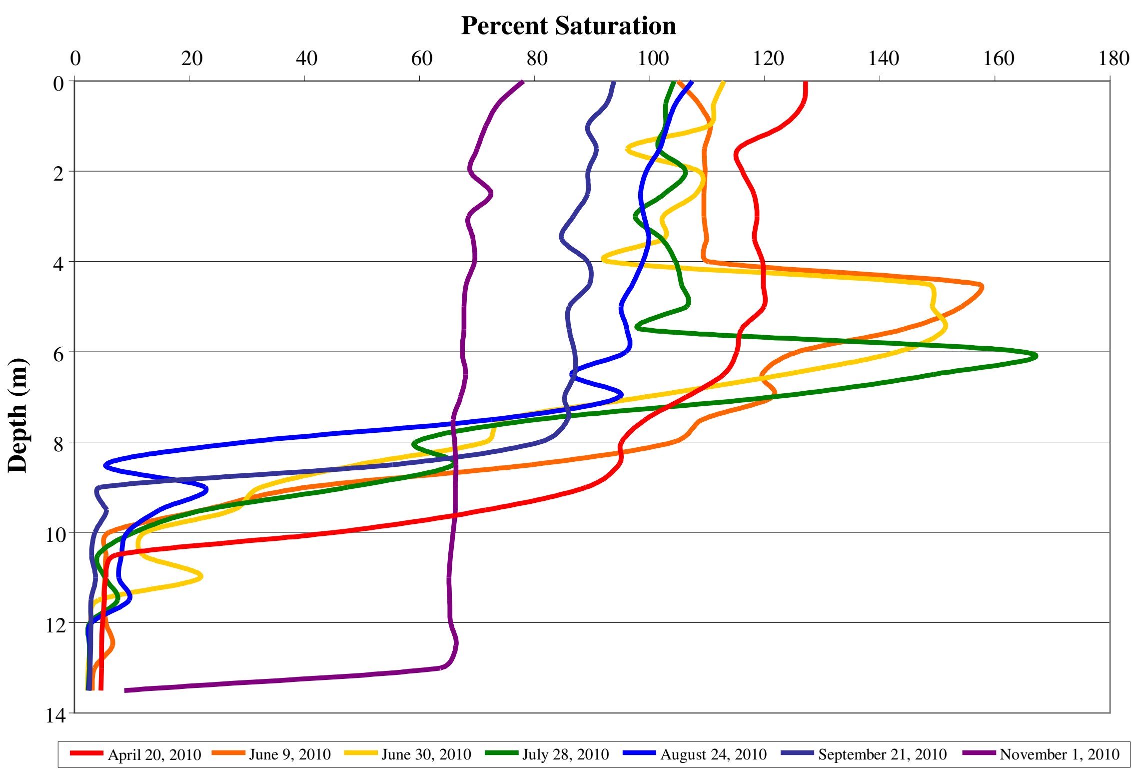


Figure 20. Percent Saturation data from 2010 for Pearl Lake, Waushara County, WI.



When dissolved oxygen data is included in the WiLMS modeling for Pearl Lake, results show a small amount of internal nutrient cycling took place in 2010. It is under oxygen-depleted conditions (anoxia) that phosphorus is readily released from the sediments of a lake. The data showed that oxygen was present down eight to ten meters throughout the growing season in Pearl Lake in 2010. Anoxia at the bottom of the lake begins soon after the lake turns over in the spring. As the lake becomes stratisfied, oxygen is consumed below the thermocline and is not replenished until the fall turnover. Only a small area, estimated at 15 acres, in Pearl Lake became anoxic during the summer. The WiLMS modeling results suggest that internal nutrient release is minor in comparison to other nutrient sources. In total approximately 59.3 lbs (26.9 Kg) of phosphorus were released from the sediments in Pearl Lake. In total the model estimated external loading contributed 1639 lbs (743 kg) to the lake. It should be noted that because a thorough watershed analysis was not conducted as part of this study, certain assumptions had to be made to estimate internal and external nutrient loading. However, it is clear the water quality in Pearl Lake both in terms of water chemistry and oxygen levels contribute to low internal nutrient cycling.

Coliform bacteria

The EPA has established primary and secondary contact water recreation criteria for the presence of *E. coli* in freshwater. Primary contact criteria are used when persons are likely to be fully immersed in the water, while secondary criteria are used for less than full immersion. For freshwater systems such as Pearl Lake, the primary contact criterion establishes a maximum allowable level of 235 bacteria/100 ml. while the secondary criterion is a maximum allowable level of 298 bacteria/100 ml. Results for Pearl Lake at Site A were 3 bacteria/100ml, far below the primary contact criterion. The remaining sites had undetectable levels of both fecal coliform and *E. coli*. These data show very little *E. coli* is present in Pearl Lake. However, these data do not indicate whether septic systems on Pearl Lake are contributing excess levels of nutrients to the lake.

Fishery Data

Pearl Lake has been stocked with fish on a less than annual basis since at least 1933. **Table 5** shows stocking data from 1972 to 2010. Previous stocking data was included in the April 2005 report (Roost and Cason, 2005).

- In the 1930s and 1940's the lake was stocked primarily with large-mouth bass (*Micropterus salmoides*) and yellow perch (*Perca flavescens*).
- In the 1950s and 1960s stocking efforts focused on rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*).
- In the 1970s walleyes (*Sander vitreus*) were the only species stocked.
- In the 1980s walleys and smallmouth bass (*Micropterus dolomieu*) were stocked.
- No stocking took place in the 1990s
- Since 2000 stocking was more diverse with bluegills (*Lepomis macrochirus*), yellow perch, black crappies (*Pomoxis nigromaculatus*), rainbow trout and brook trout

Table 6. Fish stocking data from 1972 to 2010 for Pearl Lake, Waushara County, Wisconsin.

Year	Species	Age Class	Number Fish Stocked	Avg Fish Length (in.)	Source Type
1972	Walleye	Yearling	1,200	10	Federal Hatchery
1974	Walleye	Yearling	800	13	Federal Hatchery
1975	Walleye	Adult	100		Federal Hatchery
1976	Walleye	Fingerling	100	9	Federal Hatchery
1978	Walleye	Fingerling	150	9	Federal Hatchery
1981	Smallmouth Bass	Fingerling	4,000	1	Federal Hatchery
1982	Smallmouth Bass	Fingerling	2,000	3	Federal Hatchery
1983	Smallmouth Bass	Fingerling	1,333	3	DNR Co-op Ponds
1983	Smallmouth Bass	Fingerling	666	5	Other State's Gov't Hatchery
1984	Smallmouth Bass	Fingerling	8,345	3	DNR Co-op Ponds
1984	Walleye	Adult	2	15	Field Transfer
2000	Bluegill	Adult	722	5.4	Private Hatchery
2000	Yellow Perch	Adult	2,250	5.3	Field Transfer
2000	Yellow Perch	Large Fingerling	795	3.8	Private Hatchery
2001	Bluegill	Adult	N/A	5.2	Private Hatchery
2001	Bluegill	Adult (Broodstock)	2,727	5.2	Private Hatchery
2002	Black Crappie	Yearling	1,000	4.8	Private Hatchery
2002	Bluegill	Yearling	3,000	5	Private Hatchery
2004	Black Crappie	Yearling	4,000	4	Private Hatchery
2006	Brook Trout	Adult (Broodstock)	250	13	Private Hatchery
2007	Rainbow Trout	Adult	2,300	10	Private Hatchery
2008	Rainbow Trout	Yearling	2,700	11.5	Private Hatchery
2009	Rainbow Trout	Adult	2,500	9	Private Hatchery
2010	Black Crappie	Large Fingerling	2,500	5	Private Hatchery

The most recent fishery surveys by the DNR were conducted in 1987 and 2003. The two studies employed different sampling techniques. The 1987 survey was conducted with seine nets along the southeast and northwest shores.while the 2003 survey was conducted by boom shocking fish at five locations. A comparison of the data can be found in the 2005 report. Both surveys found a fishery dominated by largemouth bass, bluegills, and northern pike (*Esox lucius*). Neither survey found smallmouth bass, walleye, or trout species and only low numbers of yellow perch were found despite considerable historic stocking efforts for each of these species. In 1987, 143 black crappies were collected while in 2003 only 2 crappies were found. Similarly, largemouth bass, bluegills, and northern pike were found in larger and more numerous in 1987 than in 2003. This may be a result of sampling technique. Regardless, these data indicated a below average size structure for bass and bluegills in Pearl Lake. Common causes for results of this type include high mortality rates due to overharvest and slow growth rates due to high densities and impaired forage base. It is unclear if these trends exist tofay. Since eight years have pasted since the most recent survey, it would be inappropriate to draw conclusions regarding the current fishery of Pearl Lake.

Fish habitat survey

During the habitat survey conducted by Cason and Associates staff, a number of observations were made. Nearly the entire shoreline possesses firm sandy bottom suitable for panfish spawning (**Figures 21 and 22**). Bluegills (*Lepomis macrochirus*) will tend to select sheltered shorelines (i.e. coves or near weed beds). Large-mouth bass and black crappies will utilize rocky points. A few significant three-square bulrush beds can be found along the north shore and the eastern undeveloped shore. There are scattered remnants of bulrush beds elsewhere. These areas are only of value during high water years. In addition, docks and swim rafts are a poor substitute for natural woody cover which is all but absent in Pearl Lake.

Table 7 provides a list of habitat requirements and improvements for game fish species found in Pearl Lake. This information can be used by individual property owners and the District as a whole to improve fish and wildlife habitat in the lake.

Figure 21. Shoreline variability on Pearl Lake, Waushara County, Wisconsin

Figure 22. Fish habitat availability in 2010 on Pearl Lake, Waushara County

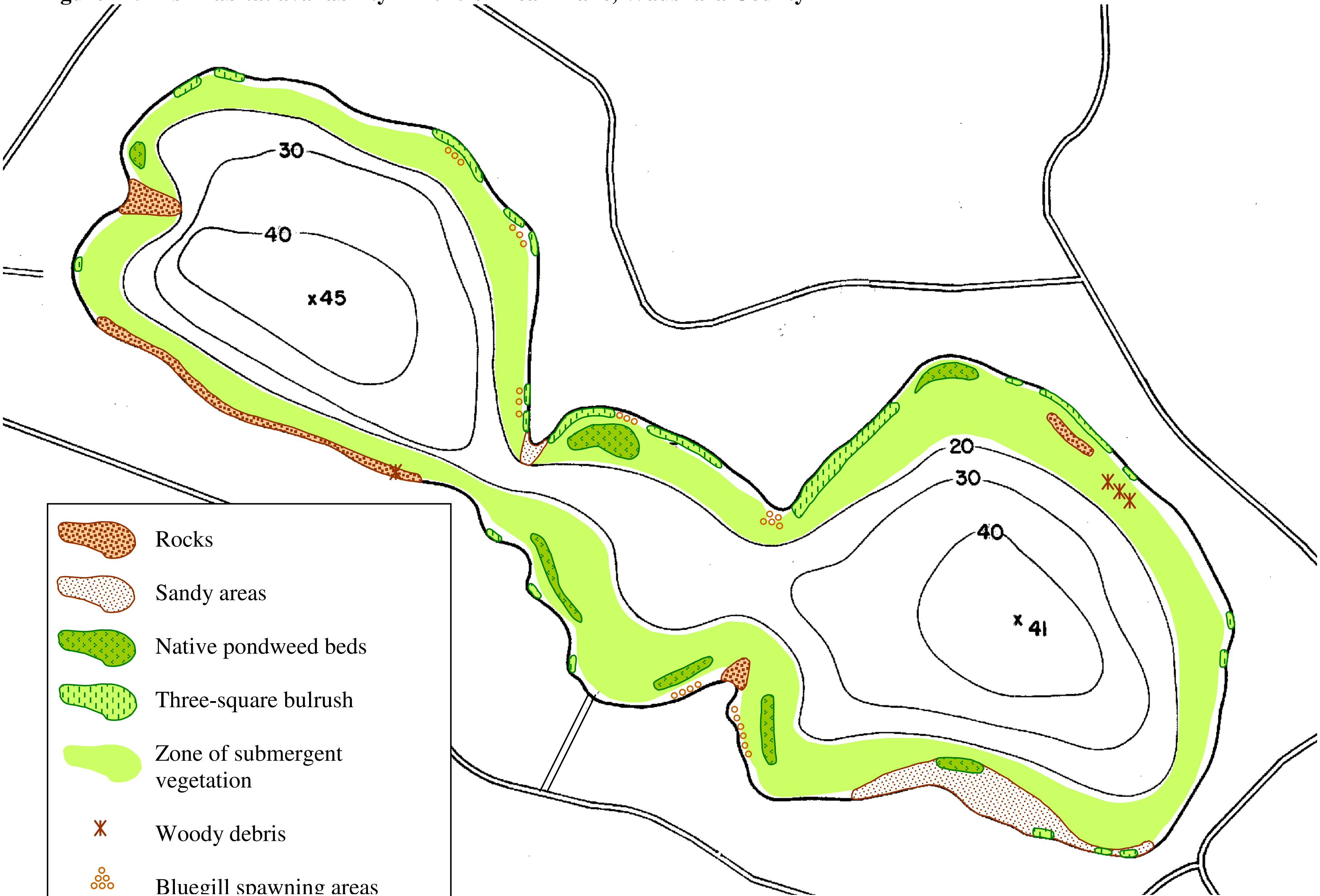


Table 7. Description of habitat requirements and improvements for fish species found in Pearl Lake, Waushara County.

Species	Habitat Requirements: Spawning	Habitat Requirements: Rearing	Habitat Requirements: Foraging	Habitat Improvements	Important Water Quality Parameters
Large-Mouth Bass (*Micropterus salmoides*)	* Shallow protected areas containing emergent vegetation with sandy to gravely substrate * Soft bottoms with woody debris present	* Shallow edges	* Waters less than 18 ft. deep containing aquatic macrophytes * Shallow open areas	* Leave woody debris in lake including small limbs *Control dense stands of nuisance vegetation	* Water temperature is a very important factor * L-M Bass prefer warm water (27-30º C)
Northern Pike *(Esox lucius)*	* Shallow flooded marshes associated with a lake or any flooded area containing emergent vegetation	* Shallow spawning areas with vegetation	* Site feeders, prefer vegetation for camouflage which allows them to ambush their prey	* Control dense stands of nuisance vegetation * Plant native macrophytes	* Do best in cool to moderately warm water temperatures. (21-27º C)
Black Crappie (*Pomoxis nigromaculatus*)	* Shallows containing sand or fine gravel substrate * Spawn near chara and other submerged vegetation	* Young live in shallow protected areas	* Midwater feeders in or near stands of aquatic vegetation and open areas * School around large submerged trees	* Plant chara which is associated to spawning sites * Submerge woody structures	* Prefer clear, warm waters
Bluegill *(Lepomis macrochirus)*	* Shallows consisting of sand or gravel substrate	* Young stick to shallow cover (emergent and submerged vegetation)	* Tend to remain in or near cover during the day and at night enter the shallows * Utilize all sources of vegetation	* Control dense stands of exotic vegetation *Add woody cover if habitat is limited	* Found in clear water verses turbid * Very susceptible to winter kill due to low oxygen levels
Yellow Perch (Perca flavescens	* Spawn in slow-moving or static waters near emergent and submerged vegetation * Also spawn on submerged brush	* Shallows among vegetation	* Feed mainly near the bottom in offshore open water habitats lacking dense vegetation	* Control dense stands of nuisance vegetation * Protect native macrophytes	* Do well in turbid, nutrient rich waters

Lake Management Alternatives

Management of Near-shore Vegetation

Although submergent and emergent plant growth in Pearl Lake is generally not significant enough to cause a nuisance to lake users, property owners have certain rights and responsibilities related to near-shore plant management.

Manual removal of vegetation
Manual removal options include raking or hand-pulling aquatic plants. Individuals can remove aquatic vegetation in front of their homes, however, there are limitations as to where plants can be hand-pulled and how much can be removed. In most instances, control of native aquatic plants is discouraged and is limited to areas next to piers and docks. When aquatic vegetation is manually removed it is restricted to an area that is 30 feet or less in width along the shore. Exotic species (Eurasian watermilfoil, curly-leaf pondweed, and purple loosestrife) may be manually removed beyond 30 feet without a permit, as long as native plants are not harmed. Manual removal beyond the 30 foot area would require a Chapter 109 (Wisconsin Administrative Code - NR 109) permit. Benefits of manual removal include low cost compared to other control methods. However, raking or hand-pulling aquatic plants can be labor intensive.

Herbicide treatment of navigation lanes
In areas where native plant growth interferes with navigation, and other management options are ineffective at reducing this nuisance, herbicide treatment of navigation lanes may be considered. A broad spectrum herbicide or mixture of herbicides can be used to target all plant species in a treatment area. If individual species are targeted, a more specific herbicide may be applied in a manner that would target that particular species. Herbicide treatment of native plants may be a less desirable option when exotic species are a threat. Because the herbicides kill plants instead of merely cutting them, more opportunistic exotic plants may be better able to colonize the treated areas. With any herbicide treatment, the risk of dilution exists.

The method used for this type of treatment involves spraying herbicides to the surface of the water within the treatment area. Only those chemicals registered with the U.S. EPA and the Wisconsin Department of Agriculture, Trade, and Consumer Protection may be used. Herbicides registered for use in Wisconsin undergo a strict registration process. Before they are labeled for aquatic use, the data must demonstrate that they pose minimal risk to human health or the environment when used according to label requirements. Often a mixture of three chemicals (Cutrine®, Aquathol K®, and Reward®), is used to target all plants and algae. This approach should be used for early season applications on low-growing plants to minimize the amount of plant matter dying off at once. However, sometimes a later season follow-up treatment is needed to maintain open water. If this approach is used, it is likely that annual treatments would be needed to maintain effective control. Any treatment of this type would require a Chapter 107 permit. The need for navigation lanes on Pearl Lake is very limited if not nonexistent.

Herbicide treatment of shorelines
As with manual removal, herbicide treatment of near-shore vegetation is an option with certain restraints. Individuals must obtain a Chapter 107 permit from the Wisconsin DNR to chemically treat aquatic plants in a 30-foot strip along their property extending out 150 feet if necessary. If native plant species are targeted, the same three chemicals used in treating navigation lanes would be used in this approach as well. Herbicides are able to provide control in shallow confined areas such as around docks. However, there is a negative public perception of chemicals. In addition, care must be taken to minimize the affect to non-target plant species. Water use restrictions after application are often necessary.

