Aquatic Plant Management Plan for
Big Hills Lake, Waushara County, Wisconsin
2011-2015



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Sponsored by:

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Executive Summary

A thorough study of Big Hills 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 Big Hills 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 Big Hills 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 Big Hills Lake Protection and Rehabilitation District.

Results of this study include:

- The most abundant plant species encountered in Big Hills Lake were muskgrass (*Chara* spp.), variable pondweed (*Potamogeton gramineus*) and leafy pondweed (*Potamogeton foliosus*).

- Eurasian watermilfoil (*Myriophyllum spicatum*) appears to have been reintroduced in 2008, four years after a successful large-scale herbicide treatment of the lake. One location near the public boat landing is being actively managed through annual treatments.

- 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 Big Hills Lake is below average. This appears to be a natural characteristic of the lake and not a *direct* result of human activities.

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

- Dissolved oxygen measurements indicate high levels of oxygen from surface to sediment throughout the growing season. This has greatly minimized internal cycling of nutrients, primarily phosphorus, in the lake.

Introduction

Big Hills Lake is located in east central Waushara County approximately five miles southwest of Saxeville, Wisconsin (**Figure 1**). It has an area of approximately 125 acres, a maximum depth of 22 feet, and an average depth of 12 feet (**Figure 2**). The watershed surrounding Big Hills Lake is predominantly forested upland. Big Hills Lake is a seepage lake that generally has good water quality, with sufficient mixing throughout the year. This mixing is sufficient to prevent the occurrence of oxygen-depleted conditions, which may otherwise lead to fish kills and release of internal nutrients. Big Hills Lake supports a fishery of northern pike, walleye, largemouth bass, and panfish

Management History

The Big Hills Lake Protection and Rehabilitation District was formed in 1977. Members of the District are concerned with the ecological health of the lake and are very active in many aspects of the management of the lake. In 2002 and 2003, NES Ecological Services conducted a comprehensive survey of Big Hills Lake. This study focused on lake water quality, aquatic vegetation, and an analysis of the lake's watershed. The result of the study was a comprehensive lake management plan. The study was funded in part through the Wisconsin Department of Natural Resources' (WDNR) Lake Management Planning Grant Program. Analysis of the data from this study resulted in a number of significant findings. Of particular concern was the identification of approximately 36 acres of Eurasian watermilfoil (*Myriophyllum spicatum*) in the lake. Milfoil was the most abundant species in the lake at the time of the survey. In addition, a lower than average diversity of native plants was found, as were less than desirable levels of emergent aquatic plants.

In the spring of 2004 approximately 18 acres of Eurasian watermilfoil were treated on Big Hills Lake with Navigate® (granular 2,4-D) at a rate of 100 lbs/acre. The following year, an inspection did not find any Eurasian watermilfoil remaining in the lake. On June 15, 2006 the WDNR conducted a point-intercept aquatic plant survey of the lake. This survey did not locate any exotic plant species growing in Big Hills Lake. Subsequent surveys through 2007 also did not located Eurasian watermilfoil in the lake. In the fall of 2008 and spring of 2009 a small number of Eurasian watermilfoil plants were found and hand-pulled near the boat landing of Big Hills Lake. Eurasian watermilfoil continued to grow in the bay near the boat landing. On September 15, 2009 an area of milfoil growth less than one acre in size was identified in the same location. Because of the number of plants present, it was recommended the District sponsor a herbicide treatment in 2010 to control milfoil in the lake. On May 12, 2010, an area of Eurasian watermilfoil one acre in size was treated with Navigate® at a rate of 150 lbs/acre.

The Big Hills Lake Protection and Rehabilitation District intends to continue taking an active role in whole-lake management of Big Hills Lake. Since the management plan completed in June 2003 is currently more than five years old, the District has undertaken this study as a means to update the lake's management plan. The District again received funding through the WDNR's Lake Planning Grant Program for this survey. The primary

Figure 1. The area surrounding Big Hills Lake, Waushara County, Wisconsin.

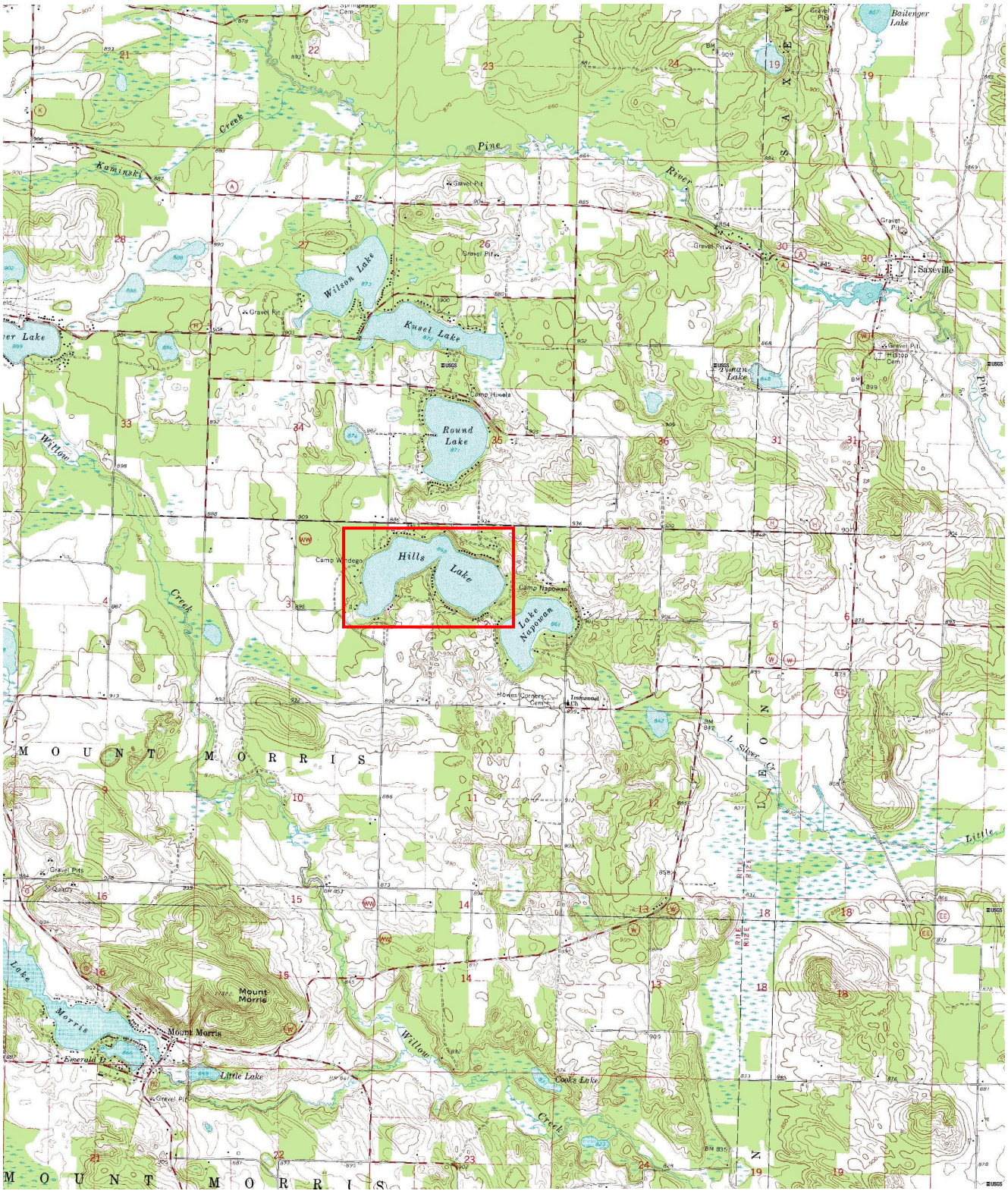
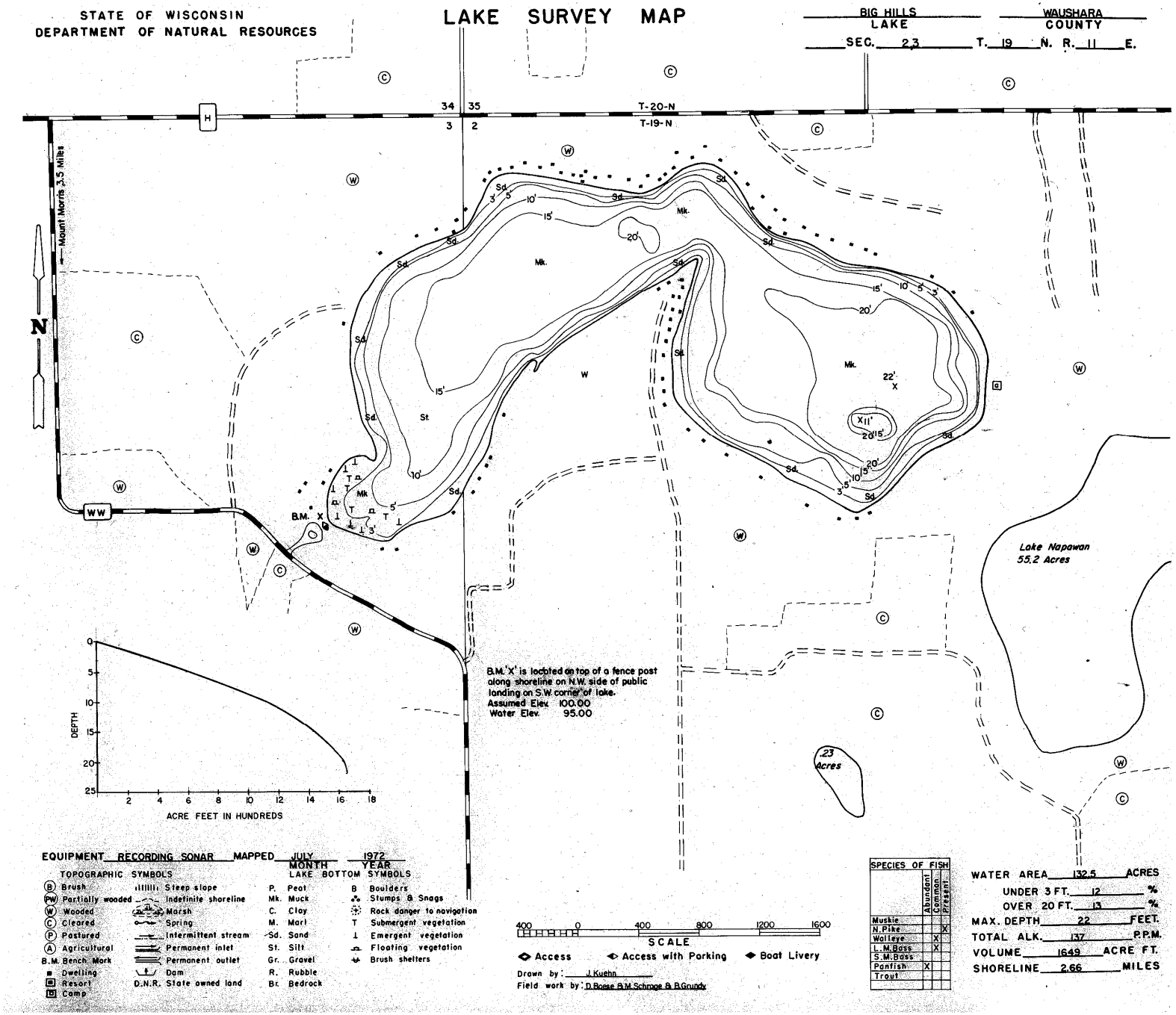