Aquatic Plant Harvesting

Mechanical harvesting involves the removal of aquatic plants from a lake using a machine that cuts and collects the plants for transport to an off-shore disposal site. Generally, harvesting equipment can be adjusted to cut to a desired depth up to 5 feet. Harvesting operations often include equipment, such as a barge, to transport plant materials from a harvester to the shore where a conveyor is used to transfer the materials to a waiting truck. Harvesting is often used for areas where dense monotypic plant growth significantly interferes with navigation. Harvesting produces fast results, and a removal of plant biomass from a lake. However, this method is limited to deeper water. In addition, harvesting is not used to restore aquatic plant communities. It is a maintenance approach used primarily for navigational issues. Harvesting can complicate the management of exotic species, particularly Eurasian watermilfoil. Because milfoil spreads efficiently through fragmentation, and harvesting results in a large number of fragments, the two are incompatible. Harvesting also comes with high initial equipment costs, as well as relatively high maintenance, labor, and insurance costs, disposal site requirements, and a need for trained staff. A WDNR permit is required by NR 109 for aquatic plant harvesting.

Exotic Species Management

Because Eurasian watermilfoil and curly-leaf pondweed exist in Pearl Lake and other exotic species exist in the State, control options for these species should be revisited. Exotic aquatic plant species have interfered with recreational activities including swimming, pleasure boating, hunting, and fishing in numerous lakes throughout Wisconsin. Communities of native aquatic plants, as well as fish and wildlife, have also suffered as a result of these aquatic invaders. In terms of exotic species, Eurasian watermilfoil is currently the most abundant, and poses the greatest threat to the District.

Herbicide treatment of exotics
Herbicides have been the most widely used and often most successful tools for controlling Eurasian watermilfoil. The most commonly employed herbicide in Wisconsin is 2,4-D (e.g. Navigate®, DMA4 IVM®, Weedar 64®). Herbicides containing 2,4-D have been effective at managing Eurasian watermilfoil in hundreds of Wisconsin

lakes. When applied at labeled rates, 2,4-D has been shown to be an effective tool at selectively controlling Eurasian watermilfoil.

The herbicide most often used to control curly-leaf pondweed is endothall (e.g. Aquathol®). While endothall herbicides are effective on a broad range of aquatic monocots, early season applications made at low rates are highly species-selective for curly-leaf pondweed. Endothall herbicides effectively kill the parent plant, but the turions are resistant to herbicides, allowing curly-leaf pondweed to regenerate annually.

Studies conducted by the Army Corps of Engineers have found that conducting treatments of curly-leaf pondweed using Aquathol® when water temperatures are in the 50-60° F range will kill plants before turions form, thus providing long-term control. Researchers found that conducting two or more treatments over consecutive seasons for established curly-leaf pondweed populations will target both the standing crop of the pondweed as well as the resulting regrowth from the turions (Skogerboe and Poovey, 2002).

Both endothall and 2,4-D are herbicides which break down microbially and do not persist in the environment. When applied at the labeled rates, herbicides are an effective management tool for control of many aquatic plant species. While no control method could be considered cheap, herbicide treatments are among the least costly of methods. This is in part due to the relatively low labor costs in comparison to measures such as hand-pulling, mechanical harvesting, etc. Perhaps the greatest consideration is that these herbicides often produce long-term control of exotics. The greatest disadvantage of herbicide treatments is that they rarely produce 100% control. In most cases, herbicides tend to work only where applied. This is more so the case with granular formulations. 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, whether in-season or in subsequent years, may be needed to reduce exotic species to target levels.

Hybrid milfoil management

Research into control options for hybrid milfoil are currently being researched by the Army Corps of Engineers and staff at Mississippi State University. Preliminary results suggested hybrid milfoil responds to herbicide treatments similarly to Eurasian watermilfoil. Anecdotal experience from applicators in the field suggested this was not the case. DNA analysis from Dr. Thum's laboratory has shown that there are multiple strains of Eurasian watermilfoil, northern watermilfoil and hybrid watermilfoil. Each strain likely responds differently to environmental conditions and control efforts. Research is ongoing. Management of hybrid watermilfoil is a relatively new focus. An alternative treatment option that has been used with some success on a small number of lakes is combining liquid 2,4-D and liquid endothall. This approach has provided seasonal control of milfoil but with late season regrowth lake-wide. This is also an approach that is more conducive to a large-scale or 'whole lake' treatment approach.

More recently, the herbicide triclopyr combined with 2,4-D has been used to treat hybrid milfoil on both a large-scale and small scale approach on lakes in the Upper Peninsula of Michigan. Results of these treatments have shown that on a large-scale this combination of herbicides appears to be effective at controlling hybrid milfoil. However, on a small scale, it is less effective. In general, treatments with triclopyr are more costly than comparable treatments with 2,4-D and/or endothall.

Biological control - 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 (*Euhrychiopsis lecontei*) 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). While numerous lakes have attempted stocking milfoil weevils in hopes of controlling milfoil in a more natural manner, this method has not proven successful in Wisconsin. 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 DNR 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. Recently, however, work carried out on a number of Portage County lakes has shown some promise at enhancing milfoil weevil populations. In order for weevils to be successful in reducing the extent of Eurasian watermilfoil, a number of environmental criteria are needed, including the availability of proper year-round habitat.

Conclusions and Recommendations

Aquatic Plant Management

Aquatic plant community
Results of the property owner survey indicated that the aesthetics and recreational opportunities of Pearl Lake are very important to residents and largely the reason for owning property on the lake. Currently, Pearl Lake has an above average diversity of submergent aquatic plants. A number of species potentially susceptible to herbicide treatments targeting Eurasian watermilfoil, including northern watermilfoil, are present in Pearl Lake. Although annual herbicide treatments have taken place for the past decade or more, a healthy native plant community continues to thrive in the lake.

Exotic species monitoring
Survey results confirm that Eurasian watermilfoil, and to a much lesser extent curly-leaf pondweed, continue to infest Pearl Lake. Milfoil levels over the past decade have been maintained at sub-nuisance levels by a proactive management approach that includes annual surveys. The results of this approach include lower management costs, and improved recreational use of the lake and a healthier lake in terms of water quality and the aquatic plant community. For these reasons, it is recommended that the District continue to sponsor annual surveys for exotic species. By scheduling surveys in the spring and again in the fall, the District would be able to take advantage of the most opportune times to survey for curly-leaf pondweed and Eurasian watermilfoil, respectively. The timing of these surveys is critical to determining the accuracy of the locations and distribution of the exotic species.

If curly-leaf pondweed begins to expand significantly in Pearl Lake, the District should expect to implement a control strategy for this species as well.

Management of Eurasian watermilfoil
Following the treatments in 2000 which totaled 12.7 acres, subsequent treatments have been less than three acres annually. One exception to this was in October 2007 when 5.8 acres of milfoil were treated. This increase was a direct result of a change in monitoring strategy. A thorough snorkeling survey of the lake was conducted in an effort to gain a more detailed grasp on the true distribution of Eurasian watermilfoil in Pearl Lake. After a number of years of repeated small-scale treatments, the District requested a more intensive approach to gain further ground on this species. Although more milfoil was identified and treated after the survey, two additional acres of milfoil were subsequently identified and treated the following spring.

Most recent treatments have utilized Navigate® (granular 2,4-D) applied at a rate of 150 lbs per acre. With this approach, some survival occurs annually. However, this regrowth is not always in the most recently treated areas and generally occurs as scattered plants or small groups of plants. Significant expansion has not taken place in the past decade. For this reason, it is recommended that the District continue to sponsor annual treatments as needed on Pearl Lake. The District should consider increasing the rate of application to 200 lbs per acre; the highest rate on the product label. Recent research by the Corps of Engineers and the Wisconsin DNR has shown that the dissipation of herbicides in lakes following treatments is rapid; sometimes lake-wide within 24 hours. A higher rate will minimize the rate of dissipation and maintain a desired concentration of herbicide in the treatment area as long as possible.

The District should also stay informed on other alternative treatment approaches being researched for control of Eurasian watermilfoil and hybrid watermilfoil. If other treatment options are found to be ecologically and economically feasible, the District should consider them as well. This information would most likely come from conversations with the DNR and the applicator firm or through presentations at conferences.

Clean Boats, Clean Waters

The Pearl Lake Protection and Rehabilitation District does not have an active Clean Boats, Clean Water (CBCW) program. Pearl Lake has a high level of recreational use. The Wisconsin DNR in cooperation with the UW-Extension Lakes Program has developed this volunteer watercraft inspection program designed to educate motivated lake organizations in preventing the spread of exotic plant and animal species in Wisconsin lakes. This program would be particularly useful to Pearl Lake since Eurasian watermilfoil and curly-leaf pondweed are both present. Through the Clean Boats, Clean Waters program, volunteers are trained to organize and conduct a program to monitor and stop the spread of exotic plants and animals both into and out of Pearl Lake.

For more information, contact:
Erin (Henegar) McFarlane
Aquatic Invasive Species Volunteer Coordinator
Phone: 715-346-4978
E-mail: erin.henegar@uwsp.edu

A printable brochure regarding the Clean Boats, Clean Waters program can be downloaded at www.uwsp.edu/cnr/uwexlakes/CBCW/Pubs/CBCW_brochure.pdf.

Education should play a big part in the Clean Boats, Clean Waters program. All individuals willing to participate should be taught to identify exotic species. The District should make it a priority to include such measures during all normally scheduled meetings whenever possible. In addition, special meetings should be considered to focus primarily on the identification of these species for riparian property owners and frequent lake users. The native plant, northern watermilfoil *(M. sibiricum)*, grows in Pearl Lake. Because it superficially looks much like Eurasian watermilfoil, care should be taken to specifically learn to differentiate between the two species. In addition to Eurasian watermilfoil, it would behoove members of the District to become familiar with the identification of other exotic species that pose a threat to Wisconsin lakes (see **Appendix F**). Additional information and education materials are available through the Wisconsin DNR and the local UW-Extension office.

If a lake user locates what he or she believes to be a new exotic species in Pearl Lake, its location should be documented by recording GPS coordinates. In addition, a sample should be collected and taken to a member of the District's Board or the coordinator of the monitoring program if such a program is implemented. Any suspicious material should be sent to the nearest Wisconsin DNR office for verification. If the identification is confirmed to be an exotic species, it will be important to initiate management measures as quickly as possible. The extent of an exotic species infestation often dictates which management option is most likely to result in successful control. **Appendix F** also contains information regarding management options for the exotic species previously mentioned. As always, education should be a key component of any exotic species management effort.

Water Quality Management

Nutrient Management Options
Elevated nutrient inputs from human activities around a lake can adversely affect both water clarity and water quality. Although water quality in Pearl Lake is relatively high, a number of practices can be carried out to ensure water quality is maintained. The most significant contributions of nutrients to the lake is likely from direct runoff from areas closest to the lake. The following are options for water quality enhancement which both the District as a whole, and individual lakefront property owners can undertake in an effort to maintain water quality.

The first step in managing nutrients in a lake is to control external sources of nutrients. These can include: encouraging the use of phosphorus-free fertilizers, improving agricultural practices, reducing run-off, and restoring vegetation buffers around waterways.

Lawn care practices
Individuals can play a large part in reducing sedimentation from local sources. Mowed grass up to the water's edge is a poor choice for the well-being of a lake. Studies show that a mowed lawn can cause seven times the amount of phosphorus and 18 times the amount of sediment to enter a waterbody (Korth and Dudiak, 2003). Lawn grasses also tend to have shallow root systems that cannot protect the shoreline as well as deeper-rooted native vegetation (Henderson et al., 1998). Property owners within the District should take care to keep leaves and grass clippings out of the lake whenever possible. They contain nitrogen and phosphorus. The best disposal for organic matter, like leaves and grass clippings is to compost them.

Fertilizers that enter the lake will encourage an increase in plant and algae biomass. Fertilizers contain nutrients that can wash directly into the lake. While elevated levels of phosphorus can cause unsightly algae blooms, nitrogen inputs have been shown to increase weed growth. Increases in plant biomass will lead to further sedimentation and navigational issues. Landowners are encouraged to perform a soil test before fertilizing. A soil test will help determine if a yard needs to be fertilized. For assistance in having soil tested, contact the local county UW-Extension office. Beginning April 1, 2010, fertilizers containing phosphorus cannot be applied to lawns or turf in Wisconsin. This change in the State's statutes is intended to provide protection to Wisconsin's lakes, rivers, streams and other water resources from phosphorus run-off. The fact is, most lawns in Wisconsin don't need additional phosphorus. The numbers on a bag of fertilizer are the percentages of available nitrogen, phosphorus and potassium found in the bag. Phosphorus free fertilizers will have a 0 for the middle number (e.g. 10-0-3).

Erosion control

Erosion is a natural process, but it's for the benefit of the landowner and health of the lake that erosion control practices be carried out to slow the process as much as possible. Sedimentation into the lake causes nutrient pollution, turbid water conditions, eliminates fish spawning habitat, and increases eutrophication. Shoreline owners are encouraged to leave existing vegetation undisturbed, as it is a great shore stabilizer. The placement of logs, brush mats, and rock riprap are also options against erosion. When riprap is used it is recommended that desirable shrubs and aquatic plants be planted within the riprap. The plantings serve as nutrient filters and habitat. Before any shoreline stabilization project is initiated, it is advised that property owners contact the local Wisconsin DNR office for project approval and to obtain any necessary permits.

Reduced impacts from boating

Boat traffic can cause an increase in suspended solids, especially in shallow areas of lakes (Hill, 2004). Studies have shown that maximum increases in turbidity occur between two and 24 hours following boating activities. The full effects of heavy boating depend upon a number of factors including propeller size, boat speed, draft, and sediment characteristics (Asplund, 1996). Silty sediments tend to have the highest susceptibility to resuspension and the highest potential for the reintroduction of nutrients into the water column. Studies have also focused on algae (chlorophyll a) concentrations but found no significant changes following boating activity. This is due primarily to an indeterminate time lag which occurs between the release of nutrients and the subsequent increase in algal growth. It has also been suggested that disturbances to the native plant communities due to watercraft use can accelerate the spread of opportunistic exotic plant species such as Eurasian watermilfoil and curly leaf pondweed (Asplund and Cook, 1997).

Wisconsin statutes require boaters to maintain no-wake speeds within 100 feet of shorelines, other boats, or fixed structures, including boat docks and swimming platforms. However, it is difficult to enforce such regulations and even slow boat traffic can have a negative impact on sediments and plant communities in shallow areas. This not only has a negative impact to the lake but shallow conditions can also damage boat propellers and motors. It is recommended that the District take the opportunity to educate members and lake users alike of the impacts boating can have on a lake.

Septic system maintenance
Septic systems are known to contribute nutrients to a lake. It is the responsibility of lakeshore property owners to ensure that septic systems are properly functioning. A failing septic system can contaminate both surface and ground water. Many Counties in Wisconsin are currently taking inventory of septic systems and enrolling them in a three-year maintenance program. Property owners should avoid flushing toxic chemicals into septic systems. This can harm important bacteria that live in the tank and naturally break down wastes. Owners should also avoid planting trees, compacting soil, or directing additional surface runoff on top of the drain field.

Wisconsin Citizen Lake Monitoring Network
District volunteers have participated in the Wisconsin Citizen Lake Monitoring Network for over 20 years. This program provides an opportunity for volunteers from lake organizations to assist in state-wide water quality monitoring. Volunteers on Pearl Lake currently collect water clarity data and water samples for analysis of phosphorus and chlorophyll. Through a database managed by the DNR, information gathered can be shared and archived. The types of data collected depend on what concerns and interests exist for a particular lake, as well as the amount of time available for monitoring. Much of the water quality data analyzed as part of this study came from this network. It is highly recommended that the District continue to participate in this program and expand the monitoring to include additional parameters. The importance of long-term data is crucial in assessing changes to the lake environment.

Fish and Wildlife Management

Vegetative buffer zones
There are beneficial alternatives to the traditional mowed lawn. The best alternative is to leave the natural shoreline undisturbed. If clearing is necessary to access and view the lake, consider very selective removal of vegetation.

If the natural shoreline has been disturbed or removed it would be ideal to restore it. Restoring a vegetative buffer zone is an important alternative. A recommended buffer zone consists of native vegetation that may extend from 25 – 100 feet or more from the water's edge onto land, and 25 – 50 feet into the water. A buffer should cover between 50% and 75% of the shoreline frontage (Henderson et al., 1998). In most cases this still allows plenty of room for a dock, swimming area, and lawn. Buffer zones are made up of a mixture of native trees, shrubs, and other upland and aquatic plants. Studies have also shown that providing complex habitats through shoreline features, such as plants and erosion control

devices, can result in significant increases in fish diversity and numbers (Jennings et al., 1999).

Shoreline vegetation also serves as an important filter against nutrient loading by trapping loose sediment. A buffer provides excellent fish and wildlife habitat, including nesting sites for birds, and spawning habitat for fish. Properly vegetated shorelines also play a key role in bank stabilization. A number of resources are available to assist property owners in creating beneficial buffer zones. These include the Wisconsin DNR, local UW-Extension office, and the County Land and Water Conservation Department. These organizations can provide descriptions of beneficial native plant species and listings of aquatic nurseries in the State.

Tree Falls and Fish Cribs

The fish habitat survey indicated a lack of woody debris in Pearl Lake. Fish and wildlife are an important part of the aquatic community. Providing fish and wildlife habitat can be as simple as leaving fallen trees and natural vegetation in place. The District should work with individual property owners to conduct intentional tree falls to increase habitat availability. This has been done on other lakes with success. The biggest hurdle to accomplishing this effort is public perception. Many property owners perceive a fallen tree as a nuisance or debris in need of removal. However, woody debris provides excellent habitat for a variety of fish and wildlife. Downed trees provide habitat for turtles, frogs, marsh birds and muskrats. Trees offer excellent cover and spawning habitat for a variety of fish. Woody debris also attracts many invertebrates that fish feed upon.

With deliberate education efforts and willing volunteers a tree-fall project can and should be conducted in the near future. On other lakes, these activities are carried out in the winter when disturbance to the lake and shoreline can be minimized. The best locations for cribs are in areas relatively devoid of appropriate fish habitat at depths of 10 to 25 feet. Better results are seen when several cribs are clustered together at a single location. Activities should be coordinated with the help and knowledge of the Wisconsin DNR. It would also benefit the District to contact the We Really Kare fishing club out of Wild Rose. With their experience and input from the Wisconsin DNR fisheries staff, an appropriate number of fish cribs and/or tree falls can be determined and planned. In addition, it would behoove the District to pursue a fishery assessment by the Wisconsin DNR. By understanding the current state of Pearl Lake's fishery, appropriate management options can be considered.

Citizen Involvement and Management Planning

Input from members of the Pearl Lake P & R District was gathered by District members as part of this study. Results have been compiled and are presented in **Appendix A**.

In addition, the results of this study were presented to the membership living on Pearl Lake at the annual meeting held on July 2, 2011. This meeting was a good forum to present and discuss the study findings and receive feedback from property owners. This was also a good opportunity to discuss lake management options with the District. This discussion allowed for the formulation of action items which have been included in this document. This management plan should help guide future decisions regarding lake management efforts. The finalized management plan will be communicated to the District Board and the DNR for approval

Implementation Plan

Management Goal 1: Reduce exotic aquatic plant growth within Pearl Lake.

Management Action: Annual monitoring and chemical treatment(s).
Timeframe: Annual surveys in spring and fall. Spring and if necessary fall treatments to control Eurasian watermilfoil.
Facilitator: District Board, Cason & Associates, LLC.

Description: Surveys for exotic species, namely Eurasian watermilfoil and curly-leaf pondweed will be conducted in the spring and fall, respectively. These surveys will be conducted by Cason & Associates staff and will focus on the littoral zone of Pearl Lake.

Spring surveys will be used to monitor the distribution of curly-leaf pondweed in the lake. To date, no treatments for curly-leaf pondweed have been conducted because of the current lack of need. If survey results show a significant expansion in the distribution of curly-leaf pondweed, management efforts will be discussed and likely employed.

Fall surveys will be used to monitor the distribution of Eurasian watermilfoil in Pearl Lake. These surveys will assess the efficacy of previous herbicide treatments and determine the need for additional treatment. Annual spring treatments are anticipated to maintain Eurasian watermilfoil at sub-nuisance levels. It is anticipated that five acres or less per year will require treatment.

The District should include funding for surveys and treatments in the annual budget. This should include approximately $750 for each survey and $4,000 for up to five acres of treatment.

Management Goal 2: Monitor and maintain water quality conditions within Pearl Lake.

Management Action: Continue with current monitoring practices. Investigate additional monitoring and water quality improvement options.
Timeframe: Annual seasonal monitoring
Facilitator: District Board, Cason & Associates, LLC

Description: Water quality data suggest that Pearl Lake is in very good condition.

The District plans to have volunteers continue with the water quality monitoring through the DNR's Citizen Lake Monitoring program. This will include seasonal monitoring of Secchi depth readings, phosphorus and chlorophyll sampling and dissolved oxygen and temperature. Data will be archived by the Wisconsin DNR's Surface Water Integrated Monitoring System (SWIMS).

Management Goal 3: Encourage shoreline improvements on an individual riparian owner basis.

Management Action: Restore or improve near-shore plant community to improve water quality and fish and wildlife habitat. Educate District members regarding the reduction of nutrients and sediments from immediate watershed.

Timeframe: Starting in 2011
Facilitator: District Board
The District board plans to provide information to its membership regarding shoreline improvement options and other actions the District as a whole and individuals can take. Particular attention will be paid to the use of vegetative buffer strips and tree falls as a means to improve fish habitat in the lake. Resources included in this plan as well as those available from the Wisconsin DNR, Waushara County and UW-Extension will be utilized. The District will also solicit appropriate speakers to address these issues at membership meetings. Shoreline improvement demonstrations may be planned upon District's discretion.

Management Goal 4: Encourage additional fishery enhancement activities.

Management Action: Pursue DNR fish survey, pursue appropriate stocking and habitat improvements in Pearl Lake.

Timeframe: Starting in 2011
Facilitator: District Board
The District board will pursue a fishery study by the Wisconsin DNR similar to the one completed in 2003. Whether or not a survey is conducted, the District Board will pursue continued fish stocking into Pearl Lake whether through the Wisconsin DNR or the We Really Kare fishing club. In addition, continue to welcome the efforts of We Really Kare Inc. in regards to the placement of additional fish cribs and the stocking of game fish in Big Hills Lake. Board members will communicate directly with We Really Kare Inc members and the Wisconsin DNR regarding any decision making or input needed. In addition, the Board will educate their membership in regards to the presence of carp in Big Hills Lake and how to handle these fish if caught by anglers.

Management Goal 5: Enroll in Clean Boats Clean Waters program.

Management Action: Enroll one to three boat landings in the DNR's Clean Boats Clean Waters program.
Timeframe: Starting in 2011
Facilitator: District Board
The District does not currently take part in the DNR's Clean Boats Clean Waters program. With heavy use by visitors to the lake, the District Board has acknowledged the

need to participate in this program. Starting in 2011, the District will solicit volunteers from its membership to take part in this program. Coordinating members are expected to participate in one of the training sessions in the State and begin become organizing additional volunteers in the District. The level of involvement and the number of trained volunteers is expected in increase annually.

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Appendix A

- Property owner survey results from Pearl Lake, conducted by the Pearl Lake Protection and Rehabilitation District, 2010.

Pearl Lake Protection and Rehabilitation District
Taxpayer Survey 2010

As part of its study for a Lake Management Plan, the Pearl Lake Protection and Rehabilitation District conducted a mail survey of taxpayers in the district. In July, 2010, 136 survey forms were mailed to all taxpayers of record. Of these, 93 were returned, for a response rate of 68 percent. Not all respondents answered all questions.

Demographics

Survey respondents had the following characteristics:

Age of Primary Owners:

18-34……..1%
35-54…….31%
55+………68%

Residency at Pearl Lake

Summer…………………..49%
Year-round-occasional…...34%
Year-round-permanent…...15%
Average annual days at lake, part-timers: 83

Permanent Residence

Pearl Lake………………..15%
Other Wisconsin city…….50%
Outside Wisconsin……….35%

Duration of ownership

1-9 years……..20%
10-19 years…...19%
20-29 years…...13%
30-39 years…...11%
40-49 years…...12%
50+ years……..25%
Average: 27.5 years
Range: 1 year to 90 years

Attendance at PRD Meeting in last three years

Yes…..70%
No……30%

Children on Property

Always……18%
Often……...57%
Seldom……16%
Rarely………7%
Never……….2%

Number of Bedrooms

One……………9%
Two…..............41%
Three…………37%
Four or more…13%

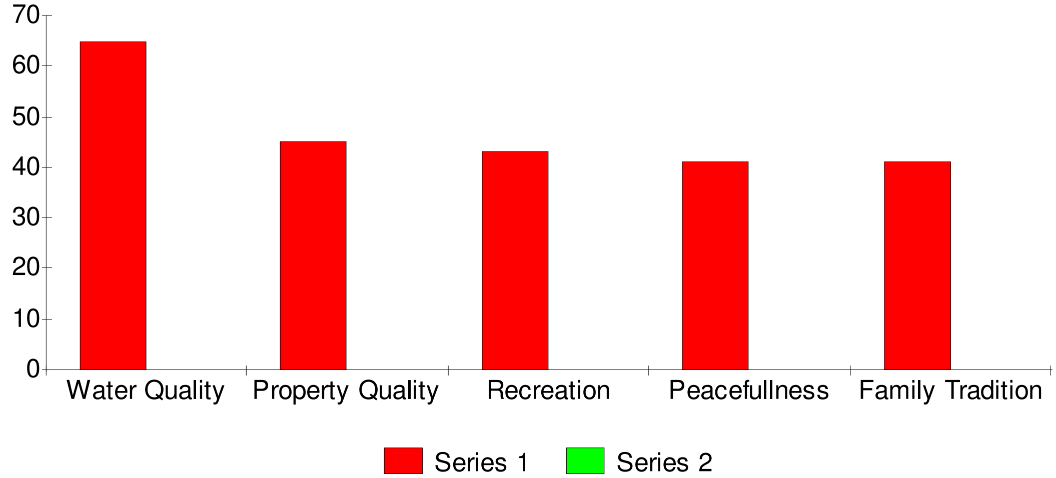
Rental of property

Never………..99%
Sometimes……1%
Often…………0%

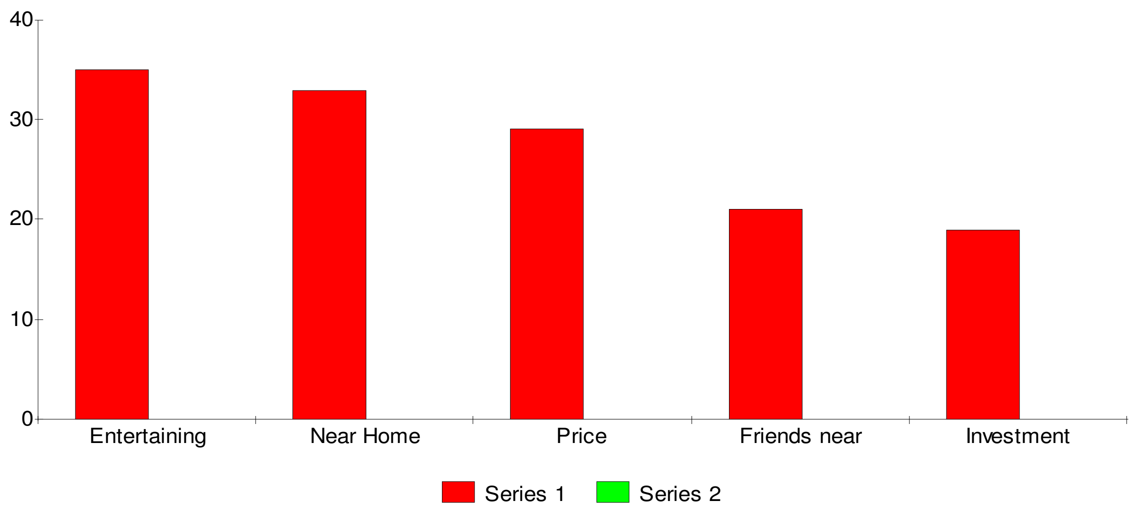
Ownership

Individually…..48%
Jointly………...34%
Trust…………..16%
Family LLC……2%

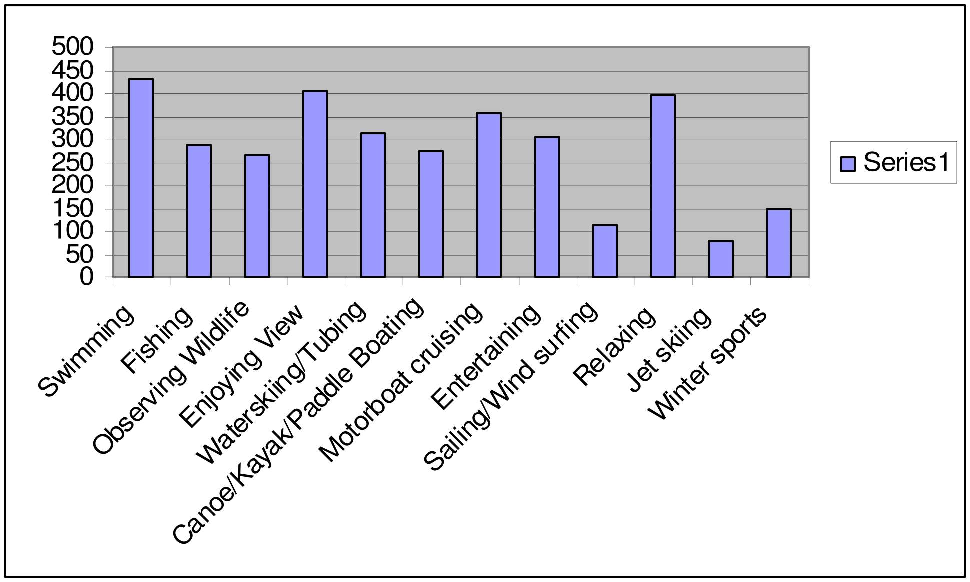
Most Important Features in Selecting Pearl Lake Property



Least Important Features in Selecting Pearl Lake Property



Weighted scores of Recreational Activities



Lake Frontage features within 25 feet of water's edge

Sand beach	80%
Retaining wall	11%
Pier/dock	74%
Sparse vegetation	20%
Stabilizing rocks	33%
Thick vegetation	22%
Boat hoist	31%
Undeveloped	17%

Types of watercraft used by respondents

Runabout, Inboard	31%
Runabout Outboard<25 hp	31%
Runabout Outboard >25 hp	19%
Pontoon Boat	43%
PWC/Jet Ski	15%
Rowboat/paddle boat	59%
Canoe/kayak	44%
Sailboat	13%

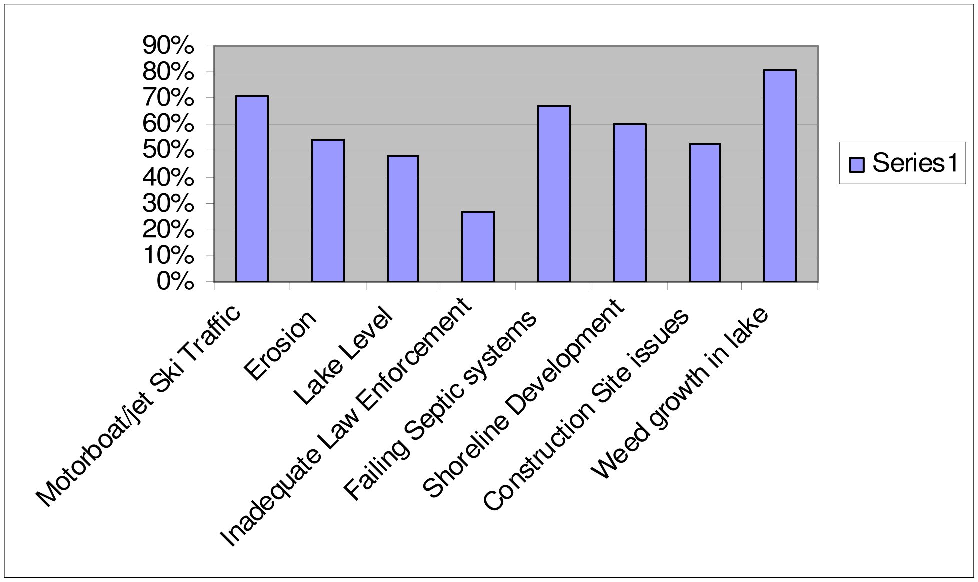
Adequate law enforcement on Pearl Lake?

Yes	73%
No	19%
Don't know	8%

Are lake use regulations adequate?

Sufficiently regulated	81%
Under regulated	16%
Over regulated	8%

Percentage respondents identifying issues as having potential for very strong future impact on Pearl Lake



Respondents feeling they can offer input into management of Pearl Lake

Yes	75%
No	25%

Satisfaction with overall management of Pearl Lake

Not at all satisfied	2%
Neutral	29%
Very Satisfied	69%

Pearl Lake Survey Report - Verbatim Comments

Respondents provided a large number of comments to several open ended questions.

Best Feature of Lake

- Undoubtedly clear, clean water is the feature of the lake most treasured by respondents. Two-thirds cited this feature. Others cited variations on this feature, as well as some others. Their responses follow:
- View
- Pearl Lake is a community of exceptionally friendly, generous and respectful people who share similar reasons for holding the lake in high regard. Combined with crystal clear water and a friendly environment there is always a reason to celebrate owning a spot on this lake.
- Clean water, excellent fishing

- Water quality and restricted power boating hours
- Beauty and clarity of the lake
- Clear clean water---view from our cottage—quiet-tranquil-peaceful
- Water quality-restricted boating activity-fishing opportunites
- Clean and quiet
- Beautiful sunsets!!
- Quality of water, regulated speed boats & tradition
- No wake rules
- Up north type land—until new condos went up
- Good swimming
- The wake/no wake hours
- Boat regulations
- Limited use/access by non-lake property owners—peaceful/playful—boating hours
- Two hours from home
- I love the 11-4 hours. Everyone can partake in what they like. It's like living on two different lakes.
- Quite and peaceful
- Quite and relaxing (except during holiday weekends)
- Peacefulness
- No wake hours is great
- Appearance of lake and property
- The lake!
- Friendly "community"—Everyone watches out for one another
- Overall atmosphere of the lake
- Improving and building of new homes to replace the rundown, old cottages
- Restricted motor boat hours
- No wake rule to allow for non-motor boat use of lake
- Friendly people
- Allowing a variety of lake uses
- People
- The beauty and the tranquility before 11 a.m. and after 4 p.m.
- All of the recreational activity available
- Friendly community
- Small, private
- Good fishing, small, 100 mils from home
- Close to home
- Beautiful sunsets
- Keep as is
- Fish habitat, controlled wake speed hours
- Peacefulness-view
- Water access plus the surrounding countryside

Most Important Change Needed

- Retaining wall restrictions
- Outlaw small skidoos
- Public beach
- I would ask folks to be more mindful of monitoring light and noise pollution. NO NEED for those spotlights at midnight that limit star gazing.
- Limit size of boats on lake
- Extend the wake speed hours by 2 hours so we don't all try to use the lake at once, IE (10-5 or 9-4) to reduce crowding
- Limit size of boats—max 100 hp
- Not allow jet skiing
- Stocking more fish—invasive weed control
- Limit size of boats (length & HP)
- Limit boat size to 20 feet, no larger. Wave runner age limit. Better supervision from parents.
- Extend restricted boating hours, e.g. 12:00-4:00
- No jet skis, fewer boats
- Limit the size of boats
- No fireworks except the 4^{th} of July
- Boaters/swimmers unable to anchor and use the shallow water
- Better monitor and charge outsiders using the lake, check boats
- Nothing
- Privatize
- Extend wake hours on Saturday
- Get rid of PWC
- At the boat landing, when loading your boat onto your trailer, don't use the power of your boat motor to load your boat (It washes out the boat landing.
- Limit the size of the Castles being built!! It really takes away the "lake" feeling.
- Eliminate jet skis (personal watercraft devices) I have personally witnessed outrageous conduct on personal watercrafts this summer, one of which could have resulted in serious injury to the operator and a homeowner who was swimming. Something has to be done to remedy this situation.
- Size of motors—no jet skis
- Monitored public boat landing.
- Close boat ramp
- No trees to be removed from hill or area from home to lake—no condos
- Size of homes on 50 ft. lots
- The hp of motor boats. The weeds boats churn up come to my beach & I also swim at 4 p.m.—The water quality is not good then—how much damage does this do to the lake and its future?
- Less crowded—too busy with 50 ft. lots
- No jet skis
- Wouldn't change anything