Figure 2. Big Hills Lake in Waushara County, Wisconsin



goals of this project have been 1) to gather baseline information on the physical, chemical and biological aspects of Big Hills Lake, 2) to address exotic aquatic plant growth, 3) to identify and address input provided by property owners, community residents and other lake users, 4) to identify and prioritize management concerns, and 5) to provide information needed to make informed decisions regarding the long-term management of Big Hills Lake for the benefit of lake users and the biotic community alike.

Methods

Aquatic Plant Assessment

On August 11, 2010, a submergent aquatic plant survey was conducted following guidelines established by the WDNR. This survey utilized the point-intercept method. A survey map for Big Hills 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 exotic 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 the exotic species in Big Hills 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 a 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. In 2010, the surveys utilized the point-intercept map and corresponding coordinates provided by the WDNR (**Figure 3**). At each location within the littoral zone of Big Hills 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 exotics in Big Hills Lake.

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

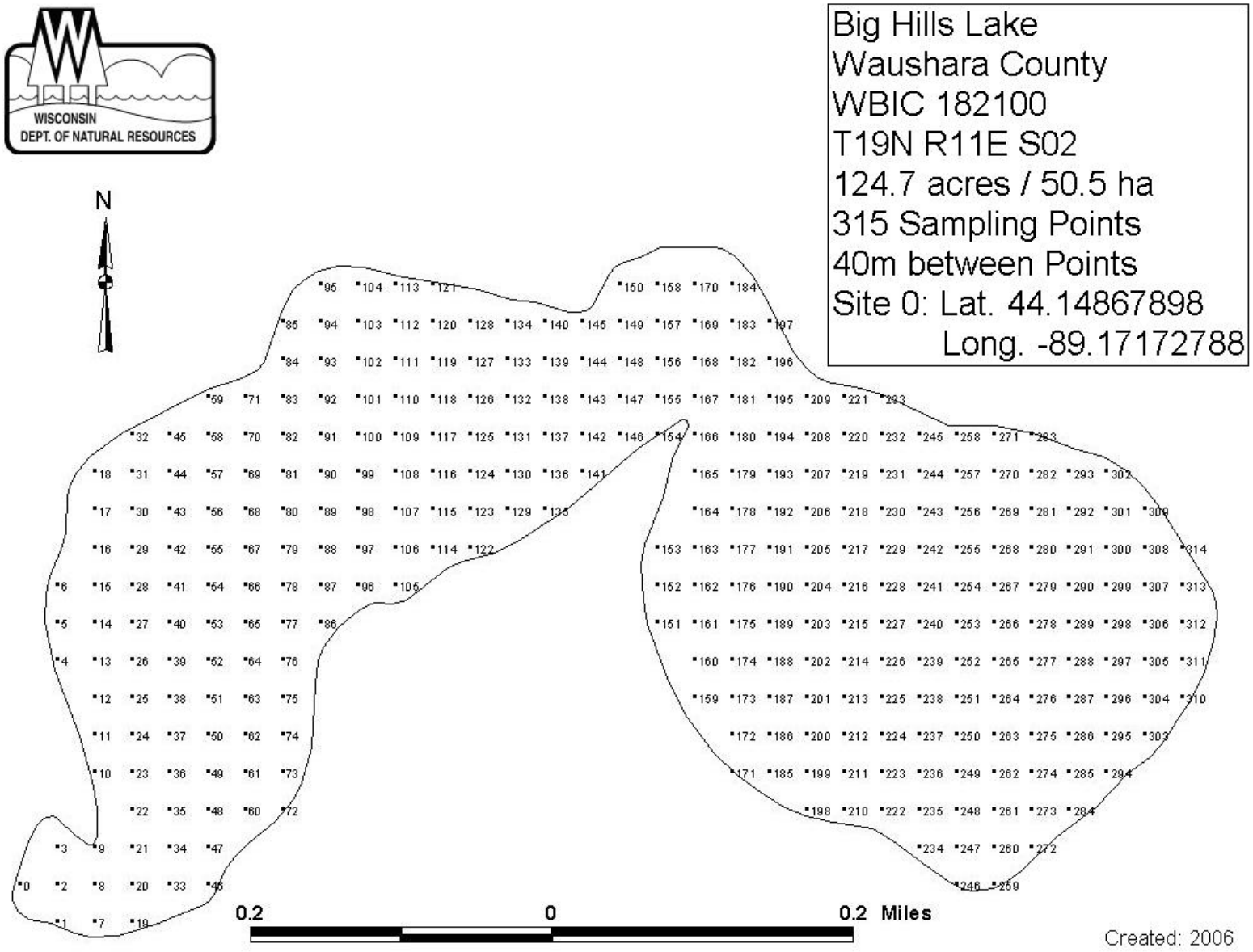


Figure 4. Plant abundance rating criteria used in submergent aquatic plant surveys.

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

Water sampling took place at the deep point on Big Hills Lake seven times in 2010; in spring (April), five times in the summer (June-September) and in the fall (November). During these sampling events, the following parameters were measured:

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

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

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. Dissolved oxygen and temperature measurements were collected with a YSI 550A dissolved oxygen meter at ½ meter intervals. Samples for the remaining parameters were collected approximately one foot below the surface and sent to the State Lab of Hygiene for analysis. All subsequent data was collected from the DNR's Surface Water Integrated Monitoring System (SWIMS).

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 Big Hills 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 Big Hills Lake by incorporating nutrient and dissolved oxygen data.

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 Big Hills 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 Big Hills Lake was conducted free of charge by Dean Halverson, President of Leede Research, a marketing research firm in Minnesota and Wisconsin. In total, 22 questions were included in this survey. This survey evaluated the health and usage of the lake and helped identify issues to be addressed as part of the larger project. A large proportion of residents (total of 100) returned their surveys. Leede Reseach analyzed the results and produced the presentation materials found in **Appendix A**.