- All good—like 11-4
- Limit size of boats on lake
- Enforcement of boating & buffer zone regulations
- Allow jet skis from 11-2 only
- No jet skis
- Better boat landing. No grip or "grates" in water
- Outlaw jet skis
- Make membership in lake association mandatory
- Fast boats too large—jet skis
- More PWC restrictions
- Restrict horsepower to 75
- Size motor restrictions to 50 hp or less
- Restrict shoreline development—leave it natural
- If I could change one thing about Pearl Lake I would change the hours of fast time and give the boaters an extra hour or two (ex. 10-4 or 11-5). This way the fishermen would still have plenty of time to fish and boating traffic during fast time would be decreased since the boaters would have more time to be out on the water. This would also make the lake safer since traffic would be lower. With a growing population on the lake more boats are out during fast time. With longer hours nobody would have to worry about squeezing in tubing, waterskiing, jet skiing or just cruising around since they would have more time to enjoy it.
- Should have mandatory check of all old septic systems that are lakeside and can pollute the lake, land and wells!! Fireworks garbage in the water after 4th of July
- More stocking of fish
- Expand water skiing hours—water ski only! Not all speed boating.
- Reduce size of bots permitted on lake; outlaw jet skis
- Resort on the lake
- Better fishing
- No change—preserve as is
- Reduce light pollution at night
- No wake hours—longer during week
- No jet skis—very noisy
- DNR rules and regulations related to remodeling/renovations/teardowns
- No jet skis—No fireworks except 4th of July and none after 10 p.m.
- I would lengthen the water ski hours by 1 to 2 hours.
- Prohibit jet skiing
- Less noise of all kinds—loud radios, boats, voices, fireworks!
- Too many large speedboats
- Prevent neighbors from placing pontoon boat in water on my property
- Restrict water usage. Put limits on sq. footage. Enforce speed limits on EE & Pearl Lake Rd.
- No chemicals, toxins
- have the city finish N. Pearl Lake Rd
- Longer water sports hours—until 6:00

- I am concerned about excess traffic on our small lake, specifically jetski joy riders, irresponsible untrained drivers and use of pontoon boats to pull skiers and tubing vehicles. This needs attention.
- Reduce regulatory interference
- The best features were that it was a natural lake and the setting was quiet and peaceful. Now it seems too crowded and noisy.
- Eliminate motor boats, jet skis, etc. The lake is too small for them and they endanger swimmers and pollute the environment and the lake. They also erode the shoreline.
- The heavy boat congestion & all the jet skis

Desired change in regulations

- Outlaw fireworks except on the 4th of July
- Limit or exclude the summer rentals of property—cottages that are 100% of the time rented to noisy people each week.
- Tighter control of jet skis and of watercraft too close to rafts/piers
- Control of jet skis-esp. not staying in one circle for a long time.
- Keep large boats in the middle of the lake to reduce shoreline erosion
- No need to regulate. Only to make people more conscience (sic) of boating laws. Too many boaters not following safety regulations.
- Do not make the channel slow/no wake or you will make a lot of happy boaters angry!!
- Let us do what we want on piers and shore within reasons. It depends on who you are as far as what you can do.
- HP of motor boats and personal water craft/jet skis
- Size of motor boats
- More law enforcement
- Self-governing and respect for regs. Should be enough.
- Restrict PWCs
- Lake appointed deputy. Jet ski use needs to be controlled.
- Consider: Expand hours for water ski only, 10-11. No tubing, no wake boards, no jet skies. This would allow for purist skiers to enjoy a calmer lake, reduce congestion from 11-4 as skiing would be basically over.
- Communication of regulations—in general and specifically: how far can piers extend—how far out can rafts be places
- Jet skiers don't follow rules—Weekends can be dangerous—need to have the rules better enforced. People do good job of following time rules.
- Enforce the regulations
- There doesn't seem to be much enforcement of lake regs
- Some things are allowed..asphalt and concrete yards. Some thngs are disallowed—screen porches and garages.
- Current regulations need to be enforced
- Longer wake hours

- Have rules enforced: Motor boats should obey no wake rules between 4:00 p.m. and 11:00 a.m.
- However, we have had trouble with boats too close to our raft and swimmers. One actually hit the raft this summer. I would like owners and visitors to be made aware of rules. Sometimes we have had problems, as noted above.

Ability to provide input on management of Peal Lake

- Longtime property owner and observer—I can be objective.
- Semi-retired—minimal spare time. Travel a lot!
- It takes too long for people to "get on board" & take action
- Been there for many years and have seen many changes
- I get input at meetings
- Just learning what lake house ownership is all about
- Would have no influence
- However, the current leadership of the association, Chuck J., is not open to discussion or dissenting points of view. Questions regarding clarification of issues are viewed as an affront to "authority" rather than an opportunity for input.
- I don't spend enough time there
- Our family has been on Pearl Lake since mid 1950's. Grandfather lived on Pearl Lake year round for 30 years.
- My age
- Do not feel knowledgeable about issues
- Age factor-87
- I feel I could voice my opinion at one of the meetings—if I wanted to.
- The owners who live closer to the lake—especially local owners—seem to have more input. Also, it seems that decisions are made prior to lake meetings and forced on others.

Additional Comments

- Would like easement area marked and cleared
- The PRD does a great job! Thank you for all that you do to retain the high quality of like at Pearl!
- Construction and building limitations seem to be inconsistently regulated and enforced with questionable results. What is approved for one is not for an other. Rules should be easily accessible, clear and appropriate for all. Property owners need to know how they can approve their and alter their property within the law that will not be changed before the work is complete. If homes are being inspected for future tax adjustment the process should be performed when owners are present and it is convenient, not during late fall or winter with meetings to respond held mid-week at inconvenient times.
- We feel privileged to be able to raise our kids on weekends at Pearl Lake!

- We've no complaints about our 47+years at Pearl Lake! Good lake-good neighbors-Good Times!We especially appreciate News Letters which keep us informed.
- Farmers should water at night "only" Maybe twice a week. Keeping water table at safe level. (We do this at home during the summer.)
- Boat restrictions should be enforced more
- Would like to understand how people can continue to build so near the shoreline
- Why do some dog owners use everyone else's property for their dogs to crap on. We see the same people do it everyday—I clean up dog poop every day and do not have a dog!
- It would be a good idea to let the people who walk their dogs clean up after them. It's not the "woods," it's people's property. I guess it falls into the category of people just don't throw their trash out the window anymore. Also, to walk on the left, facing traffic.
- We love Pearl Lake—water quality is excellent—we love the 11 am-4p.m and 4pm-11 am no wake.
- Safety on the lake seems to be getting worse. Boaters are not paying attention or don't care and cut other boaters off, come within 25-50 ft. or less of a skier/wake boarder and are using excessive sped. (Some may not know what the rules or regulations are.) At times the lake is so choppy from all the boats that it is hard to ski & wakeboard.
- The speed limit of 25 would be nice because of the walkers
- Need access for a public beach. Since the bar closed, there is no public beach!!—Public access sign are overgrown and hard to see.—Public access road deteriorating due to erosion.—Please do NOT PRIVATIZE PEARL LAKE!!
- Action should be taken to have (or encourage) homeowners to turn off lights at night, particularly on beach.
- How come some (the 5 new places) & others construct walls, landscape, etc. & rest can't.
- Please check out deeper areas of the lake for Eurasian milfoil—I believe it can be found about 100 feet from shore considering what is floating to our beach.
- We enjoy the 11-4 fast boat time—we feel it is a good compromise
- All septic systems should be pumped regularly. Consistency in codes from county is important. Too many variances. Why does the county mandate only"newer" systems be pumped every three years?
- Be cautious in regulations, Education is the key. When blatant disrespect of lake occurs report to appropriate agency. Self regulation and respect for the lake is important. Leave city life and attitudes in the city. Enjoy the peace, night sky and wild life—fish or fowl.
- 40 years ago it (the lake) was filled with fish and many varieties of mollusks (snails, clams) arthropods, frogs, turtles and had a healthy weed life. All that has changed. When I skin dive, I'm lucky to see more than 4 or 5 fish in a half hour. I have seen a marked decline in the fish population since the early 80s. I've been skin diving in the lake for 45 years, and the fish, arthropod mollusk and plant populations have decreased *very* substantially.

- Every lake property owner should pay their dues ($10.00) to support the lake association. The benefits apply to all owners—everyone should pay.
- Chuck Johanns does a great job!!!
- Size and speed of boats should be regulated to fit the size of the lake
- All night lights on the lake are "light pollution" and detract from the beauty of the night. PRD officers are doing a good job.
- Please check into the old septic problem. Major problem of all the old septic systems that run downhill into the lake!! Should be checks by law! Many old cottages fall into this category and nothing is done about it. Major pollution into the lake, land and wells. Who wants to swim in sewage.
- The sheriff never seems to be there when the idiots are out, especially jet skis in the channel. Enforcement of existing rules, expansion of pure water ski hours to relieve congestion and continuation of clean water practices s/b the primary areas of focus. Further regulation is not needed, enforcement is! Further restrict fish stocking as these fish are being taken by non-resident put-ins…quite the waste of $. Also consider: Restrict the speed limit of pontoon boats & consider banning of jet skis. Society as a whole had become less congenial and today's environment on the lake on weekend days suffers as traffic increases during late afternoons 10-4 would help!
- Thanks for asking!
- I own a second property that has 150' lake frontage that has no dock and is totally undeveloped.
- Renters need to be informed of rules and follow them
  1) Jet skis contribute to lake pollution and do not follow boat pattern around lake;
  2) Boats drive too close to beach, rafts and piers;
  3) When boats depart from and return to shore boats cross in front of neighbors swim area, which is dangerous;
  4) Beach parties should end at midnight. NOISY
  5) Fireworks leave a lot of debris in lake—sinks to bottom;
- 6) 11 am 4 pm rule very important on a small lake.
- My father-in-law bought his property in 1926. After he passed away he gave it to XXXX. When XXXX wanted to sell it last year—I couldn't bear dto think of it not being in the family, so I bought it. Glad I did!!
- Thanks for limiting fireworks to 11 p.m. on July 4th.

Appendix B

- GPS coordinates for aquatic plant surveys conducted on Pearl Lake, Waushara County, Wisconsin

Site	Latitude	Longitude	Site	Latitude	Longitude	Site	Latitude	Longitude
1	44.0913	-89.1254	52	44.0901	-89.1235	103	44.0893	-89.1220
2	44.0910	-89.1255	53	44.0899	-89.1235	104	44.0890	-89.1220
3	44.0907	-89.1255	54	44.0896	-89.1235	105	44.0921	-89.1216
4	44.0904	-89.1255	55	44.0893	-89.1235	106	44.0918	-89.1216
5	44.0921	-89.1250	56	44.0924	-89.1231	107	44.0915	-89.1216
6	44.0918	-89.1251	57	44.0921	-89.1231	108	44.0912	-89.1216
7	44.0915	-89.1251	58	44.0918	-89.1231	109	44.0910	-89.1216
8	44.0913	-89.1251	59	44.0915	-89.1231	110	44.0907	-89.1216
9	44.0910	-89.1251	60	44.0913	-89.1231	111	44.0904	-89.1216
10	44.0907	-89.1251	61	44.0910	-89.1231	112	44.0901	-89.1216
11	44.0904	-89.1251	62	44.0907	-89.1231	113	44.0898	-89.1216
12	44.0902	-89.1251	63	44.0904	-89.1231	114	44.0896	-89.1216
13	44.0924	-89.1247	64	44.0901	-89.1231	115	44.0893	-89.1216
14	44.0921	-89.1247	65	44.0899	-89.1231	116	44.0890	-89.1216
15	44.0918	-89.1247	66	44.0896	-89.1232	117	44.0887	-89.1216
16	44.0915	-89.1247	67	44.0893	-89.1232	118	44.0921	-89.1212
17	44.0913	-89.1247	68	44.0924	-89.1227	119	44.0918	-89.1212
18	44.0910	-89.1247	69	44.0921	-89.1227	120	44.0915	-89.1212
19	44.0907	-89.1247	70	44.0918	-89.1227	121	44.0912	-89.1212
20	44.0904	-89.1247	71	44.0915	-89.1227	122	44.0910	-89.1212
21	44.0901	-89.1247	72	44.0912	-89.1227	123	44.0907	-89.1212
22	44.0899	-89.1247	73	44.0910	-89.1227	124	44.0904	-89.1212
23	44.0924	-89.1243	74	44.0907	-89.1227	125	44.0901	-89.1212
24	44.0921	-89.1243	75	44.0904	-89.1228	126	44.0898	-89.1212
25	44.0918	-89.1243	76	44.0901	-89.1228	127	44.0896	-89.1212
26	44.0915	-89.1243	77	44.0899	-89.1228	128	44.0893	-89.1212
27	44.0913	-89.1243	78	44.0896	-89.1228	129	44.0890	-89.1212
28	44.0910	-89.1243	79	44.0893	-89.1228	130	44.0887	-89.1212
29	44.0907	-89.1243	80	44.0924	-89.1223	131	44.0918	-89.1208
30	44.0904	-89.1243	81	44.0921	-89.1223	132	44.0915	-89.1208
31	44.0901	-89.1243	82	44.0918	-89.1223	133	44.0912	-89.1208
32	44.0899	-89.1243	83	44.0915	-89.1223	134	44.0910	-89.1208
33	44.0924	-89.1239	84	44.0912	-89.1224	135	44.0907	-89.1208
34	44.0921	-89.1239	85	44.0910	-89.1224	136	44.0904	-89.1208
35	44.0918	-89.1239	86	44.0907	-89.1224	137	44.0901	-89.1208
36	44.0915	-89.1239	87	44.0904	-89.1224	138	44.0898	-89.1208
37	44.0913	-89.1239	88	44.0901	-89.1224	139	44.0896	-89.1208
38	44.0910	-89.1239	89	44.0899	-89.1224	140	44.0893	-89.1208
39	44.0907	-89.1239	90	44.0896	-89.1224	141	44.0890	-89.1208
40	44.0904	-89.1239	91	44.0893	-89.1224	142	44.0887	-89.1208
41	44.0901	-89.1239	92	44.0890	-89.1224	143	44.0915	-89.1204
42	44.0899	-89.1239	93	44.0921	-89.1220	144	44.0912	-89.1204
43	44.0896	-89.1239	94	44.0918	-89.1220	145	44.0910	-89.1204
44	44.0924	-89.1235	95	44.0915	-89.1220	146	44.0907	-89.1204
45	44.0921	-89.1235	96	44.0912	-89.1220	147	44.0904	-89.1204
46	44.0918	-89.1235	97	44.0910	-89.1220	148	44.0901	-89.1204
47	44.0915	-89.1235	98	44.0907	-89.1220	149	44.0898	-89.1204
48	44.0913	-89.1235	99	44.0904	-89.1220	150	44.0896	-89.1204
49	44.0910	-89.1235	100	44.0901	-89.1220	151	44.0893	-89.1204
50	44.0907	-89.1235	101	44.0898	-89.1220	152	44.0890	-89.1204
51	44.0904	-89.1235	102	44.0896	-89.1220	153	44.0887	-89.1205

Site	Latitude	Longitude
154	44.0884	-89.1205
155	44.0882	-89.1205
156	44.0909	-89.1200
157	44.0890	-89.1201
158	44.0887	-89.1201
159	44.0884	-89.1201
160	44.0882	-89.1201
161	44.0893	-89.1197
162	44.0890	-89.1197
163	44.0887	-89.1197
164	44.0884	-89.1197
165	44.0882	-89.1197
166	44.0879	-89.1197
167	44.0876	-89.1197
168	44.0873	-89.1197
169	44.0870	-89.1197
170	44.0893	-89.1193
171	44.0890	-89.1193
172	44.0887	-89.1193
173	44.0884	-89.1193
174	44.0882	-89.1193
175	44.0879	-89.1193
176	44.0876	-89.1193
177	44.0873	-89.1193
178	44.0870	-89.1193
179	44.0868	-89.1193
180	44.0893	-89.1189
181	44.0890	-89.1189
182	44.0887	-89.1189
183	44.0884	-89.1189
184	44.0881	-89.1189
185	44.0879	-89.1189
186	44.0876	-89.1189
187	44.0873	-89.1189
188	44.0870	-89.1189
189	44.0868	-89.1189
190	44.0890	-89.1185
191	44.0887	-89.1185
192	44.0884	-89.1185
193	44.0881	-89.1185
194	44.0879	-89.1185
195	44.0876	-89.1185
196	44.0873	-89.1185
197	44.0870	-89.1185
198	44.0868	-89.1185
199	44.0890	-89.1181
200	44.0887	-89.1181
201	44.0884	-89.1181
202	44.0881	-89.1181
203	44.0879	-89.1181
204	44.0876	-89.1181
205	44.0873	-89.1182
206	44.0870	-89.1182
207	44.0867	-89.1182
208	44.0887	-89.1177
209	44.0884	-89.1177
210	44.0881	-89.1178
211	44.0879	-89.1178
212	44.0876	-89.1178
213	44.0873	-89.1178
214	44.0870	-89.1178
215	44.0867	-89.1178
216	44.0884	-89.1174
217	44.0881	-89.1174
218	44.0879	-89.1174
219	44.0876	-89.1174
220	44.0873	-89.1174
221	44.0870	-89.1174
222	44.0867	-89.1174
223	44.0865	-89.1174
224	44.0881	-89.1170
225	44.0879	-89.1170
226	44.0876	-89.1170
227	44.0873	-89.1170
228	44.0870	-89.1170
229	44.0867	-89.1170
230	44.0865	-89.1170
231	44.0862	-89.1170
232	44.0859	-89.1170
233	44.0884	-89.1166
234	44.0881	-89.1166
235	44.0879	-89.1166
236	44.0876	-89.1166
237	44.0873	-89.1166
238	44.0870	-89.1166
239	44.0867	-89.1166
240	44.0865	-89.1166
241	44.0862	-89.1166
242	44.0859	-89.1166
243	44.0887	-89.1162
244	44.0884	-89.1162
245	44.0881	-89.1162
246	44.0878	-89.1162
247	44.0876	-89.1162
248	44.0873	-89.1162
249	44.0870	-89.1162
250	44.0867	-89.1162
251	44.0865	-89.1162
252	44.0862	-89.1162
253	44.0859	-89.1162
254	44.0890	-89.1158
255	44.0887	-89.1158
256	44.0884	-89.1158
257	44.0881	-89.1158
258	44.0878	-89.1158
259	44.0876	-89.1158
260	44.0873	-89.1158
261	44.0870	-89.1158
262	44.0867	-89.1158
263	44.0865	-89.1158
264	44.0862	-89.1158
265	44.0859	-89.1158
266	44.0892	-89.1154
267	44.0890	-89.1154
268	44.0887	-89.1154
269	44.0884	-89.1154
270	44.0881	-89.1154
271	44.0878	-89.1154
272	44.0876	-89.1154
273	44.0873	-89.1154
274	44.0870	-89.1154
275	44.0867	-89.1154
276	44.0864	-89.1155
277	44.0862	-89.1155
278	44.0859	-89.1155
279	44.0856	-89.1155
280	44.0895	-89.1150
281	44.0892	-89.1150
282	44.0890	-89.1150
283	44.0887	-89.1150
284	44.0884	-89.1150
285	44.0881	-89.1150
286	44.0878	-89.1150
287	44.0876	-89.1150
288	44.0873	-89.1151
289	44.0870	-89.1151
290	44.0867	-89.1151
291	44.0864	-89.1151
292	44.0862	-89.1151
293	44.0859	-89.1151
294	44.0856	-89.1151
295	44.0895	-89.1146
296	44.0892	-89.1146
297	44.0890	-89.1146
298	44.0887	-89.1146
299	44.0884	-89.1146
300	44.0881	-89.1147
301	44.0878	-89.1147
302	44.0876	-89.1147
303	44.0873	-89.1147
304	44.0870	-89.1147
305	44.0867	-89.1147
306	44.0864	-89.1147