Results and Discussion

Aquatic Plant Community

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

A total of 12 aquatic plant species were found during the 2010 survey (**Table 1**). This is below the state-wide average of 13 species. Big Hills Lake lies near the border of the Northern Central Hardwood Forests and Southeastern Wisconsin Till Plain regions of Wisconsin (**Figure 5**). The average number of species found in lakes in these regions is 14 species (Nichols, 1999). The most abundant plant species encountered in Big Hills Lake were muskgrass (*Chara* spp.), variable pondweed (*Potamogeton gramineus*) and leafy pondweed (*Potamogeton foliosus*). These species were found at 58.9%, 17.1% and 15.8% of the sites within vegetated areas, respectively. **Figures 6-8** show the distribution and density of these species across Big Hills Lake at the time of the survey. **Figure 9** presents the relative abundance of submergent aquatic plant species found in Big Hills Lake at the time of the 2010 survey.

Figure 5. Ecoregions of Wisconsin (after Omernick and Gallant, 1988).

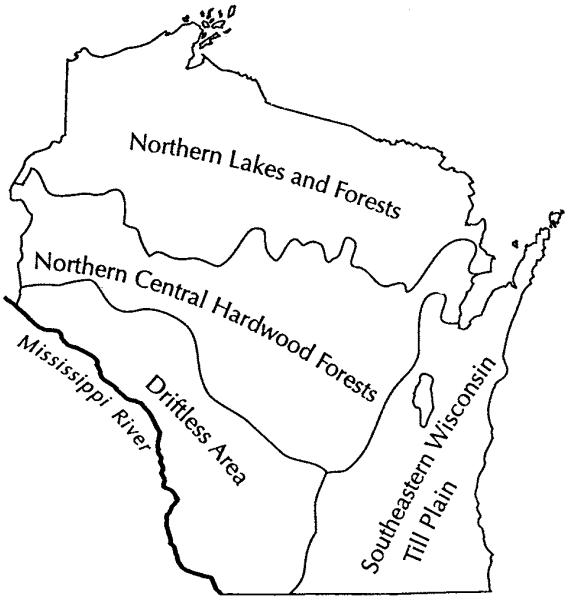


Table 1 also shows the frequency of occurrence for plant species in the lake. Percent frequency values reflect the relationship between the number of locations where a particular species was found versus the total number of locations sampled. Percent composition values reflect the abundance of a particular species in relation to all other species found.

Appendix C contains the plant survey data collected for Big Hills Lake in 2010.

In 2006, the Wisconsin DNR conducted a point-intercept survey of Big Hills Lake using the same technique as in 2010. Results of this survey are also found in **Table 1**. In general, the same plant species were found in 2006 and 2010. In 2006, the most abundant submergent plants were again muskgrass, variable pondweed and leafy pondweed. Frequency values for the submergent plants varied some between the two surveys. However these differences are not alarming and could be attributed to natural changes in the plant community. Eurasian watermilfoil and other exotic plant species were not identified during the 2006 survey. One noticeable

Table 1. Summary of aquatic plant survey data collected on August 11, 2010 and June 15, 2006 on Big Hills Lake, Waushara County, WI.

		2010		2006	
Species common name	**scientific name**	**Percent Frequency**	**Relative Frequency**	**Percent Frequency**	**Relative Frequency**
Eurasian watermilfoil	*Myriophyllum spicatum*	visual	--	--	--
Muskgrass	*Chara* sp.	58.9	41.1	23.26	15.9
Variable pondweed	*Potamogeton gramineus*	17.12	12.0	31.01	21.2
Leafy pondweed	*Potamogeton foliosus*	15.75	11.0	11.63	7.9
Flat-stem pondweed	*Potamogeton zosteriformis*	13.01	9.1	4.65	3.2
Bushy pondweed	*Najas flexilis*	7.53	5.3	6.98	4.8
Small pondweed	*Potamogeton pusillus*	7.53	5.3	2.33	1.6
Filamentous algae	--	6.16	4.3	55.81	38.1
Common waterweed	*Elodea canadensis*	6.16	4.3	3.88	2.6
Sago pondweed	*Stuckenia pectinata*	4.11	2.9	4.65	3.2
Wild celery	*Vallisneria americana*	4.11	2.9	0.78	0.5
Floating-leaf pondweed	*Potamogeton natans*	2.05	1.4	--	--
Illinois pondweed	*Potamogeton illinoensis*	0.68	0.5	0.78	0.5
Freshwater sponge	--	visual	--	--	--
Water stargrass	*Heteranthera dubia*	--	--	0.78	0.5
Three sqaure	*Schoenoplectus pungens*	--	--	visual	--

exception between the two surveys was that filamentous was found at a higher frequency of occurrence in 2006 than in 2010.

In 2002 a similar aquatic plant survey was conducted on Big Hills Lake. However this survey utilized a transect method. As part of this survey, 33 evenly spaced transects were mapped around the lake perpendicular to the shoreline. At each transect, aquatic plant samples were collected at specific depths. Results of this survey are similar to those collected in 2010. However, 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. A number of emergent plant species were identified during the 2002 survey which did not appear in the 2010 data sets. This is most likely due to the sampling design. In 2002, the most abundant species were Eurasian watermilfoil, bushy pondweed (*Najas flexilis*) and muskgrass. In 2002, the submergent species, water stargrass (*Heteranthera dubia*), and northern watermifoil (*Myriophyllum sibiricum*) were identified at low frequencies of occurrence (<2%), but were not found in 2010. Similarly, in 2010, floating leaf pondweed (*Potamogeton natans*) and small pondweed (*Potamogeton pusillus*) were identified. These species were not included in the 2002 data sets.

Figure 6. Locations of muskgrass (*Chara* spp.) found on August 11, 2010 on Big Hills Lake, Waushara County, Wisconsin.

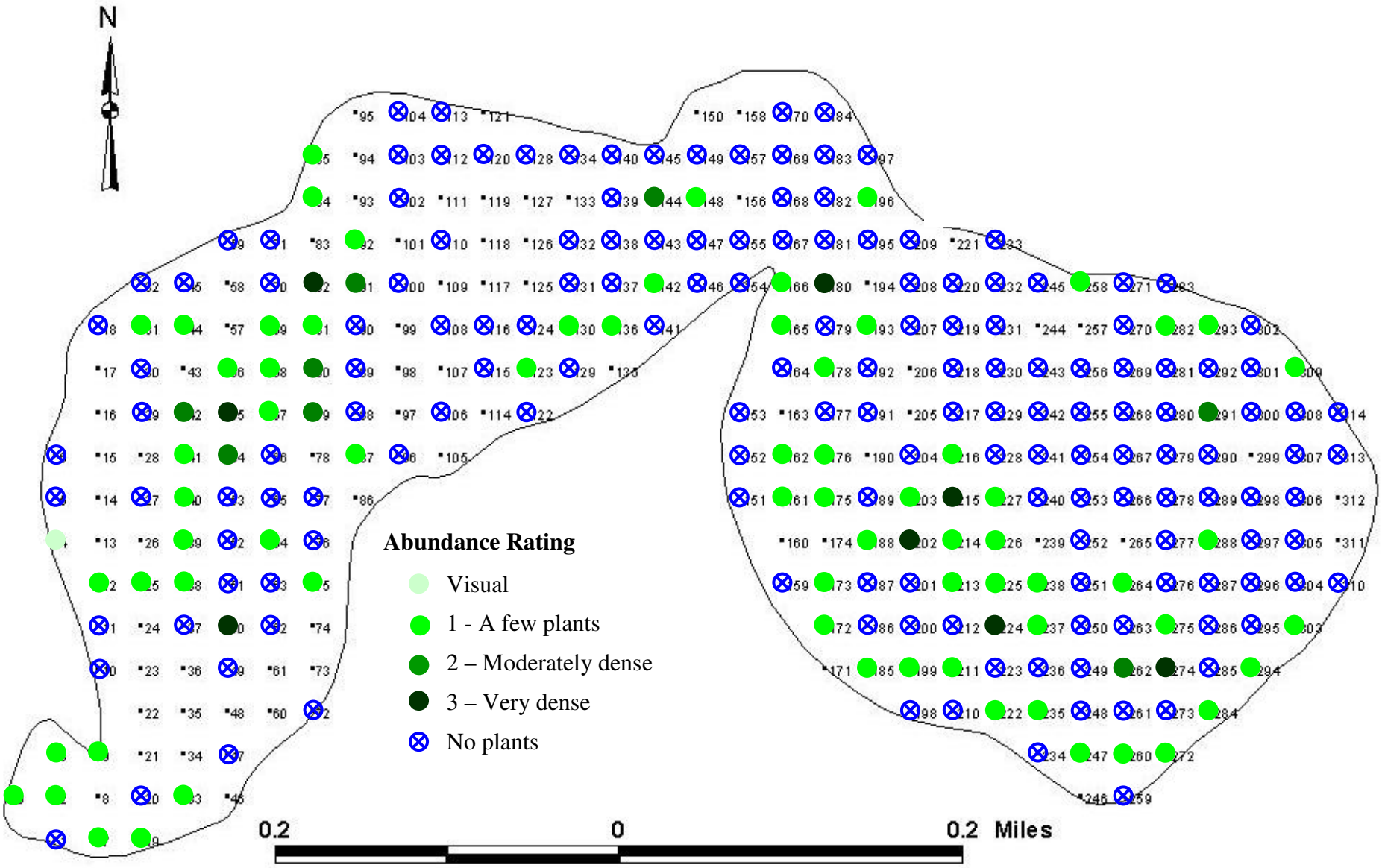


Figure 7. Locations of variable pondweed (*Potamogeton gramineus*) found on August 11, 2010 on Big Hills Lake, Waushara County, Wisconsin.

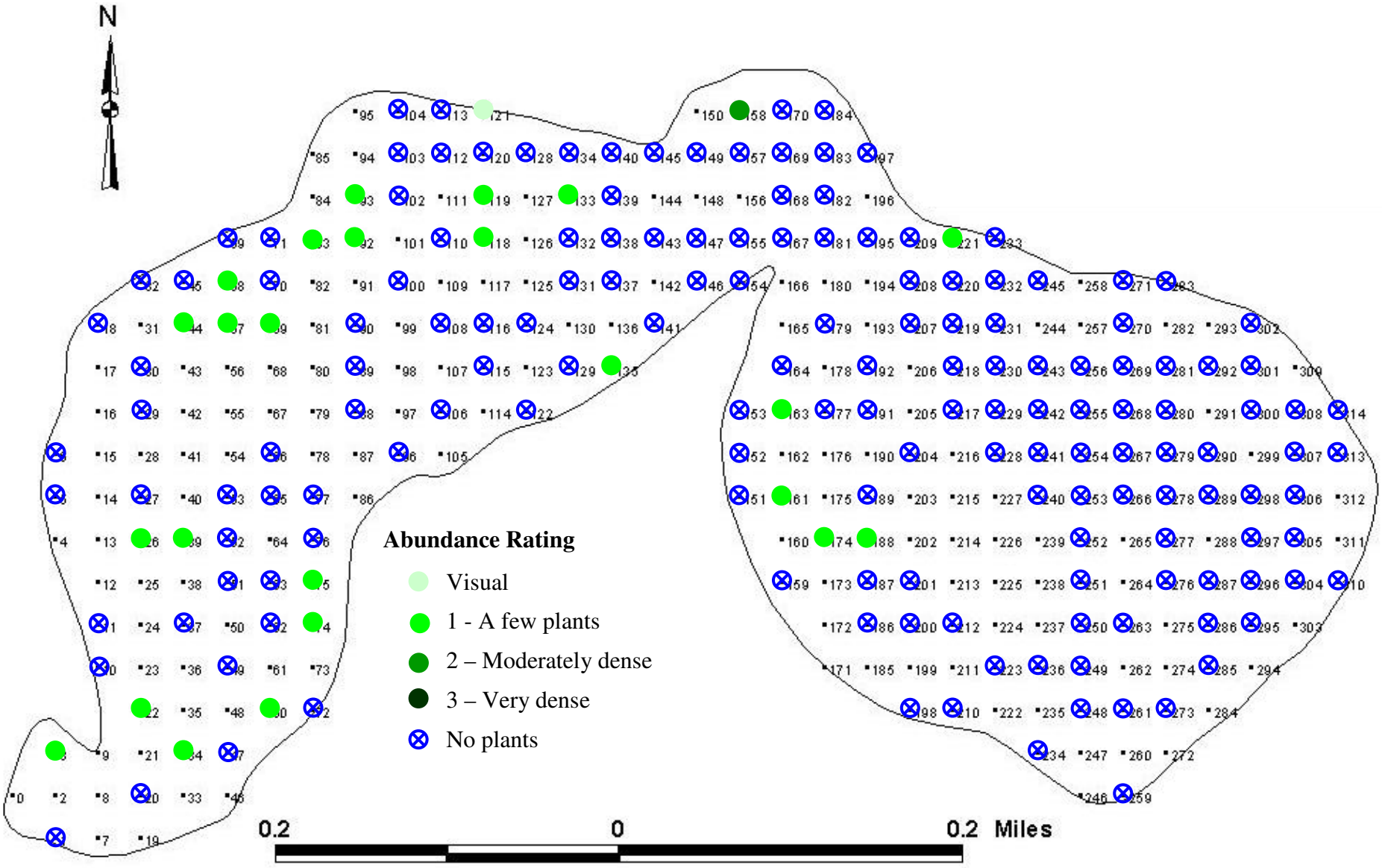


Figure 8. Locations of leafy pondweed (*Potamogeton foliosus*) found on August 11, 2010 on Big Hills Lake, Waushara County, Wisconsin.

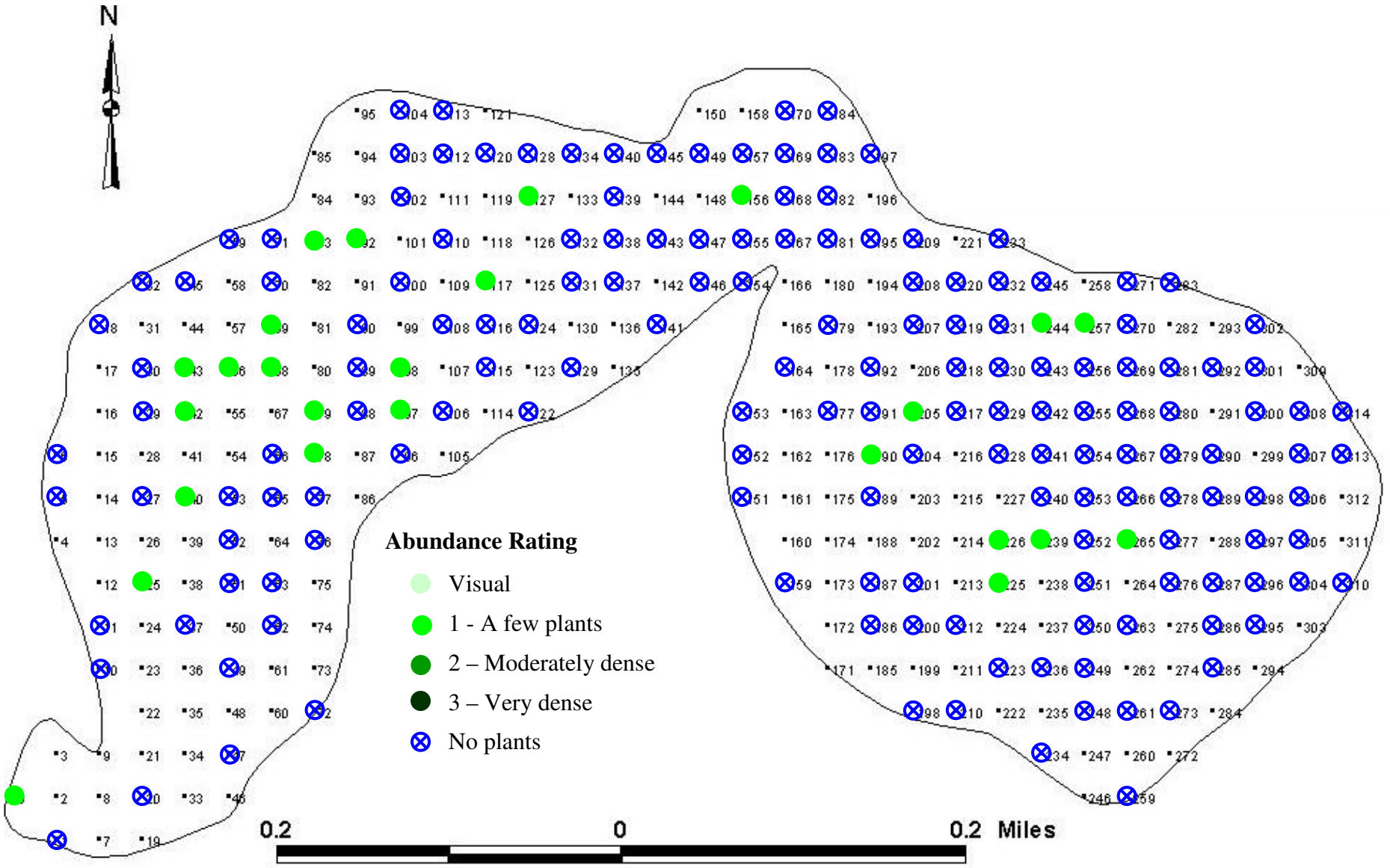
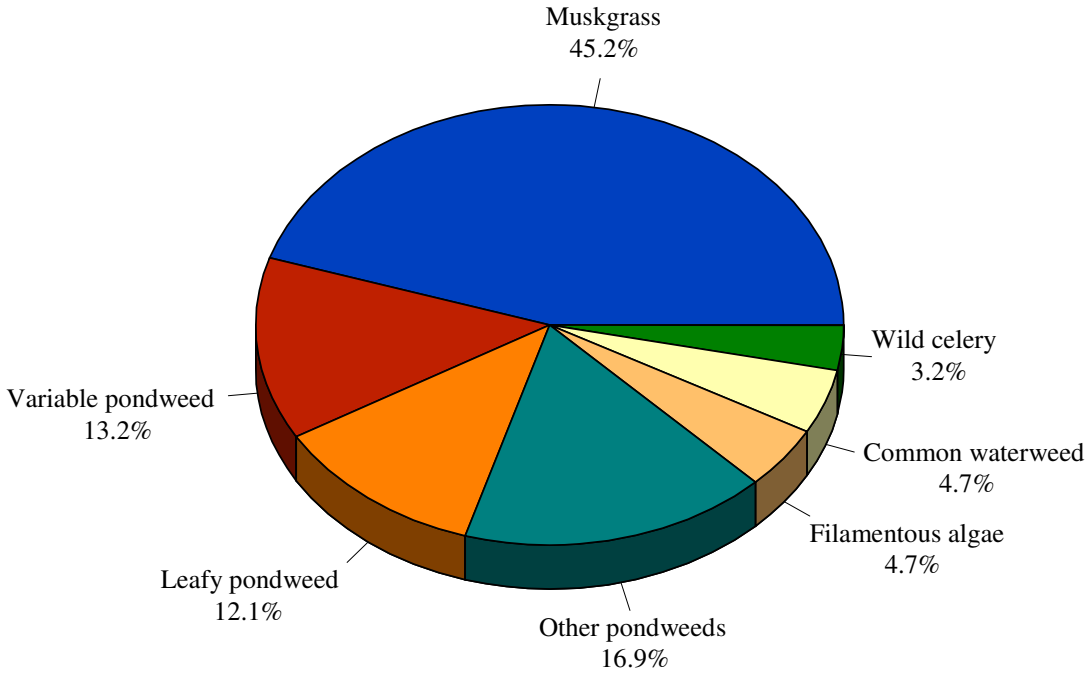