Site	Latitude	Longitude
307	44.0862	-89.1147
308	44.0859	-89.1147
309	44.0856	-89.1147
310	44.0895	-89.1142
311	44.0892	-89.1142
312	44.0890	-89.1143
313	44.0887	-89.1143
314	44.0884	-89.1143
315	44.0881	-89.1143
316	44.0878	-89.1143
317	44.0876	-89.1143
318	44.0873	-89.1143
319	44.0870	-89.1143
320	44.0867	-89.1143
321	44.0864	-89.1143
322	44.0862	-89.1143
323	44.0859	-89.1143
324	44.0856	-89.1143
325	44.0853	-89.1143
326	44.0895	-89.1139
327	44.0892	-89.1139
328	44.0889	-89.1139
329	44.0887	-89.1139
330	44.0884	-89.1139
331	44.0881	-89.1139
332	44.0878	-89.1139
333	44.0876	-89.1139
334	44.0873	-89.1139
335	44.0870	-89.1139
336	44.0867	-89.1139
337	44.0864	-89.1139
338	44.0862	-89.1139
339	44.0859	-89.1139
340	44.0856	-89.1139
341	44.0853	-89.1139
342	44.0892	-89.1135
343	44.0889	-89.1135
344	44.0887	-89.1135
345	44.0884	-89.1135
346	44.0881	-89.1135
347	44.0878	-89.1135
348	44.0875	-89.1135
349	44.0873	-89.1135
350	44.0870	-89.1135
351	44.0867	-89.1135
352	44.0864	-89.1135
353	44.0862	-89.1135
354	44.0859	-89.1135
355	44.0856	-89.1135
356	44.0853	-89.1135
357	44.0892	-89.1131
358	44.0889	-89.1131
359	44.0887	-89.1131
360	44.0884	-89.1131
361	44.0881	-89.1131
362	44.0878	-89.1131
363	44.0875	-89.1131
364	44.0873	-89.1131
365	44.0870	-89.1131
366	44.0867	-89.1131
367	44.0864	-89.1131
368	44.0862	-89.1131
369	44.0859	-89.1131
370	44.0856	-89.1131
371	44.0853	-89.1131
372	44.0889	-89.1127
373	44.0887	-89.1127
374	44.0884	-89.1127
375	44.0881	-89.1127
376	44.0878	-89.1127
377	44.0875	-89.1127
378	44.0873	-89.1127
379	44.0870	-89.1127
380	44.0867	-89.1127
381	44.0864	-89.1127
382	44.0861	-89.1127
383	44.0859	-89.1128
384	44.0856	-89.1128
385	44.0853	-89.1128
386	44.0850	-89.1128
387	44.0887	-89.1123
388	44.0884	-89.1123
389	44.0881	-89.1123
390	44.0878	-89.1123
391	44.0875	-89.1123
392	44.0873	-89.1123
393	44.0870	-89.1123
394	44.0867	-89.1124
395	44.0864	-89.1124
396	44.0861	-89.1124
397	44.0859	-89.1124
398	44.0856	-89.1124
399	44.0853	-89.1124
400	44.0850	-89.1124
401	44.0881	-89.1119
402	44.0878	-89.1119
403	44.0875	-89.1120
404	44.0873	-89.1120
405	44.0870	-89.1120
406	44.0867	-89.1120
407	44.0864	-89.1120
408	44.0861	-89.1120
409	44.0859	-89.1120
410	44.0856	-89.1120
411	44.0853	-89.1120
412	44.0878	-89.1116
413	44.0875	-89.1116
414	44.0873	-89.1116
415	44.0870	-89.1116
416	44.0867	-89.1116
417	44.0864	-89.1116
418	44.0861	-89.1116
419	44.0859	-89.1116
420	44.0875	-89.1112
421	44.0873	-89.1112
422	44.0870	-89.1112
423	44.0867	-89.1112

Appendix C

- 2010 aquatic plant survey data for Pearl Lake, Waushara County, WI.

Aquatic plant species key:

FIAL	filamentous algae
CEDE	*Ceratophyllum demersum*, Coontail
CHAR	*Chara* sp, Muskgrasses
ELCA	*Elodea canadensis*, Common waterweed
HEDU	*Heteranthera dubia*, Water star-grass
MOSS	moss
MYSI	*Myriophyllum sibiricum*, Northern water milfoil
MYSP	*Myriophyllum spicatum*, Eurasian water-milfoil
NAFL	*Najas flexilis*, Bushy pondweed
NITE	*Nitella* sp., Nitella
POAM	*Potamogeton amplifolius*, Large-leaf pondweed
POFO	*Potamogeton foliosus*, Leafy pondweed
POFR	*Potamogeton friesii*, Frie's pondweed
POGR	*Potamogeton gramineus*, Variable pondweed
POIL	*Potamogeton illinoensis*, Illinois pondweed
PONA	*Potamogeton natans*, Floating-leaf pondweed
POPU	*Potamogeton pusillus*, Small pondweed
POZO	*Potamogeton* zosteriformis, Flat-stem pondweed
SCTA	*Schoenoplectus tabernaemontani*, Softstem bulrush
SCAM	*Scirpus americanus*, Three Square
STPE	*Stuckenia pectinata*, Sago pondweed
VAAM	*Vallisneria americana*, Wild celery

sampling point	Depth (ft)	comments	FIAL	CEDE	CHAR	ELCA	HEDU	MOSS	MYSI	MYSP	NAFL	NITE	POAM	POFO	POFR	POGR	POIL	PONA	POPU	POZO	SCTA	SCAM	STPE	VAAM
1	5				2													1						
2	16			1																				
3	24.1	No Plants																						
4	8.1				v											v			1					
5	2.5		1		1	3														1				
6	5				1	1											1			1				
7	1.8				1																			
8	22.7				1																			
9	31	No Plants																						
10	32.5	No Plants																						
11	27.5	No Plants																						
12	4.8				2				1										1	1				
13	1		v		v																			
14	6.6				1								1											
15	15.6				1																			
16	11.5	No Plants																						
17	29.5	No Plants																						
18	36.1	No Plants																						
19	37.8	No Plants																						
20	33.5	No Plants																						
21	22	No Plants																						
22	0.5				v																			
23	3.3		1		1																			
24	17.3				1																			
25	22				1																			
26	29.8	No Plants																						
27	35.1	No Plants																						
28	40	No Plants																						
29	40.8	No Plants																						
30	38.1	No Plants																						
31	15.5				1																			
31	31.1	No Plants																						
33	3.7								1	v	1		1	1	1	1		v		1				
34	19.8				1																			
35	26	No Plants																						
36	32.4	No Plants																						
37	36.6	No Plants																						
38	41.1	No Plants																						
39	42.6	No Plants																						
40	41.8	No Plants																						
41	34.2	No Plants																						
42	27.8	No Plants																						
43	2										v													
44	8.9				2											v								
45	24.1				2																			
46	31.7	No Plants																						
47	36.1	No Plants																						

sampling point	Depth (ft)	comments	FIAL	CEDE	CHAR	ELCA	HEDU	MOSS	MYSI	MYSP	NAFL	NITE	POAM	POFO	POFR	POGR	POIL	PONA	POPU	POZO	SCTA	SCAM	STPE	VAAM
48	39.1	No Plants																						
49	42.1	No Plants																						
50	44	No Plants																						
51	44.2	No Plants																						
52	40.4	No Plants																						
53	32.4	No Plants																						
54	24.3				1																			
55	2										1													
56	9.2				1					1														
57	26.3	No Plants																						
58	32.8	No Plants																						
59	37.4	No Plants																						
60	38.6	No Plants																						
61	42.1	No Plants																						
62	44.4	No Plants																						
63	45	No Plants																						
64	42.5	No Plants																						
65	39	No Plants																						
66	28.1	No Plants																						
67	21.8				1																			
68	16.5		1		1																			
69	26	No Plants																						
70	32	No Plants																						
71	35.5	No Plants																						
72	39.4	No Plants																						
73	43.4	No Plants																						
74	45	No Plants																						
75	45.8	No Plants																						
76	46	No Plants																						
77	41.8	No Plants																						
78	31.5	No Plants																						
79	22.1				1																			
80	1.5		1		v																			
81	22.5				1																			
82	29.4	No Plants																						
83	33.7	No Plants																						
84	38.8	No Plants																						
85	43.1	No Plants																						
86	45.4	No Plants																						
87	45.5	No Plants																						
88	45.5	No Plants																						
89	43.1	No Plants																						
90	37.1	No Plants																						
91	30.1	No Plants																						
92	12.4						1		1		1													
93	3.2		v																					
94	24.1				1																			

sampling point	Depth (ft)	comments	FIAL	CEDE	CHAR	ELCA	HEDU	MOSS	MYSI	MYSP	NAFL	NITE	POAM	POFO	POFR	POGR	POIL	PONA	POPU	POZO	SCTA	SCAM	STPE	VAAM
95	29.8	No Plants																						
96	35	No Plants																						
97	40.1	No Plants																						
98	44.1	No Plants																						
99	44.1	No Plants																						
100	43.5	No Plants																						
101	41.6	No Plants																						
102	36.1	No Plants																						
103	31.5	No Plants																						
104	16.9				1																			
105	1	No Plants																						
106	21.7				1																			
107	28.1	No Plants																						
108	33.9	No Plants																						
109	37.5	No Plants																						
110	40.2	No Plants																						
111	42.5	No Plants																						
112	41.5	No Plants																						
113	38.8	No Plants																						
114	34.4	No Plants																						
115	31.1	No Plants																						
116	24.8				1																			
117	2.5		v		1				v						1	v								
118	2.5				1																			
119	16.1				3																			
120	29.5	No Plants																						
121	28.8	No Plants																						
122	29.1	No Plants																						
123	33.3	No Plants																						
124	36.1	No Plants																						
125	37.5	No Plants																						
126	35.6	No Plants																						
127	32.5	No Plants																						
128	29.5	No Plants																						
129	25.5	No Plants																						
130	5.2				1				1							v		1		1				
131	6.3		1		2					1														
132	16.2		1		3																			
133	21.5				1																			
134	22.7							2																
135	25	No Plants																						
136	30.6	No Plants																						
137	32.5	No Plants																						
138	32.4	No Plants																						
139	30.4	No Plants																						
140	27.5	No Plants																						
141	27.4	No Plants																						

sampling point	Depth (ft)	comments	FIAL	CEDE	CHAR	ELCA	HEDU	MOSS	MYSI	MYSP	NAFL	NITE	POAM	POFO	POFR	POGR	POIL	PONA	POPU	POZO	SCTA	SCAM	STPE	VAAM
142	22.5				2																			
143	0.5				1						1											v		1
144	8.1				3						1					v		v						
145	19.4				1																			
146	22.1				1																			
147	22	No Plants																						
148	21.7											1												
149	20.3																							
150	24.1				2																			
151	22.7				3																			
152	27.4	No Plants																						
153	24.6				1																			
154	17.6				1																			
155		Terrestrial																						
156	0.5										1											v		
157	5.1		1							1													1	
158	26.6	No Plants																						
159	20		1		2																			
160	2				1						1													
161	1		1		1				1		1											v		
162	21				3																			
163	24.4				1																			
164	19.6				1																			
165	6.2		1								1					1				1				
166	2.9		1		1						1					v								
167	5.3				2													1						
168	2.5				1						1													
169		Terrestrial																						
170	5.2		1		1				1									v						
171	18				3																			
172	23.6				2							1												
173	23				1																			
174	20.6							1																
175	17.8				2																			
176	18.2				3																			
177	17.5				3				1															
178	8.6								1											1				
179	2.6				1				v					3						1			v	
180	3				1						1					1						v		
181	12.6				2													v						
182	17.1				1				1															
183	25.1	No Plants																						
184	25.8	No Plants																						
185	21.8				2																			
186	20.7	No Plants																						
187	19.3				1																			
188	16.8			1	1				1															

sampling point	Depth (ft)	comments	FIAL	CEDE	CHAR	ELCA	HEDU	MOSS	MYSI	MYSP	NAFL	NITE	POAM	POFO	POFR	POGR	POIL	PONA	POPU	POZO	SCTA	SCAM	STPE	VAAM
189	5				1						1													
190	4				3																			
191	11.5				2											1								
192	25.4	No Plants																						
193	26.9	No Plants																						
194	27.4	No Plants																						
195	24.5							1																
196	20.7	No Plants																						
197	18.2				2																			
198	11.1				3				1											1				
199	2				v																			
200	14.4				1				1							1								
201	22.5				1							1												
202	28.1	No Plants																						
203	28.4	No Plants																						
204	26.1	No Plants																						
205	21.9			2																				
206	17.4				1																			
207	9				1				1															
208	2.4				1						1							1						
209	20.6				2																			
210	25.2							1																
211	28	No Plants																						
212	27	No Plants																						
213	22				1																			
214	15.3			1																				
215	3.9	No Plants																						
216	8				2						1							v						
217	23.1	No Plants																						
218	27.4	No Plants																						
219	26.9	No Plants																						
220	20.6	No Plants																						
221	14.4				2																			
222	5.7	No Plants																						
223	0.5	No Plants																						
224	20.9			2																				
225	23.4				1																			
226	28	No Plants																						
227	22.9				1			2																
228	19				1																			
229	18.1				1																			
230	17.7				1	1			1		1													
231	14.7				1																			
232	6.4				1				1										1	1				1
233	1.9				1						1											v		
234	11.6				1																			
235	23.6							2																

sampling point	Depth (ft)	comments	FIAL	CEDE	CHAR	ELCA	HEDU	MOSS	MYSI	MYSP	NAFL	NITE	POAM	POFO	POFR	POGR	POIL	PONA	POPU	POZO	SCTA	SCAM	STPE	VAAM
236	28.2	No Plants																						
237	24.6							1																
238	19				3																			
239	17.7				2																			
240	20.9	No Plants																						
241	18.4				2																			
242	16.3			2					1															
243	1																				v	v		
244	13				1						1													
245	22.2				1																			
246	29.1	No Plants																						
247	31.6	No Plants																						
248	30.7	No Plants																						
249	25.4							1																
250	24.4							1				1												
251	24.4				1																			
252	20.3	No Plants																						
253	14.2			1	1				1		1													
254	1																					v		
255	3.8				2						1							1						
256	21.3				2																			
257	27.1	No Plants																						
258	30.1	No Plants																						
259	34.5	No Plants																						
260	33.7	No Plants																						
261	31.7	No Plants																						
262	29.8	No Plants																						
263	25.1				1																			
264	20.3				2																			
265	11.2				2						1					1								
266	1.5				v						1											v		
267	10.4				1																			
268	21.8				1																			
269	29.1	No Plants																						
270	34	No Plants																						
271	35.4	No Plants																						
272	37.2	No Plants																						
273	36.7	No Plants																						
274	35.6	No Plants																						
275	32.6	No Plants																						
276	27.2	No Plants																						
277	19.8				1																			
278	10.7				1						1													1
279	1.2	No Plants																						
280	5						1										1						1	
281	16.1				1																			
282	20.2	No Plants																						

sampling point	Depth (ft)	comments	FIAL	CEDE	CHAR	ELCA	HEDU	MOSS	MYSI	MYSP	NAFL	NITE	POAM	POFO	POFR	POGR	POIL	PONA	POPU	POZO	SCTA	SCAM	STPE	VAAM
283	28.8	No Plants																						
284	33.9	No Plants																						
285	36.6	No Plants																						
286	38.3	No Plants																						
287	38.9	No Plants																						
288	39	No Plants																						
289	39.8	No Plants																						
290	37.8	No Plants																						
291	32.2	No Plants																						
292	21.5				1																			
293	9.5										1					1							1	
294	1.9				1											1								
295	7.8														1					1				1
296	19.9				1																			
297	24.8							1																
298	30.9	No Plants																						
299	36.2	No Plants																						
300	39.3	No Plants																						
301	39.7	No Plants																						
302	40	No Plants																						
303	40.4	No Plants																						
304	41.1	No Plants																						
305	39.2	No Plants																						
306	33.9	No Plants																						
307	18.7				1																			
308	8.4				1						1								1					
309	2.4				1		1																	
310	10		1		1																			1
311	20.2			1				1																
312	23.5							1																
313	30	No Plants																						
314	35.7	No Plants																						
315	40.1	No Plants																						
316	40.1	No Plants																						
317	41.8	No Plants																						
318	42.2	No Plants																						
319	42	No Plants																						
320	41.3	No Plants																						
321	36.3	No Plants																						
322	30	No Plants																						
323	19.9	No Plants																						
324	9.1				2																			
325	1	No Plants																						
326	6.8								1								1	v					1	1
327	21.4				1																			
328	24.5				1			1																
329	28.2	No Plants																						