Figure 9. Submergent aquatic plant community composition from August 11, 2010 in Big Hills Lake, Waushara County, WI.



Simpson Diversity Index

The plant data collected from Big Hills 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 Big Hills Lake based on the 2010 data was 0.78. 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 Big Hills 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 common waterweed (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 Big Hills Lake, a lake-wide value of 5.64 (**Table 2**) was cacluated. The average value

Table 2. Big Hills Lake Floristic Quality Index (FQI) analysis table.

Species	Common Name	C
Chara spp.	Muskgrasses	7
Elodea canadensis	Common waterweed	3
Najas flexilis	Bushy pondweed	6
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	5
Potamogeton pusillus	Small pondweed	7
Potamogeton zosteriformis	Flat-stem pondweed	6
Stuckenia pectinata	Sago pondweed	3
Vallisneria americana	Wild celery	6
	N	11
	mean C	5.64
	FQI	18.7

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 in Big Hills 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 18.7 was calculated for Big Hills Lake (**Table 2).** 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 Big Hills Lake, specifically in terms of the plant community, is below 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.

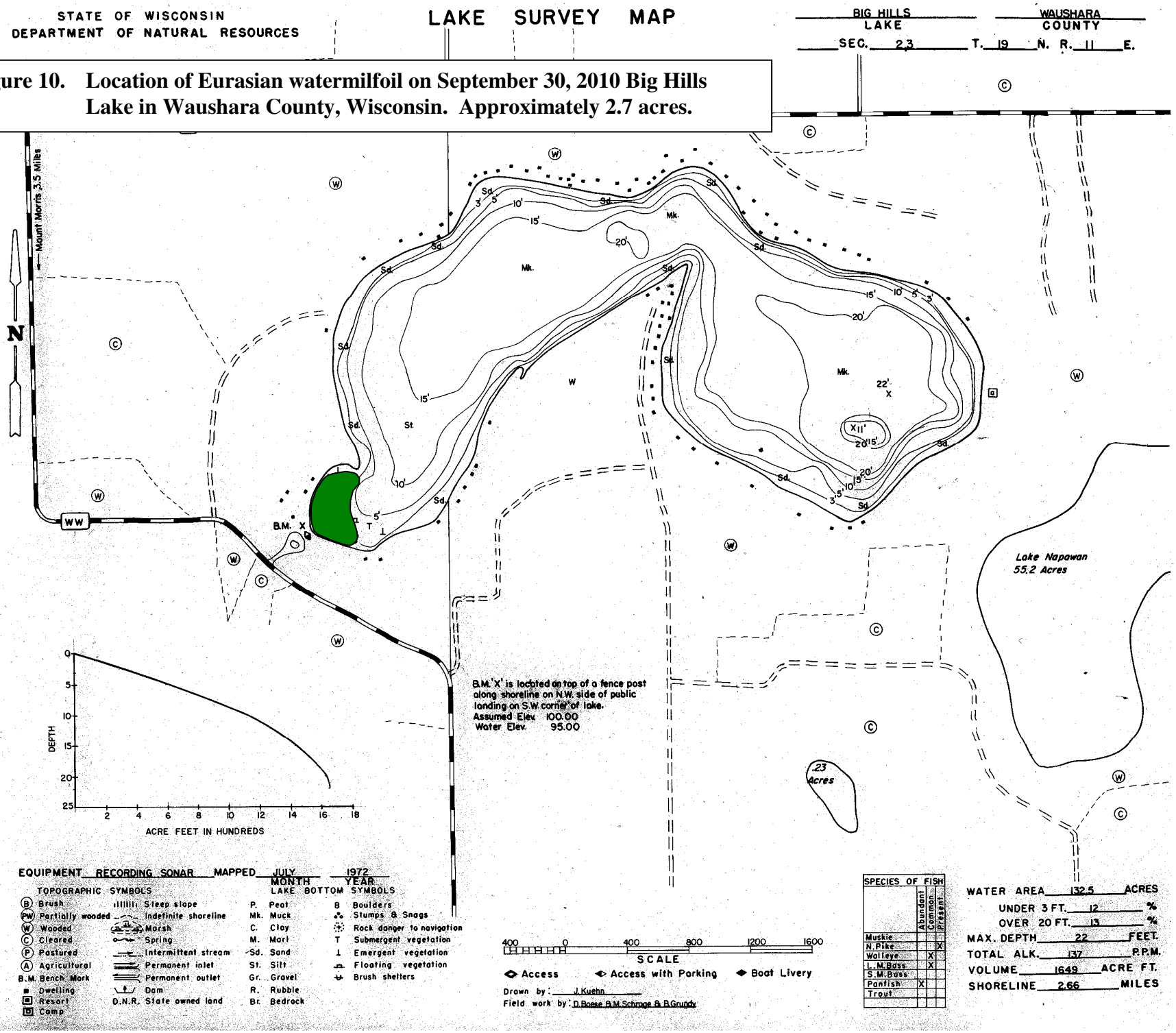
Results of the property owner survey indicated that a majority of residents feel there is a 'healthy amount of plants' in Big Hills Lake. Also, when asked if they felt there is a need for an aquatic plant control program, 44% responded 'Yes', 17% responded 'No' and

39% responded 'Don't Know'. They also indicated that a combination of both cutting aquatic plants and chemical applications should be used to control growth in the lake.

Exotic Species Surveys

Eurasian watermilfoil has been the only exotic species identified in Big Hills Lake. According to the DNR, it was first reported in the lake in 1979. During the surveys conducted in 2010, Eurasian watermilfoil was found in one location (**Figure 10**). On June 9th, a few surviving plants were found in the west end bay near the boat landing. Milfoil was confirmed in this location during the point-intercept survey on August 11th. Although sparse, the area of milfoil growth had expanded some. During the September 30th survey, further expansion was noted. In total, an area of 2.7 acres was mapped in this bay. On May 18, 2011, this area was treated in the same manner as recent surveys. Navigate® was again applied at a rate of 150 lbs/acre.

Figure 10. Location of Eurasian watermilfoil on September 30, 2010 Big Hills Lake in Waushara County, Wisconsin. Approximately 2.7 acres.