sampling point	Depth (ft)	comments	FIAL	CEDE	CHAR	ELCA	HEDU	MOSS	MYSI	MYSP	NAFL	NITE	POAM	POFO	POFR	POGR	POIL	PONA	POPU	POZO	SCTA	SCAM	STPE	VAAM
330	33	No Plants																						
331	38.5	No Plants																						
332	41.1	No Plants																						
333	41.5	No Plants																						
334	41.8	No Plants																						
335	42	No Plants																						
336	40.5	No Plants																						
337	36.8	No Plants																						
338	29.6	No Plants																						
339	24.8							1																
340	17.9				1																			
341	1	No Plants																						
342	13.1				1				1		1					1							1	
343	22							2																
344	26.6	No Plants																						
345	31	No Plants																						
346	36	No Plants																						
347	40.3	No Plants																						
348	40.8	No Plants																						
349	40.8	No Plants																						
350	40.5	No Plants																						
351	38.7	No Plants																						
352	35	No Plants																						
353	32	No Plants																						
354	27.5	No Plants																						
355	21.8				1																			
356	4.8				1						1				1		v							
357	1										v											1		
358	8.9	No Plants																						
359	19.5				1																			
360	23.8				3																			
361	28.8	No Plants																						
362	33.9	No Plants																						
363	36.1	No Plants																						
364	37.8	No Plants																						
365	39.2	No Plants																						
366	38.2	No Plants																						
367	35	No Plants																						
368	30.8	No Plants																						
369	25.6	No Plants																						
370	21.5				1																			
371	5.6				1											1								
372	1.5				1											1								
373	4.5				1											1								
374	17.9	No Plants																						
375	24.5							2																
376	28	No Plants																						

sampling point	Depth (ft)	comments	FIAL	CEDE	CHAR	ELCA	HEDU	MOSS	MYSI	MYSP	NAFL	NITE	POAM	POFO	POFR	POGR	POIL	PONA	POPU	POZO	SCTA	SCAM	STPE	VAAM
377	32.3	No Plants																						
378	33.5	No Plants																						
379	36.6	No Plants																						
380	35.9	No Plants																						
381	34.4	No Plants																						
382	30.4	No Plants																						
383	24.9				1																			
384	20.2				1																			
385	12.3															v		v						
386	0.5	No Plants																			v			
387	0.5	No Plants																						
388	4.1				1																			
389	19.8				1																			
390	21.5				2																			
391	23.4				1			2																
392	29.5	No Plants																						
393	32.6	No Plants																						
394	33.7	No Plants																						
395	32.6	No Plants																						
396	29.2	No Plants																						
397	26.5	No Plants																						
398	20				3																			
399	10.1				1				1															
400	3.4				1				1							1								
401	2.4				1																			
402	5.1				1														1					
403	20.2				3																			
404	21.5				1																			
405	27.7	No Plants																						
406	30.1	No Plants																						
407	30.3	No Plants																						
408	28.4	No Plants																						
409	22.6		1	1																				
410	7.6				1				v							v		v						
411	2				1																			
412	1.5										v					1								
413	6.9				1				1		1					1		1	1					
414	19.2				1																			
415	16.3				2																			
416	24.4				1																			
417	19				1																			
418	20.4			1	1																			
419	2.6				1						1					v								
420	0.5	No Plants																						
421	1.7				1																			
422	1.8				1																			
423	3				1											v								

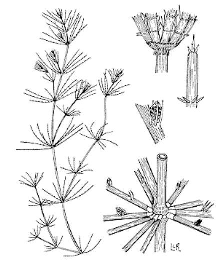
Appendix D

- The Importance of Aquatic Plants

The Importance of Aquatic Plants

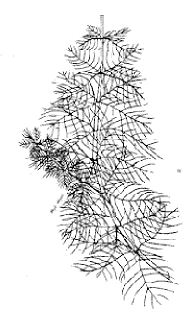
Plant information was gathered from Borman et al. (1997), Eggers and Reed (1997), Fasset (1940), Fink (1994), Nichols and Vennie (1991), and Whitley et al. (1999).

Muskgrass (*Chara* spp.) and **stonewort** (*Nitella* spp.) are complex algae that resemble higher plants. They are similar in appearance, but muskgrass is identified by its pungent, skunk-like odor. Both have whorls of branched leaves. Ecologically, musk grass provides shelter for juvenile fish and is associated with black crappie spawning sites. Waterfowl love to feast on musk grass when the plant bears its seed-like oogonia. This species serves an important role in stabilizing bottom sediments, tying up nutrients in the water column, and maintaining water clarity.



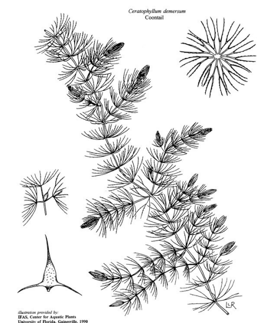
Slender naiad (*Najas flexilis*) also known as **bushy pondweed** has a finely branched stem that grows from a rootstock. Leaves are short (1-4 cm), pointed and grow in pairs. Bushy pondweed is an annual and must grow from seed each year. It tends to establish well in disturbed areas. Bushy pondweed is a one of waterfowl's favorite foods and considered very important. Waterfowl, marsh birds, and muskrats relish seeds, leaves and stems. Bushy pondweed stabilizes bottom sediment and offers cover for fish.

Northern Watermilfoil (*Myriophyllum sibiricum*) produces whorls of feather-like leaflets from a fairly stout stem. Northern watermilfoil is identified by its 5 to 12 pairs of leaflets that become progressively longer near the base of the leaf – giving the leaf a candelabra-like appearance. The leaves and fruit of this plant are eaten by a variety of waterfowl. Its finely divided leaves are habitat for numerous invertebrates that fish feed upon. Northern watermilfoil is an indicator of good water quality, as the plant seldom survives in more eutrophic environments.



Variable Pondweed (*Potamogeton gramineus*) is a perennial herb that emerges from a rhizome. It has a leafy appearance with many linear to lance-shaped leaves lacking stalks. The length and width of the leaves can vary from plant to plant and lake to lake. It is usually found in firm sediment. The fruits and tubers of variable pondweed are eaten by ducks and geese. Muskrats, and beaver feed on most parts of this plant. Variable pondweed also provides cover for fish and invertebrates.

Flat-stem Pondweed (*Potamogeton zosteriformis*) emerges from a rhizome, which has strongly flattened stems. The leaves are narrow and grow 4-8 inches long. Leaves contain a prominent mid-vein and many fine parallel veins. Ecologically, flat-stem pondweed provides a home for fish and invertebrates, and is grazed by waterfowl and muskrats.



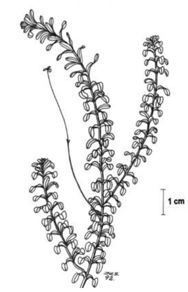
Coontail *(Ceratophyllum demersum)* produces whorls of narrow, toothed leaves on a long trailing stem that often resembles the tail of a raccoon. The leaves tend to be more crowded toward the tip. Coontail blankets the bottom, which helps to stabilize bottom sediments. Tolerant to nutrient rich environments, coontail filters a high amount of phosphorus out of the water column. Coontail provides a home for invertebrates and juvenile fish. Seeds are consumed by waterfowl, but are not of high preference.

Small pondweed (*Potamogeton pusillus*) has slender stems which emerge form a slight rhizome that branches repeatedly. Submersed leaves are linear and attach directly to the stem. Small pondweed is very similar to many other fine-leaved pondweeds. Small pondweed can grow in turbid conditions. Small pondweed can be a valuable food source for waterfowl and a number of mammals. It can also provide a home for fish and invertebrates.

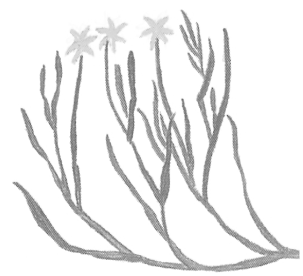
Wild Celery (*Vallisneria americana*) also known as **eelgrass** has long ribbon-like leaves that emerge in clusters. Leaves have a prominent central stripe and leaf tips tend to float gracefully at the water's surface. In the fall, a vegetative portion of the rhizome will break free and float to other locations. Wild celery is considered one of the best all natural waterfowl foods. The entire plant is relished by waterfowl, especially canvasbacks. Eelgrass beds serve as an important food source for sea ducks, marsh birds, and shore birds. Fish also find wild celery to be a popular hiding spot.

Sago Pondweed (*Potamogeton pectinatus*) is a perennial herb that emerges from a slender rhizome that contains many starchy tubers. Leaves are sharp, thin, and resemble a pine needle. Reddish nutlets (seeds) that resemble beads on a string rise to the water surface in mid-summer. Sago pondweed produces a large crop of seeds and tubers that are valued by waterfowl. Juvenile fish and invertebrates utilize sago pondweed for cover.

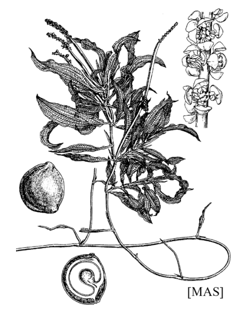
Elodea (*Elodea canadensis*) or **common waterweed** is made up of slender stems with small, lance-shaped leaves that attach directly to the stem. Leaves are found in whorls of two or three and are more crowded toward the stem tip. The branching stems of elodea provide valuable cover for fish and are home for many insects that fish feed upon. Elodea also provides food for muskrats and waterfowl.



Water Stargrass (*Heteranthera dubia*) resembles some of the narrow-leaved pondweeds. It is dark green to brown with thread-like leaves scattered on flexible stems. A close examination of the leaves will show that they have several veins but no obvious midvein. It reproduces from plant fragments. Water stargrass usually becomes abundant in late summer. It settles to the bottom in late autumn where it forms a decaying mat in the winter that provides habitat to many small aquatic animals. Water stargrass provides valuable habitat for fish and serves as a source of macroinvertebrates for fish.

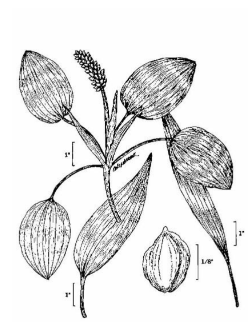


Illinois Pondweed (*Potamogeton illinoiensis*) is a perennial herb that emerges from a rhizome. Its stout stems support lance-shaped leaves that come to a sharp point. Illinois pondweed provides excellent cover for fish and invertebrates. Ducks, geese, muskrats, and beaver find most parts of this plant to be a tasty meal.

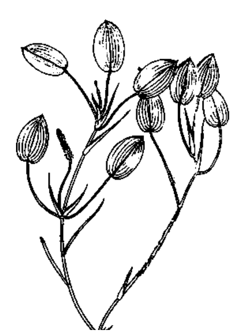


Floating Leaf Plants - Plants that have leaves that float at the water's surface.

Large-Leaf Pondweed (*Potamogeton amplifolius*) also referred to by fisherman as **cabbage weed**, is a perennial herb that emerges from a ridged black rhizome. This pondweed is the largest of all pondweeds. The sturdy stem supports large broad leaves that are numerously veined (25-37). Growing upright throughout most of the water column, large-leaf pondweed provides excellent shade, shelter, and foraging habitat for fish. Producing a large number of nutlets, cabbage weed is also valued by waterfowl.



Floating Leaf Pondweed (*Potamogeton natans*) is a perennial that emerges from a red-spotted rhizome. Leaves that rest at the waters surface are heart shaped. Submerged leaves tend to be longer and skinnier than floating leaves. Fish find this pondweed to be useful for foraging opportunities and shelter. Growing upright in the water column, floating leaf pondweed attracts many aquatic invertebrates. Muskrats, ducks, and geese all graze on the plant.



Appendix E

- 2010 water quality data for Pearl Lake, Waushara County, WI.

DATE	Chlorophyll ug/L	Chlorophyll TSI	Total Phosphorus mg/L	Phosphorus TSI	Secchi depth m	Secchi TSI	Average TSI
3/2/1976	--	--	0.019	*46.61*	--	--	*46.61*
5/13/1976	--	--	0.013	*41.14*	6.00	*34.18*	*37.66*
8/12/1976	--	--	0.15	*76.40*	--	--	*76.40*
11/16/1976	--	--	0.06	*63.19*	--	--	*63.19*
6/19/1986	--	--	--	--	6.40	*33.25*	*33.25*
8/2/1986	--	--	--	--	5.49	*35.47*	*35.47*
8/23/1986	--	--	--	--	4.88	*37.17*	*37.17*
9/6/1986	--	--	--	--	4.27	*39.09*	*39.09*
9/13/1986	--	--	--	--	4.11	*39.62*	*39.62*
9/27/1986	--	--	--	--	4.27	*39.09*	*39.09*
10/11/1986	--	--	--	--	4.42	*38.59*	*38.59*
10/19/1986	--	--	--	--	5.26	*36.08*	*36.08*
11/2/1986	--	--	--	--	3.96	*40.16*	*40.16*
11/16/1986	--	--	--	--	4.57	*38.10*	*38.10*
4/5/1987	--	--	--	--	4.42	*38.59*	*38.59*
4/12/1987	--	--	--	--	4.88	*37.17*	*37.17*
4/18/1987	--	--	--	--	5.11	*36.51*	*36.51*
4/26/1987	--	--	--	--	7.62	*30.74*	*30.74*
5/10/1987	--	--	--	--	9.45	*27.64*	*27.64*
5/23/1987	--	--	--	--	10.21	*26.52*	*26.52*
6/6/1987	--	--	--	--	8.84	*28.60*	*28.60*
6/13/1987	--	--	--	--	9.45	*27.64*	*27.64*
6/28/1987	--	--	--	--	6.55	*32.91*	*32.91*
7/3/1987	--	--	--	--	5.94	*34.32*	*34.32*
7/11/1987	--	--	--	--	5.56	*35.27*	*35.27*
7/25/1987	--	--	--	--	5.03	*36.72*	*36.72*
8/1/1987	--	--	--	--	5.49	*35.47*	*35.47*
8/29/1987	--	--	--	--	3.81	*40.72*	*40.72*
9/6/1987	--	--	--	--	3.81	*40.72*	*40.72*
9/13/1987	--	--	--	--	4.27	*39.09*	*39.09*
9/16/1987	--	--	--	--	4.27	*39.09*	*39.09*
10/30/1987	--	--	--	--	4.19	*39.35*	*39.35*
5/1/1988	--	--	--	--	7.32	*31.32*	*31.32*
5/21/1988	--	--	--	--	11.43	*24.89*	*24.89*
5/28/1988	--	--	--	--	9.22	*27.99*	*27.99*
6/11/1988	--	--	--	--	8.08	*29.90*	*29.90*
6/18/1988	--	--	--	--	7.85	*30.31*	*30.31*
7/9/1988	--	--	--	--	5.03	*36.72*	*36.72*
7/30/1988	--	--	--	--	5.03	*36.72*	*36.72*
8/6/1988	--	--	--	--	4.57	*38.10*	*38.10*
8/13/1988	--	--	--	--	4.50	*38.34*	*38.34*
8/21/1988	--	--	--	--	4.57	*38.10*	*38.10*
9/4/1988	--	--	--	--	4.57	*38.10*	*38.10*
9/10/1988	--	--	--	--	4.11	*39.62*	*39.62*
9/25/1988	--	--	--	--	5.03	*36.72*	*36.72*
10/2/1988	--	--	--	--	5.03	*36.72*	*36.72*
10/22/1988	--	--	--	--	4.11	*39.62*	*39.62*
5/7/1989	--	--	--	--	9.60	*27.41*	*27.41*
5/29/1989	--	--	--	--	8.08	*29.90*	*29.90*

DATE	Chlorophyll ug/L	Chlorophyll TSI	Total Phosphorus mg/L	Phosphorus TSI	Secchi depth m	Secchi TSI	Average TSI
6/10/1989	--	--	--	--	10.74	*25.79*	*25.79*
6/21/1989	--	--	--	--	9.75	*27.18*	*27.18*
7/4/1989	--	--	--	--	7.62	*30.74*	*30.74*
7/16/1989	--	--	--	--	7.47	*31.03*	*31.03*
7/30/1989	--	--	--	--	6.55	*32.91*	*32.91*
8/27/1989	--	--	--	--	5.79	*34.69*	*34.69*
10/8/1989	--	--	--	--	3.81	*40.72*	*40.72*
5/6/1990	--	--	--	--	7.77	*30.45*	*30.45*
6/16/1990	--	--	--	--	9.37	*27.75*	*27.75*
6/30/1990	--	--	--	--	7.77	*30.45*	*30.45*
8/4/1990	--	--	--	--	5.41	*35.67*	*35.67*
8/11/1990	--	--	--	--	5.18	*36.29*	*36.29*
9/1/1990	--	--	--	--	4.34	*38.84*	*38.84*
9/16/1990	--	--	--	--	4.34	*38.84*	*38.84*
4/27/1991	--	--	--	--	7.32	*31.32*	*31.32*
5/11/1991	--	--	--	--	9.53	*27.52*	*27.52*
5/26/1991	--	--	--	--	7.77	*30.45*	*30.45*
6/16/1991	--	--	--	--	8.15	*29.76*	*29.76*
6/29/1991	--	--	--	--	8.00	*30.03*	*30.03*
7/7/1991	--	--	--	--	6.71	*32.58*	*32.58*
8/11/1991	--	--	--	--	5.49	*35.47*	*35.47*
9/1/1991	--	--	--	--	4.72	*37.63*	*37.63*
9/7/1991	--	--	--	--	4.34	*38.84*	*38.84*
9/28/1991	--	--	--	--	4.11	*39.62*	*39.62*
6/14/1992	--	--	--	--	8.08	*29.90*	*29.90*
6/30/1992	--	--	--	--	6.93	*32.10*	*32.10*
7/11/1992	--	--	--	--	8.61	*28.98*	*28.98*
7/31/1992	--	--	--	--	7.16	*31.63*	*31.63*
8/9/1992	--	--	--	--	6.55	*32.91*	*32.91*
7/7/1993	--	--	--	--	7.01	*31.94*	*31.94*
8/7/1993	--	--	--	--	5.18	*36.29*	*36.29*
8/21/1993	--	--	--	--	5.49	*35.47*	*35.47*
9/4/1993	--	--	--	--	5.49	*35.47*	*35.47*
10/24/1993	--	--	--	--	6.40	*33.25*	*33.25*
6/20/1994	--	--	--	--	7.01	*31.94*	*31.94*
7/30/1994	--	--	--	--	6.40	*33.25*	*33.25*
8/6/1994	--	--	--	--	5.79	*34.69*	*34.69*
9/4/1994	--	--	--	--	6.10	*33.95*	*33.95*
6/11/1995	--	--	--	--	8.53	*29.10*	*29.10*
7/9/1995	--	--	--	--	7.62	*30.74*	*30.74*
8/11/1995	--	--	--	--	6.10	*33.95*	*33.95*
9/17/1995	--	--	--	--	4.57	*38.10*	*38.10*
5/26/1996	--	--	--	--	9.14	*28.11*	*28.11*
6/29/1996	--	--	--	--	7.92	*30.17*	*30.17*
7/7/1996	--	--	--	--	8.23	*29.63*	*29.63*
8/13/1996	--	--	--	--	4.72	*37.63*	*37.63*
10/15/1996	--	--	--	--	4.57	*38.10*	*38.10*
4/25/1997	--	--	0.008	*34.14*	7.16	*31.63*	*32.88*
5/11/1997	--	--	--	--	9.14	*28.11*	*28.11*