Water Quality Analysis

Water Chemistry
When asked what the best feature of Big Hills Lake is, property owners most often selected the water quality and clarity.

Previous water quality data available for Big Hills Lake has been compiled. This includes Secchi depth (water transparency) from 1987 to present and limited chlorophyll and phosphorus data back to 1999. 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 Big Hills Lake since 1999 contain phosphorus levels below 0.05 mg/L (**Figure 11**). In general, these data indicate good to very good water quality within Big Hills 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 16.3 µg/L measured in November 2010 (**Figure 12**). The remaining chlorophyll concentrations measured since 1997 have been below 10.0 µg/L. Without more data to compare, it is difficult to determine if high cholorphyll concentrations in the fall are common on Big Hills Lake or if the results from 2010 are anomalous.

Figure 11. Total phosphorus data from 1999 to present for Big Hills Lake, Waushara County, Wisconsin.

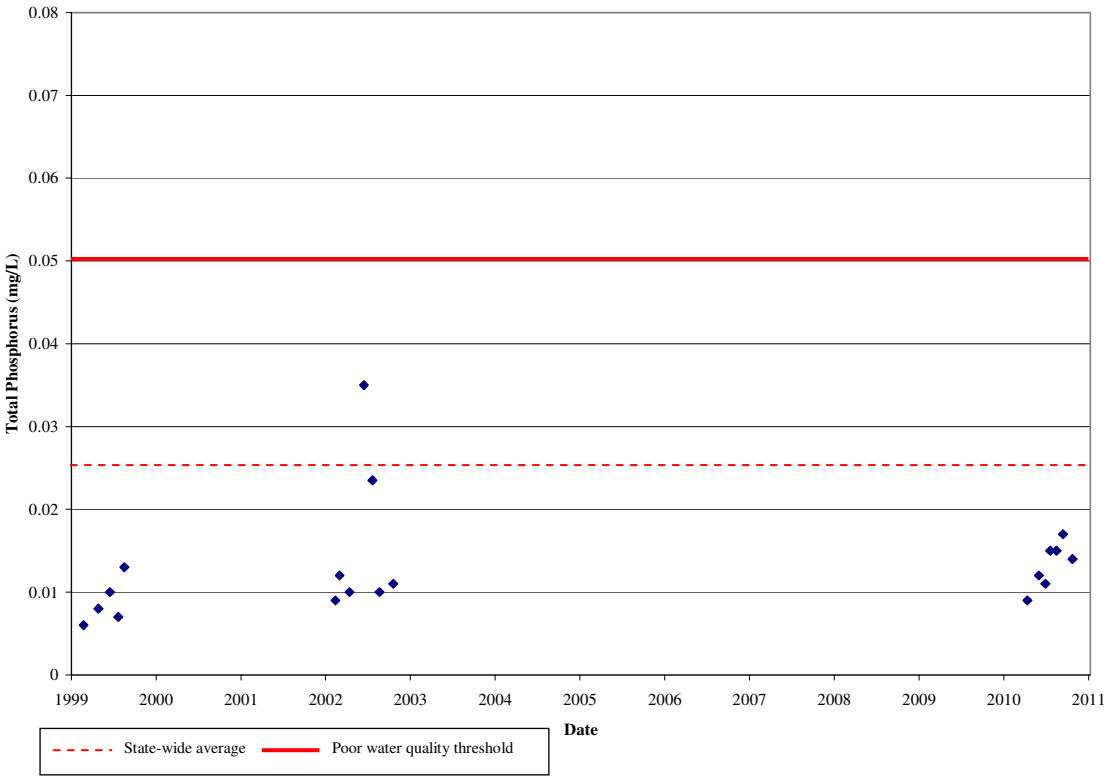
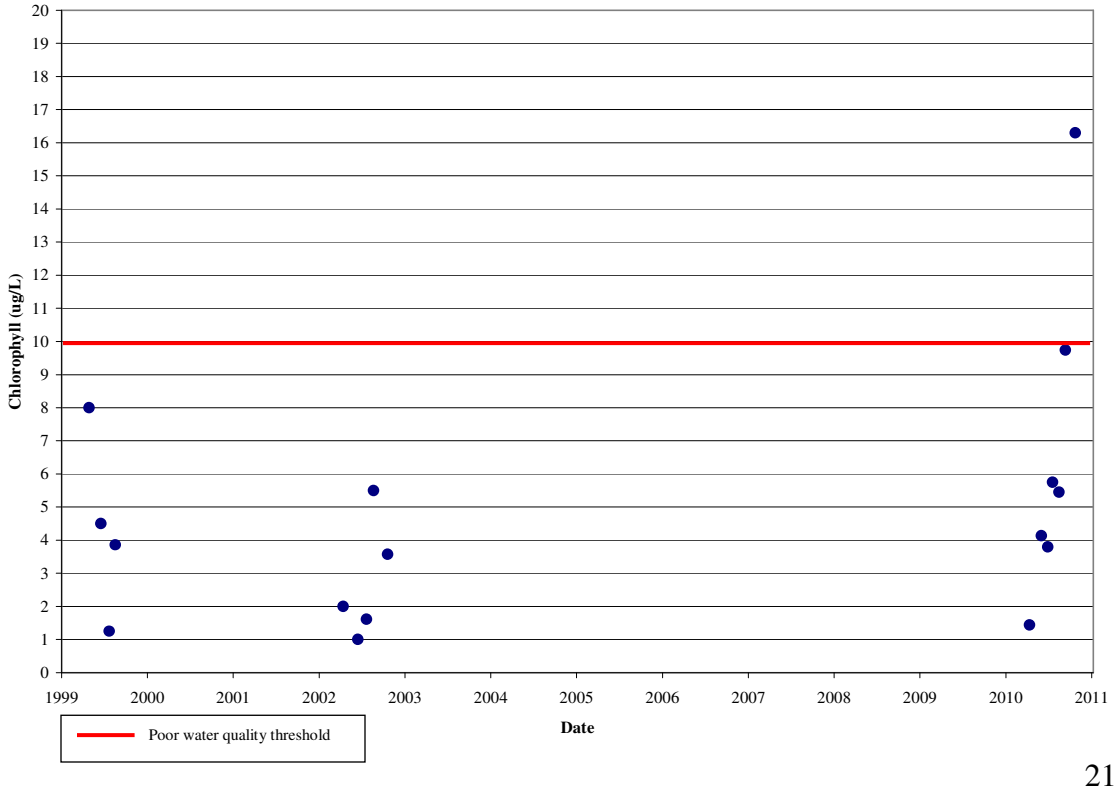


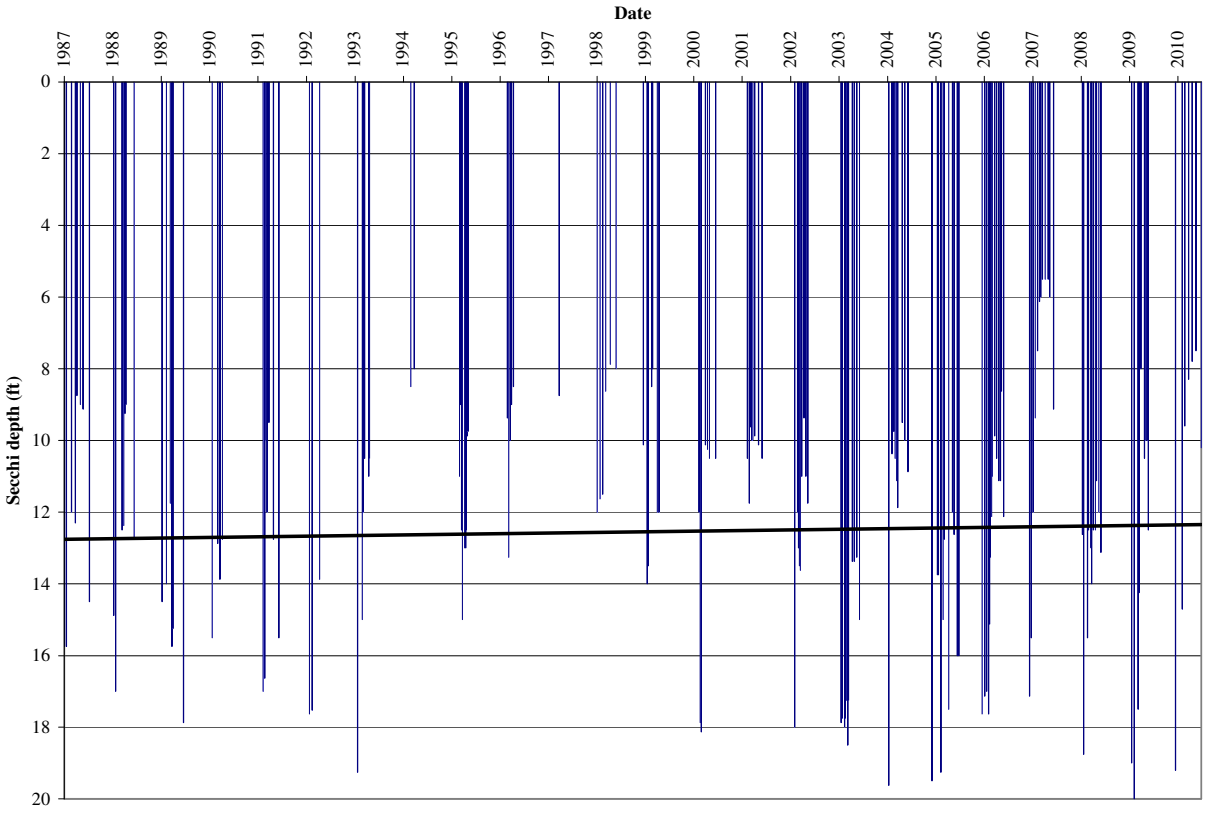
Figure 12. Chlorophyll data from 1999 to present for Big Hills Lake, Waushara County, Wisconsin.



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 Big Hills Lake since 1987 have been between 5.5 and 20.0 feet, with a large majority of the results being greater than six feet (**Figure 13**). As with the previous water quality parameters, the water clarity data as a whole indicate good to very good water quality in Big Hills Lake. Property owners on Big Hills Lake who responded to the Leede Research survey rated the clarity of the lake as 5.7 out of 7. A majority of respondents (77%) also indicated that clarity was poorest following heavy boat/jet ski use.

Figure 13. Water clarity data from 1987 to present for Big Hills 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 (**Figure 14**). Classic eutrophic lakes have TSI values starting around 50. Most of the TSI values calculated from Big Hills Lake's water quality data were between 30 and 40 (**Figure 15**). TSI values indicate Big Hills Lake would be considered a mesotrophic lake.

Figure 14. Relationship between trophic state in lakes and parameters including Secchi transparency, chlorophyll, and total phosphorus.

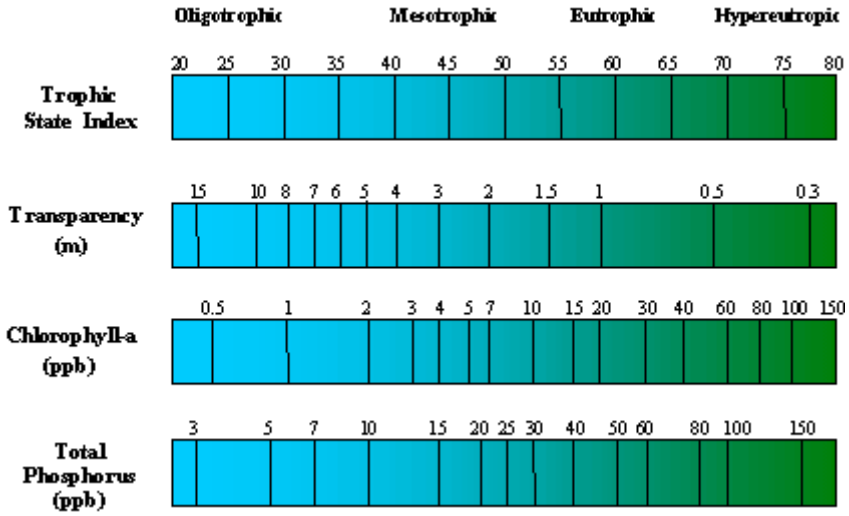
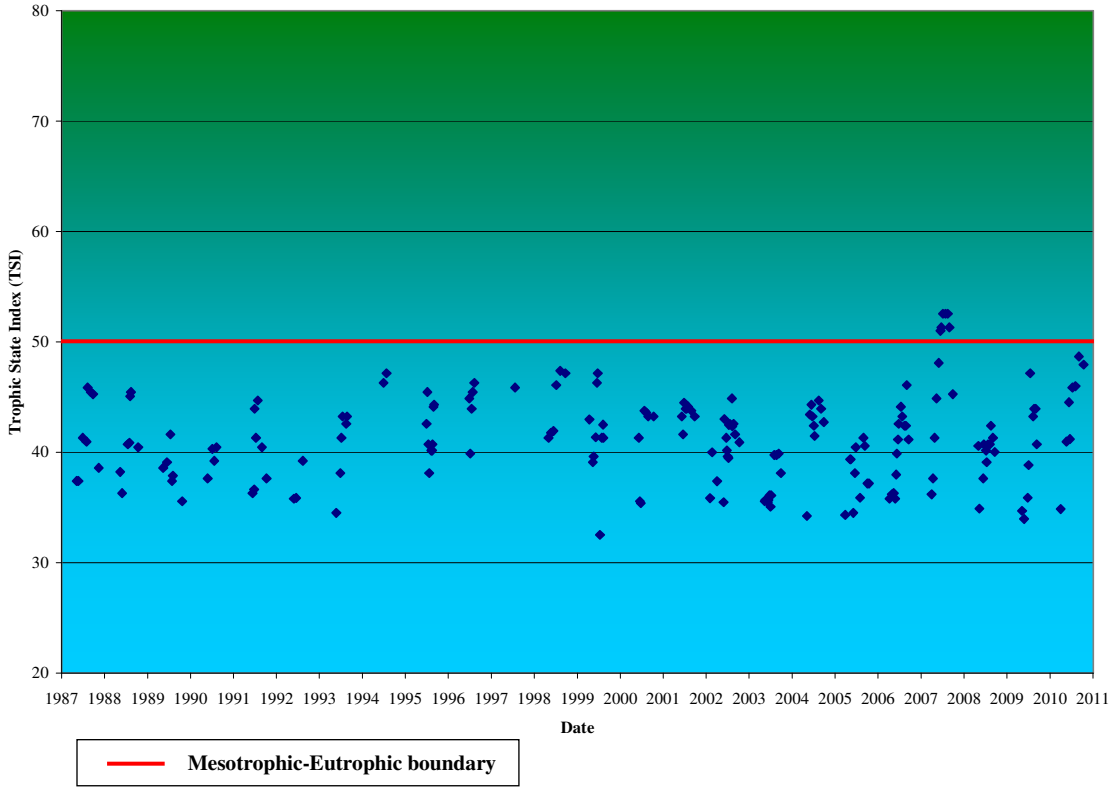
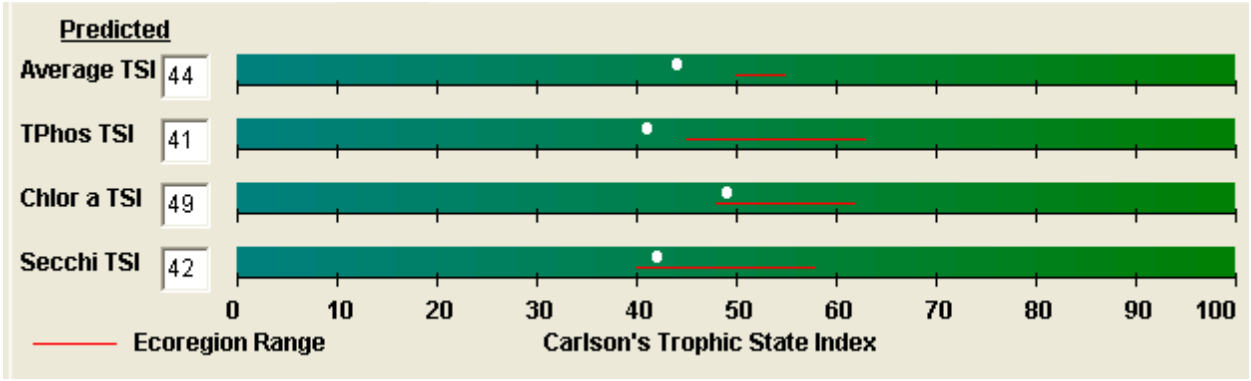


Figure 15. Trophic State Index values from 1987 to present for Big Hills Lake, Waushara County, Wisconsin.



Results of the WiLMS modeling (**Figure 16**) found that the observed trophic state index values for Big Hills Lake fell below or near the bottom range of expected values given the ecoregion where the lake exists. In other words, the water quality of Big Hills Lake based on the three parameters tested is better than expected for a lake in central Wisconsin.

Figure 16. Results of Wisconsin Lake Modeling Suite (WiLMS) analysis in 2010 for Big Hills Lake, Waushara County, Wisconsin.



Additional water quality data

Table 3 contains the pH, conductivity and alkalinity data collected on Big Hills Lake in 2010.