DATE	Chlorophyll ug/L	Chlorophyll TSI	Total Phosphorus mg/L	Phosphorus TSI	Secchi depth m	Secchi TSI	Average TSI
6/17/1997	1.23	32.63	0.005	27.36	8.84	28.60	29.53
7/11/1997	1.54	34.84	0.012	39.98	7.32	31.32	35.38
8/18/1997	1.97	37.25	0.008	34.14	7.32	31.32	34.24
10/15/1997	3.88	43.90	0	--	4.88	37.17	40.53
4/18/1998		--	0.006	29.99	9.14	28.11	29.05
6/16/1998	1.1	31.53	ND	--	7.92	30.17	30.85
7/15/1998	1.12	31.71	<0.005	--	6.71	32.58	32.15
8/18/1998	2.17	38.20	0.006	29.99	5.49	35.47	34.55
10/10/1998	3.51	42.92	0.01	37.35	4.57	38.10	39.46
4/14/1999		--	0.007	32.21	4.57	38.10	35.15
6/17/1999	0.75	27.78	ND	--	7.16	31.63	29.70
7/22/1999	0.98	30.40	ND	--	6.10	33.95	32.18
8/20/1999	1.68	35.69	0.008	34.14	4.27	39.09	36.31
10/18/1999	3	41.38	0.011	38.73	4.72	37.63	39.24
3/27/2000		--	0.016	44.13	3.81	40.72	42.43
6/19/2000	1.1	31.53	0.005	27.36	7.01	31.94	30.28
6/27/2000		--	--	--	6.71	32.58	32.58
7/13/2000	1.2	32.39	0.006	29.99	6.10	33.95	32.11
7/29/2000		--	--	--	5.49	35.47	35.47
8/14/2000	1.3	33.17	0.008	34.14	4.27	39.09	35.47
8/30/2000		--	--	--	4.88	37.17	37.17
9/15/2000		--	--	--	4.27	39.09	39.09
10/1/2000		--	--	--	4.57	38.10	38.10
10/17/2000	3	41.38	0.01	37.35	4.88	37.17	38.63
4/24/2001		--	0.007	32.21	8.23	29.63	30.92
6/19/2001	1.3	33.17	0.01	37.35	7.01	31.94	34.16
6/30/2001		--	--	--	8.84	28.60	28.60
7/16/2001	0.5	--	ND	--	7.62	30.74	30.74
8/1/2001		--	--	--	6.40	33.25	33.25
8/17/2001		--	--	--	7.01	31.94	31.94
8/20/2001	1.2	32.39	0.01	37.35	7.32	31.32	33.69
9/2/2001	--	--	--	--	7.01	31.94	31.94
9/18/2001	--	--	--	--	5.18	36.29	36.29
10/10/2001	--	--	--	--	4.27	39.09	39.09
10/17/2001	6	48.18	0.01	37.35	4.27	39.09	41.54
10/20/2001	--	--	--	--	4.11	39.62	39.62
4/24/2002	--	--	0.01	37.35	9.14	28.11	32.73
6/17/2002	--	--	0.008	34.14	9.14	28.11	31.12
7/17/2002	0.5	--	0.006	29.99	7.62	30.74	30.36
8/15/2002	1.72	35.92	0.007	32.21	6.71	32.58	33.57
10/15/2002	5.46	47.25	0.013	41.14	3.96	40.16	42.85
4/22/2003		--	0.01	37.35	6.10	33.95	35.65
6/17/2003	0.94	29.99	0.008	34.14	9.45	27.64	30.59
6/20/2003		--	--	--	9.14	28.11	28.11
7/7/2003		--	--	--	6.40	33.25	33.25
7/16/2003	1.45	34.25	0.009	35.83	5.33	35.88	35.32
8/7/2003		--	--	--	5.18	36.29	36.29
8/23/2003		--	--	--	5.79	34.69	34.69
8/27/2003	1.93	37.05	0.008	34.14	5.56	35.27	35.49

DATE	Chlorophyll ug/L	Chlorophyll TSI	Total Phosphorus mg/L	Phosphorus TSI	Secchi depth m	Secchi TSI	Average TSI
9/8/2003		--	--	--	4.42	*38.59*	*38.59*
9/24/2003		--	--	--	4.50	*38.34*	*38.34*
10/10/2003		--	--	--	4.72	*37.63*	*37.63*
10/15/2003	4.3	*44.91*	0.014	*42.21*	4.88	*37.17*	*41.43*
4/20/2004		--	0.019	*46.61*	7.01	*31.94*	*39.27*
6/14/2004	0.99	*30.50*	0.007	*32.21*	8.23	*29.63*	*30.78*
6/30/2004		--	--	--	8.23	*29.63*	*29.63*
7/8/2004		--	--	--	7.62	*30.74*	*30.74*
7/14/2004	1.04	*30.98*	0.008	*34.14*	7.01	*31.94*	*32.35*
7/16/2004		--	--	--	7.47	*31.03*	*31.03*
7/24/2004		--	--	--	6.40	*33.25*	*33.25*
8/1/2004		--	--	--	6.10	*33.95*	*33.95*
8/9/2004		--	--	--	5.49	*35.47*	*35.47*
8/17/2004	2.42	*39.27*	0.009	*35.83*	5.49	*35.47*	*36.86*
8/25/2004		--	--	--	5.49	*35.47*	*35.47*
9/2/2004		--	--	--	5.49	*35.47*	*35.47*
9/10/2004		--	--	--	5.79	*34.69*	*34.69*
10/13/2004	2.8	*40.70*	0.014	*42.21*	4.95	*36.94*	*39.95*
4/25/2005		--	0.008	*34.14*	6.71	*32.58*	*33.36*
5/24/2005		--	--	--	7.01	*31.94*	*31.94*
6/1/2005		--	--	--	8.84	*28.60*	*28.60*
6/9/2005		--	--	--	8.84	*28.60*	*28.60*
6/17/2005		--	--	--	9.14	*28.11*	*28.11*
6/19/2005	1.03	*30.89*	0.012	*39.98*	9.14	*28.11*	*32.99*
6/25/2005		--	--	--	8.53	*29.10*	*29.10*
7/3/2005		--	--	--	7.32	*31.32*	*31.32*
7/11/2005		--	--	--	5.79	*34.69*	*34.69*
7/18/2005	1.71	*35.86*	0.007	*32.21*	5.49	*35.47*	*34.51*
7/19/2005		--	--	--	5.49	*35.47*	*35.47*
7/27/2005		--	--	--	5.18	*36.29*	*36.29*
8/4/2005		--	--	--	5.18	*36.29*	*36.29*
8/12/2005		--	--	--	5.79	*34.69*	*34.69*
8/15/2005	2.32	*38.86*	0.009	*35.83*	5.79	*34.69*	*36.46*
8/20/2005		--	--	--	5.49	*35.47*	*35.47*
8/28/2005		--	--	--	5.33	*35.88*	*35.88*
9/5/2005		--	--	--	5.18	*36.29*	*36.29*
9/13/2005		--	--	--	5.18	*36.29*	*36.29*
9/21/2005		--	--	--	5.79	*34.69*	*34.69*
10/16/2005	3.58	*43.11*	0.01	*37.35*	5.33	*35.88*	*38.78*
4/14/2006		--	0.013	*41.14*	5.49	*35.47*	*38.30*
6/12/2006	1.25	*32.79*	0.007	*32.21*	7.62	*30.74*	*31.91*
7/15/2006	1.02	*30.79*	0.012	*39.98*	5.18	*36.29*	*35.69*
8/14/2006	1.8	*36.37*	0.011	*38.73*	4.65	*37.86*	*37.65*
10/17/2006	2.65	*40.16*	0.015	*43.20*	4.65	*37.86*	*40.41*
4/30/2007		--	0.008	*34.14*	7.01	*31.94*	*33.04*
6/18/2007	0.85	*29.01*	0.006	*29.99*	5.79	*34.69*	*31.23*
7/21/2007	1.52	*34.71*	0.008	*34.14*	5.33	*35.88*	*34.91*
8/22/2007	3.2	*42.01*	0.008	*34.14*	5.26	*36.08*	*37.41*
10/17/2007		--	--	--	4.42	*38.59*	*38.59*

Pearl Lake (N 44º 5.408 W 89º 7.350')
Depth 13.9 m

Date	April 20, 2010		
Depth (m)	Temp (F.)	D.O. (mg/l)	% Sat.
0	54.5	13.57	127.1
0.5	54.5	13.56	126.6
1	54.5	13.24	123.0
1.5	54.4	12.36	115.4
2	54.0	12.46	116.1
2.5	53.6	12.72	118.1
3	53.0	12.89	118.6
3.5	52.9	12.84	118.2
4	52.8	13.01	119.6
4.5	52.7	13.05	119.7
5	52.4	13.14	119.8
5.5	51.1	12.88	115.9
6	50.7	12.88	115.1
6.5	50.6	12.66	112.8
7	48.9	12.17	106.3
7.5	47.9	11.54	99.2
8	47.2	11.22	95.1
8.5	46.5	11.23	94.6
9	45.3	10.68	88.9
9.5	44.4	8.71	71.5
10	43.9	5.60	45.3
10.5	43.1	0.92	7.2
11	42.7	0.69	5.5
11.5	42.5	0.66	5.2
12	42.5	0.61	4.9
12.5	42.4	0.59	4.7
13	42.3	0.59	4.7
13.5	42.3	0.55	4.6

Pearl Lake
Depth 13.7 m

Date	June 9, 2010		
Depth (m)	Temp (F.)	D.O. (mg/l)	% Sat.
0	69.7	9.38	104.9
0.5	69.5	9.65	108.5
1	69.3	9.92	110.5
1.5	69.3	9.87	109.5
2	69.2	9.90	109.6
2.5	69.2	9.86	109.4
3	69.2	9.82	109.4
3.5	69.1	9.82	109.9
4	68.9	10.01	110.2
4.5	66.8	14.82	157.0
5	64.2	14.95	154.2
5.5	62.7	14.38	144.0
6	61.5	12.95	125.6
6.5	60.2	11.96	119.5
7	59.1	11.91	121.3
7.5	57.8	11.11	109.1
8	57.1	10.72	104.1
8.5	54.7	7.85	79.5
9	52.2	4.37	40.4
9.5	51.2	4.60	22.4
10	49.2	0.65	6.0
10.5	47.9	0.65	5.5
11	47.1	0.63	5.3
11.5	46.3	0.60	5.1
12	45.8	0.66	5.5
12.5	45.4	0.81	6.6
13	45.1	0.41	3.5
13.5	45.0	0.38	3.1
14			

Pearl Lake
Depth 13.7 m

Date	June 30, 2010		
Depth (m)	Temp (F.)	D.O. (mg/l)	% Sat.
0	75.5	9.70	112.9
0.5	75.6	9.00	111.1
1	75.6	8.90	110.1
1.5	75.6	9.08	96.1
2	75.6	8.70	108.5
2.5	75.6	8.90	108.0
3	75.6	8.70	102.3
3.5	75.6	8.50	102.4
4	75.5	9.50	93.0
4.5	73.0	11.82	148.3
5	69.8	15.01	149.1
5.5	67.3	14.80	151.2
6	65.0	13.30	143.0
6.5	63.0	11.53	123.5
7	60.4	9.96	99.1
7.5	58.5	7.60	74.4
8	56.4	7.45	71.4
8.5	54.7	5.30	49.3
9	53.0	3.53	32.4
9.5	51.3	3.08	27.6
10	49.5	1.40	12.3
10.5	48.4	1.36	11.9
11	47.4	2.45	21.9
11.5	46.4	0.53	4.2
12	45.6	0.34	2.8
12.5	45.2	0.30	2.7
13	45.0	0.29	2.4
13.5	44.7	0.28	2.3
14			

Pearl Lake
Depth 13.8 m

Date	July 28, 2010		
Depth (m)	Temp (F.)	D.O. (mg/l)	% Sat.
0	80.3	8.43	104.2
0.5	80.6	8.38	102.8
1	80.6	8.16	102.7
1.5	80.6	7.90	101.5
2	80.6	8.54	106.2
2.5	80.7	8.20	102.5
3	80.6	8.29	97.5
3.5	80.6	7.95	102.1
4	80.6	8.15	104.5
4.5	80.4	8.32	105.5
5	80.0	8.19	106.4
5.5	78.8	7.66	98.7
6	75.8	13.40	165.0
6.5	72.5	12.64	149.3
7	69.0	11.02	121.3
7.5	65.5	7.80	80.2
8	62.8	5.60	59.3
8.5	60.4	6.46	65.9
9	58.0	4.09	47.5
9.5	56.1	2.40	22.6
10	54.3	1.20	10.4
10.5	52.7	0.66	4.1
11	50.0	0.60	5.3
11.5	48.6	0.79	7.5
12	47.6	0.33	2.7
12.5	46.8	0.31	2.6
13	46.2	0.30	2.6
13.5	45.8	0.29	2.4
14			

Pearl Lake
Depth 14.0 m

Date	August 24, 2010		
Depth (m)	Temp (F.)	D.O. (mg/l)	% Sat.
0	78.8	8.70	107.4
0.5	78.9	8.65	104.5
1	78.9	8.50	103.0
1.5	79.0	8.45	101.7
2	79.0	8.31	99.4
2.5	78.9	8.20	98.4
3	78.9	8.20	99.0
3.5	78.8	8.29	99.8
4	78.7	8.20	98.8
4.5	78.6	8.23	97.0
5	78.5	8.10	95.0
5.5	78.2	8.15	96.0
6	78.0	7.80	95.8
6.5	77.5	7.25	86.4
7	74.5	6.20	94.7
7.5	74.0	6.82	72.5
8	66.0	2.70	29.8
8.5	63.2	0.54	5.5
9	60.5	2.23	22.7
9.5	58.1	1.56	14.8
10	55.6	0.96	9.2
10.5	53.5	0.90	8.2
11	51.5	0.86	7.7
11.5	50.0	1.20	9.5
12	49.0	0.40	3.0
12.5	48.0	0.32	2.7
13	46.9	0.31	2.7
13.5	46.4	0.30	2.5
14	45.8	0.29	2.4

Pearl Lake
Depth 13.5 m

Date	September 21, 2010		
Depth (m)	Temp (F.)	D.O. (mg/l)	% Sat.
0	66.8	8.69	93.8
0.5	66.8	8.43	92.5
1	66.7	8.27	89.2
1.5	66.7	8.37	90.7
2	66.7	8.22	89.3
2.5	66.7	8.22	89.2
3	66.7	8.02	86.7
3.5	66.7	7.82	84.7
4	66.7	8.30	89.2
4.5	66.6	8.26	89.5
5	66.6	7.95	86.0
5.5	66.6	7.95	86.0
6	66.6	8.04	86.9
6.5	66.6	8.02	86.9
7	66.6	7.69	85.2
7.5	66.6	7.92	85.7
8	66.5	7.46	80.9
8.5	66.0	5.16	55.3
9	62.6	0.44	4.5
9.5	59.1	0.56	5.6
10	56.5	0.37	3.6
10.5	54.5	0.32	3.0
11	52.6	0.39	3.7
11.5	50.9	0.32	2.9
12	49.4	0.33	2.9
12.5	48.1	0.33	2.8
13	47.3	0.32	2.7
13.5	47.2	0.31	2.6
14			

Pearl Lake
Depth 13.9 m

Date	November 1, 2010		
Depth (m)	**Temp (F.)**	**D.O. (mg/l)**	**% Sat.**
0	52.0	8.62	78.0
0.5	52.4	8.07	73.7
1	52.2	7.77	71.5
1.5	52.5	7.69	70.0
2	52.6	7.49	68.8
2.5	52.8	7.86	72.4
3	52.8	7.51	68.5
3.5	52.8	7.54	69.3
4	52.8	7.44	69.5
4.5	52.8	7.49	68.1
5	52.8	7.40	67.7
5.5	52.8	7.41	67.7
6	52.8	7.45	67.4
6.5	52.8	7.38	68.0
7	52.8	7.39	67.1
7.5	52.8	7.25	65.8
8	52.8	7.25	66.1
8.5	52.8	7.29	66.3
9	52.8	7.23	66.2
9.5	52.8	7.24	66.2
10	52.8	7.22	65.8
10.5	52.8	7.18	65.4
11	52.8	7.15	65.1
11.5	52.8	7.11	65.2
12	52.8	7.17	65.4
12.5	52.7	7.23	66.3
13	52.5	6.97	63.6
13.5	50.2	1.06	8.7
14			

Appendix F

- Threat of exotic aquatic species to Pearl Lake

Exotic Species

It is important that members of the Pearl Lake P & R District familiarize themselves with some of the existing and additional threats posed by invasive species. The following descriptions are given to promote awareness of exotic species.

Eurasian Watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum*) produces long spaghetti-like stems that often grow up to the water's surface. Leaves are feather-like and resemble bones on a fish. Three to five leaves are arranged in whorls around the stem, and each leaf contains 12-21 pairs of leaflets. At mid-summer small reddish flower spikes may emerge above the water's surface. Perhaps the most distinguishing characteristic though, is the plant's ability to form dense, impenetrable beds that inhibit boating, swimming, fishing, and hunting.

Eurasian watermilfoil is native to Europe, Asia and Northern Africa. Of the eight milfoil (*Myriophyllum*) species found in Wisconsin, Eurasian watermilfoil is the only exotic. The plant was first introduced into U.S. waters in 1940. By 1960, it had reached Wisconsin's lakes. Since then, its expansion has been exponential (Brakken, 2000).

Eurasian watermilfoil begins growing earlier than native plants, giving it a competitive advantage. The dense surface mats formed by the plant block sunlight and have been found to displace nearly all native submergent plants. Over 200 studies link declines in native plants with increases in Eurasian watermilfoil (Madsen, 2001). The resultant loss of plant diversity degrades fishery habitat (Pullman, 1993), and reduces foraging opportunities for waterfowl and aquatic mammals. Eurasian watermilfoil has been found to reduce predatory success of fish such as largemouth bass (Engel, 1985), and spawning success for trout (*Salmonidae spp.*) (Newroth, 1985).

The continued spread of Eurasian watermilfoil can produce significant economic consequences. In the Truckee River Watershed below Lake Tahoe, located in western Nevada and northeastern California, economic damages caused by Eurasian watermilfoil to the recreation industry have been projected at $30 to $45 million annually (Eiswerth et al., 2003). In Tennessee Valley Authority Reservoirs, Eurasian watermilfoil was found to depress real estate values, stop recreational activities, clog municipal and industrial water intakes and increase mosquito breeding (Smith, 1971).

Eurasian watermilfoil has been found to reduce water quality in lakes by several means. Dense mats of Eurasian watermilfoil have been found to alter temperature and oxygen profiles – producing anoxic conditions in bottom water layers (Unmuth et al., 2000). These anoxic conditions can cause localized die-offs of mollusks and other invertebrates. Eurasian watermilfoil has also been found to increase phosphorus concentration in lakes through accelerated internal nutrient cycling (Smith and Adams, 1986). Increased phosphorus concentrations released by dead and dying Eurasian watermilfoil have been linked to algae blooms and reduced water clarity.

Eurasian Watermilfoil Management Options

Historically, management of Eurasian watermilfoil has included mechanical, biological, and chemical means. It is important to consider each of these control measures before management efforts on any water body are undertaken. After weighing the pros and cons of each option, the wisest course of action should be chosen.

Hand pulling
Hand pulling of Eurasian watermilfoil is a useful tool when the extent of milfoil occurs at very low frequencies. For this method to be successful care must be taken to remove the entire root mass along with the plant or else it will quickly regenerate. If a pioneering population of Eurasian watermilfoil was found in a small location, this method may be a useful management tool. However, if it is unsuccessful at reducing or eliminating milfoil, other management options should be considered. This is still a viable option for riparian property owners. Without obtaining a permit, individuals can hand pull aquatic plants in a 30-foot strip along their property extending out as far as necessary. If *exotic* plants are singled out for hand removal, there are no restrictions on the extent of hand-pulling. If large amounts of milfoil are present, it will be labor intensive. If individuals choose to hand pull, care should be taken to properly identify Eurasian watermilfoil and minimize its fragmentation.

Mechanical harvesting
Mechanical control methods include hand cutters and boat-mounted mechanical weed harvesters (Nichols, 1974). While these methods provide temporary nuisance relief, they are rarely recommended as control methods for Eurasian watermilfoil. Eurasian watermilfoil can reproduce effectively through fragmentation (Borman et al., 1997). Free-floating plant matter left from cutting operations can spread quickly and encourage additional infestations within the lake or in neighboring lakes.

Although harvesting does remove plant matter, a source of nutrients to the lake, it is unlikely that harvesting will induce a shift back to a native plant-dominated community. It is not recommended that Eurasian watermilfoil be controlled long-term through mechanical harvesting.

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 (*Euhrychiopsis lecontei*) 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). While numerous lakes have attempted stocking milfoil weevils in hopes of controlling milfoil in a more natural manner, this method has not proven successful in

Wisconsin. 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 DNR 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. Recently, however, work carried out on a number of Portage County lakes has shown some promise at enhancing milfoil weevil populations. In order for weevils to be successful in reducing the extent of Eurasian watermilfoil, a number of environmental criteria are needed, including the availability of proper year-round habitat. In the event of milfoil infestation, a survey of existing weevils should be conducted to determine the likelihood of success if weevils were chosen as a management tool.

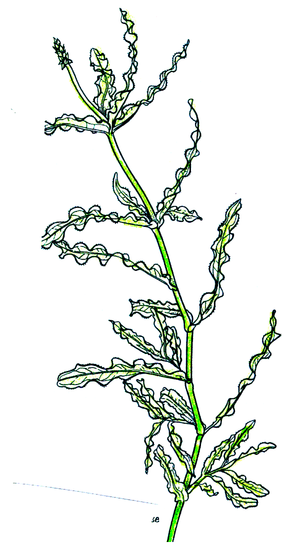
Until more evidence that suggests weevil stocking is an effective control agent for Eurasian watermilfoil, this method should be discouraged as a control option for most lakes.

Herbicides

Herbicides have been the most widely used and often most successful tools for controlling Eurasian watermilfoil. The two herbicide groups most commonly employed are fluridone (Avast®, Sonar®) and 2,4-D (Aquacide®, Aquakleen®, Navigate®, and Weedar 64®). Whole-lake fluridone treatments have been conducted on several Wisconsin Lakes. In addition, for fluridone to be most effective, a relatively long contact time is needed. 2,4-D herbicides, on the other hand, have been very effective at controlling Eurasian watermilfoil in hundreds of Wisconsin lakes. 2,4-D is a herbicide which rapidly breaks down and does not persist in the environment. When applied at labeled rates, 2,4-D has been shown to be an effective tool at selectively controlling Eurasian watermilfoil.

Curly-leaf Pondweed

Curly-leaf pondweed (*Potamogeton crispus*) has oblong leaves that are two to four inches long and attach to a slightly flattened stem in an alternate pattern. The most distinguishing characteristics are the curled appearance of the leaves, and the serrated leaf edges. Curly-leaf pondweed also produces a seed-like turion, which resembles a miniature pinecone. Curly-leaf pondweed produces turions in early summer allowing the plant to regenerate annually. Turion production begins when water temperatures reach above 60º F.



This exotic pondweed is a cold-water specialist. Curly-leaf pondweed can begin growing under the ice, giving it a competitive advantage over native plants, which are still lying dormant. By mid-summer when water temperatures reach the upper 70° F range, it begins to die off.

Curly-leaf pondweed has been found in the U.S. since at least 1910. A native of Europe, Asia, Africa and Australia, this plant is now found throughout much of the U.S. (Baumann et al., 2000).

As with Eurasian watermilfoil, curly-leaf pondweed's aggressive early season growth allows it to out compete native species and grow to nuisance levels. Because the plant dies back during the peak of the growing season for other plants though, it is better able to coexist with native species than Eurasian watermilfoil. Perhaps the most significant problem associated with curly-leaf pondweed involves internal nutrient cycling. The die-off and decomposition of the plant during the warmest time of year often leads to a sudden nutrient release in the water. This often leads to nuisance algae blooms and poor water quality.

Curly-leaf Pondweed Management Options

Curly-leaf pondweed has primarily been managed through mechanical and chemical means. If curly-leaf pondweed were to be introduced, the following control options should be considered to determine the best course of action.

Hand pulling
As with Eurasian watermilfoil, this method may be appropriate for riparian property owners. Hand pulling is most effective when curly-leaf pondweed is discovered in its pioneering stage. If it has existed long enough to produce turions, hand pulling may become a long-term, labor-intensive process. To be most effective, as with other curly-leaf pondweed control options, early response is recommended.

Mechanical harvesting and cutting

Both mechanical harvesting and hand cutting are commonly used to control curly-leaf pondweed. Cutting the plant provides temporary nuisance relief and may increase recreational opportunities on the lake. And although harvesting may not encourage dispersal of the plant, as it does with Eurasian watermilfoil, it is unlikely to provide any long-term control.

Herbicides

The herbicide most often used to control curly-leaf pondweed is Aquathol®. Aquathol® is an endothall salt-based herbicide which also rapidly breaks down. While endothall herbicides are effective on a broad range of aquatic monocots, early season applications made at low rates are highly species-selective for curly-leaf pondweed. While herbicides effectively kill the parent plant, the turions are resistant to herbicides, allowing curly-leaf pondweed to regenerate annually.

Studies conducted by the Army Corps of Engineers have found that conducting treatments of curly-leaf pondweed using Aquathol® when water temperatures are in the 50-60° F range will kill plants before turions form, thus providing long-term control. Researchers found that conducting treatments over three or more consecutive seasons for established curly-leaf pondweed populations will target both the standing crop of the pondweed as well as the resulting regrowth from the turions (Skogerboe and Poovey, 2002). These findings make Aquathol® the tool of choice for controlling curly-leaf pondweed in the lakes of Wisconsin.

Purple Loosestrife

Purple loosestrife (*Lythrum salicaria*) forms bright purple flowers in a spike atop stems that reach 2 to 7 feet in height. Lance-shaped leaves are arranged oppositely along the stem. 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.*). Purple loosestrife plants produce hundreds of thousands of tiny seeds. When purple loosestrife is cut, seeds stick to mowing equipment and are spread to new locations. This invasive plant causes significant economic damage by clogging waterways and irrigation canals. Unlike cattails, purple loosestrife has little food or cover value for wildlife (Borman et. al. 1997).

Purple Loosestrife Management Options

There are several methods that are commonly used for purple loosestrife control including digging or hand pulling, cutting, herbicide treatments and biological controls.

Manual removal
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 may need to be done for a number of years before desired control is achieved.

Herbicides
Herbicide treatments are the least labor intensive of methods. The preferred herbicide is glyphosate (Eagre®, Rodeo®). This compound rapidly biodegrades upon contact with soil or water. As a result, 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 at a very low cost of 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. A DNR permit is required for treatment; however the fee is waived. This option should be considered if the distribution of purple loosestrife increases significantly.

Loosestrife beetles
Two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) are currently available from the Wisconsin DNR in an effort to control purple loosestrife by biological means. Research has shown that these insects are almost exclusively dependent upon purple loosestrife and do not threaten native plants. Although, as with most biological

control agents, these insects will not eradicate loosestrife, they may significantly weaken the population and allow native species to reclaim infested areas. According to the WDNR, tests have shown significant declines in loosestrife as a result of biological control. The purple loosestrife control program established through the DNR provides a parent stock of beetles to individuals who are willing to raise the insects in a controlled environment until they are able to reproduce. Once the young have matured, they are released and are able to begin control of the purple loosestrife. As with other exotic plant control projects, annual monitoring should be employed to assess the success of control measures. If significant progress is not made, alternative management options can be considered to control purple loosestrife.

Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are small (1/4" to 2") mollusks with elongated shells marked by alternating light and dark markings. They produce dense elastic strands, called byssal threads, by which they can securely attach to nearly any surface, often forming barnacle-like incrustations. Mussels spawn in the early spring when water temperatures reach 54º F. Fertilized eggs develop into microscopic free-swimming larvae called veligers. After three to four weeks, the surviving veligers settle onto firm objects where they quickly attach themselves. Within a year the young grow into adults that can live four to six years.

Zebra mussels were introduced to the Great Lakes region in the late 1980s through discharged ballast water of ships traveling the Saint Lawrence Seaway. These ships originated from European ports. Zebra mussels are native to the Ukraine and Russia near the Black and Caspian Seas. Since the 1700s zebra mussels have spread throughout European river systems.

Although zebra mussels do not cause much harm to the surrounding environment, they can negatively impact recreation and business by clogging water intake pipes, encrust boat hulls and piers, and wash up on beaches.

Zebra Mussel Management Options

Currently there is no lake-wide control option that isn't deadly to other aquatic life forms. In some areas of Europe and Lake Erie large populations of diving ducks have been shown to significantly decrease the population of zebra mussels each year. However, given the zebra mussel's high reproductive capacity, populations are able to recover each summer. In addition, diving duck populations in the Great Lakes region are low since they are only prevalent in the region during winter and summer migrations.

A number of fish species have been known to feed on zebra mussels. These include the freshwater drum, round goby, yellow perch, catfish, and carp. Certain fish species will feed on the adults while others eat the free-swimming juveniles. Although fish predation occurs, it is not significant enough to significantly decrease zebra mussel populations.

In recent years scientists have noted that native freshwater sponges in Lake Michigan appear to be increasing in number and attaching themselves to zebra mussels. In doing so, the sponges can kill the zebra mussels by cutting off the mussel's food and water supply.

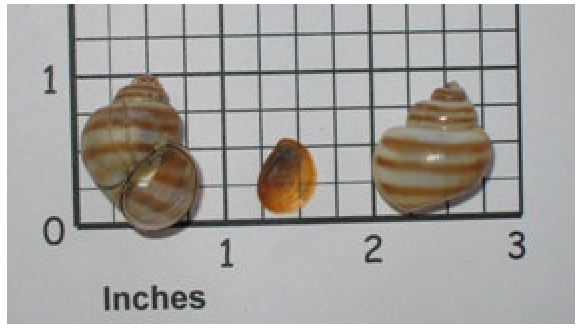
Some success has been achieved by manually removing mussels from a lake. Although this method can dramatically reduce populations, it does not eradicate the mussels. In addition, it should be noted that this option is also very labor intensive.

Recently a quarry in Virginia was able to eradicate zebra mussels from its waters. This was accomplished by applying a solution of potassium chloride over a three-week period in January. At the rate the solution was applied, it did not pose a risk to the environment or humans. This option would be most effective in small contained systems where cost does not prohibit control efforts.

Current research is focused on studying the environmental cues and physiological pathways that coordinate zebra mussel spawning. If the timing of male and female spawning can be disrupted, the numbers of fertilized eggs would be greatly reduced.

Mystery Snails

Two nonnative mystery snails have been identified in Wisconsin lakes. They are the Chinese mystery snail (*Bellamya chinensis*) and the banded mystery snail (*Viviparus georgianus*). Little is currently known about these species. However, it appears these exotic species can have an indirect negative impact to native snail populations.



Banded Mystery Snail

Mystery snails are larger in size to many native species. They also have thick hard shells and hard opercula which cover the opening in their shells. These features make them less edible or desirable to predators.

Chinese Mystery Snail

The banded mystery snail is native to the southeastern US. Chinese mystery snails are native to Asia. They were first imported into the US in the late nineteenth century. Both species have likely spread through the U.S. via the aquarium trade and as hitchhikers on boats and trailers.

Mystery snails are tolerant of pollution and can survive in stagnant water conditions.
Mystery snails do not eat plants (macrophytes). Instead, they feed on
detritus and in lesser amounts algae and phytoplankton.
Lakes with high densities of mystery snails often see large die-offs of the snails usually associated with low oxygen conditions.

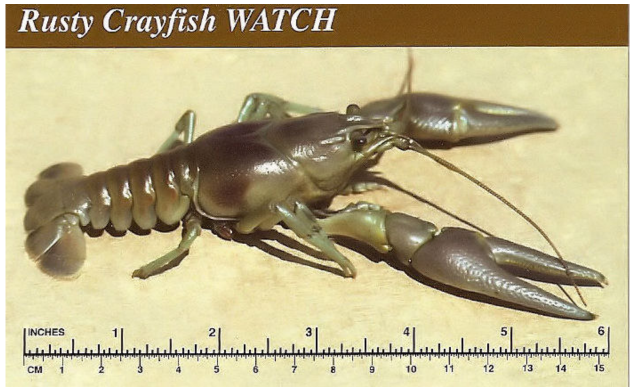
Current research is focused on the life-cycle of these snails and the environmental conditions under which population growth is hindered or promoted.

Mystery Snail Management Options

Currently there is no control option for mystery snails that would not be detrimental to native snail populations. Individuals can physically remove these snails from their lake frontages. However, care should be taken to ensure they are the nonnative species. Also, the snails should be disposed of in a way that does not encourage their spread or attract unwanted pests.

More information regarding the life-cycle and monitoring of mystery snails in Wisconsin can be found at: www.uwsp.edu/cnr/uwexlakes/clmn/AIS-Manual/7Snails09.pdf.

Rusty Crayfish



Rusty crayfish *(Orconectes rusticus)* are native to streams in the Ohio River Basin. They likely reached the lakes of Wisconsin by anglers who used them as live bait. They are still caught and sold as bait and by biological supply companies. In Wisconsin it is illegal to possess both live crayfish and fishing equipment in a boat while on the water. It is also illegal to release crayfish into a lake or stream in the State without a permit. A fishing license is required to harvest crayfish in Wisconsin.

Rusty crayfish prefer areas that offer rocks, logs, or other debris as cover. Bottom types may be clay, silt, sand, gravel, or rock. Rusty crayfish inhabit both pools and fast water areas of streams.

Rusty crayfish are prolific and aggressive. They eat small fish, insects, fish eggs and aquatic vegetation. Invading rusty crayfish can displace native crayfish, reduce the amount and kinds of aquatic plants, decrease the density and variety of invertebrates, and reduce some fish populations. By eating aquatic vegetation, rusty crayfish can damage lake habitats that are important for fish spawning, cover, and food.

Rusty Crayfish Management Options

It is difficult to control rusty crayfish without detrimentally impacting native crayfish populations. Some lakes have had success trapping and removing these crayfish. This can be and often is a very labor intensive undertaking that does not ensure long-term control. Care must be taken to remove only the rusty crayfish and leave the native species. As with all nuisance exotic species, preventing or slowing the spread of this species into new waters is the best way to prevent the ecological problems they cause.