Table 3. Additional water quality data collected in 2010 on Big Hills Lake, Waushara County, WI.

	pH	Conductivity	Alkalinity	Ammonia	Nitrates & Nitrites	Total Kjeldahl Nitrogen	N:P
Date	**SU**	**mmhos/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	
4/20/2010	8.27	247	105.0	0.343	0.205	0.87	119
6/9/2010	8.76	230	97.2	--	--	--	--
7/7/2010	8.80	224	95.9	--	--	--	--
7/28/2010	8.62	222	95.0	--	--	--	--
8/24/2010	8.65	228	98.2	ND	ND	0.63	42
9/21/2010	8.53	237	101.0	--	--	--	--
11/1/2010	8.22	243	103.0	--	--	--	--

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 Big Hills Lake were tested for ammonia, nitrates and nitrites and

total Kjeldahl nitrogen (**Table 3**). 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 Big Hills Lake in 2010 show higher than expected nitrogen levels in the spring and low nitrogen levels in the summer. Ammonia, nitrates and nitrites were undetectable during the summer sampling event. Total nitrogen levels were less than 1 mg/L nitrogen.

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 Big Hills Lake in 2010 were 119 and 42. 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 Big Hills Lake fell between 8.2 and 8.8.

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 Big Hills Lake in 2010, were below 300 μmhos/cm, in the range of 220-250 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 Big Hills 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 Big Hills Lake in 2010 are presented in **Appendix E** and **Figures 17 and 18**. 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 5 meters in Big Hills Lake. Most of the time, sufficient oxygen levels were uniformly found from surface to sediment. These data suggest Big Hills Lake does not experience stratification the way other deeper lakes in the state do.

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 4** 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 Big Hills Lake in 2010 can also be found in **Appendix E**. A number of the oxygen saturation profiles in **Figure 18** 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 the desirable range.

Table 4. Oxygen solubility in water at different temperatures.

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

When dissolved oxygen data is included in the WiLMS modeling for Big Hills Lake, results show an insignificant level 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 throughout the entire water column within Big Hills Lake in 2010. If anoxia took place it would have only been a short-lived occurrence in the very deepest areas of the lake; greater than 20 feet (6 meters). Although the deepest readings in July and August 2010 showed lowered oxygen levels, true anoxia was not apparent in the data.

Figure 17. Dissolved oxygen data from 2010 for Big Hills Lake, Waushara County, WI.

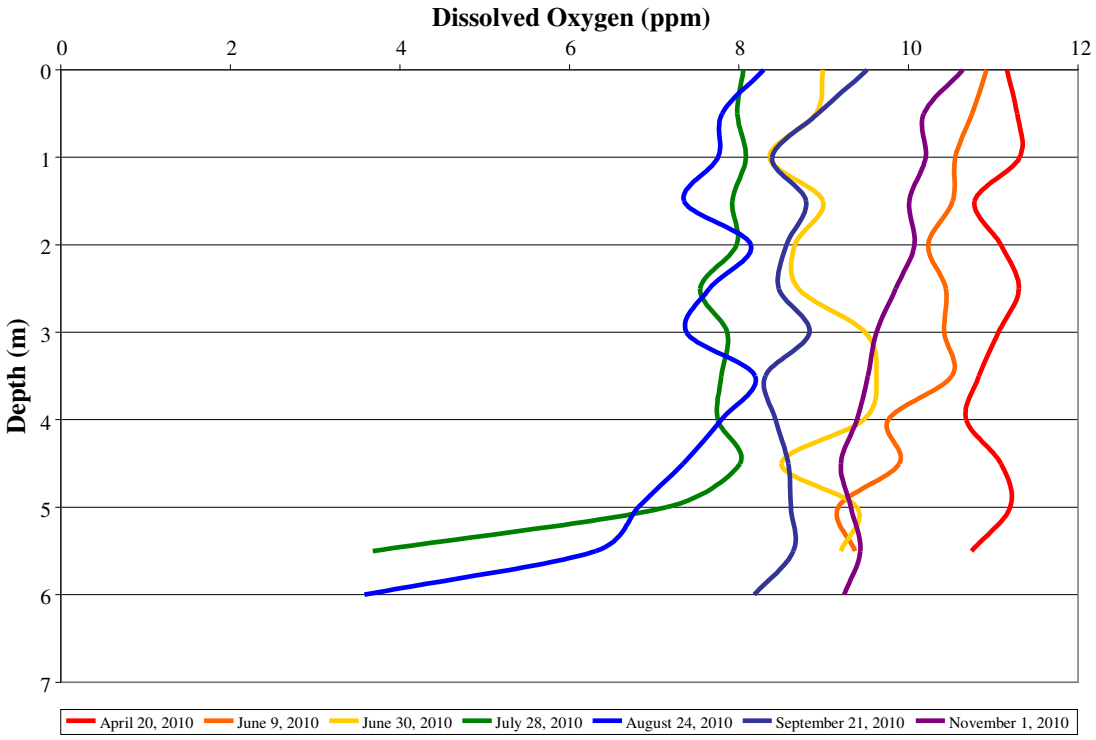
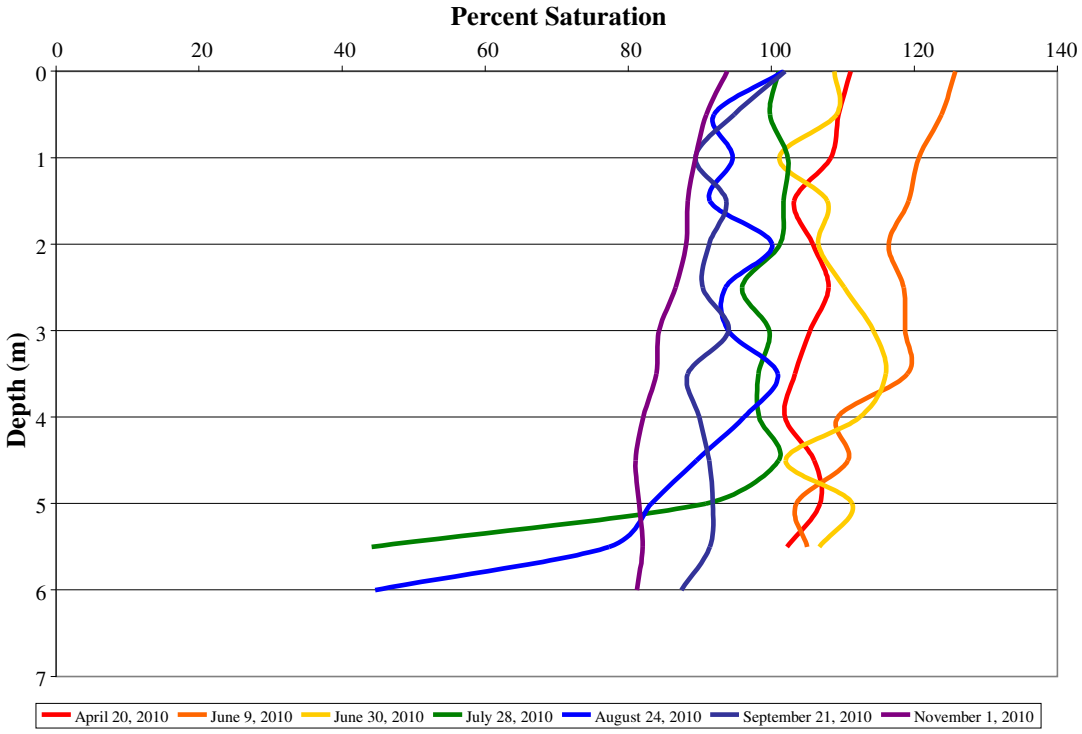


Figure 18. Percent Saturation data from 2010 for Big Hills Lake, Waushara County, WI.



Fishery Data

Big Hills Lake has been stocked with fish on an annual basis since 1999 (**Table 5**). This has been in large part due to the efforts of We Really Kare Inc., a fishing club based in Wild Rose, Wisconsin in partnership with the Big Hills Lake P & R District. Prior to 1999, the walleye (*Sander vitreus*) were the primary stocking species. Since 1999, stocked species have included walleye, yellow perch ((*Perca flavescens*), black crappies (*Pomoxis nigromaculatus*), fathead minnows (*Pimephales promelas*) and golden shiners (*Notemigonus crysoleucas*).

In 2010 the Wisconsin DNR conducted a survey of the fishery of Big Hills Lake. This survey utilized fyke and seine nets and boomshocking. Results of the survey (Appendix G) indicate largemouth bass are the dominant predator fish with an abundant population exhibiting poor size structures and growth rates. This is likely due to limited habitiat and cover. Other predator species including northen pike and walleye are also present but at low levels. Recommendations by the DNR include removing the 14 inch size limit on largemouth bass and replacing it with a no size limit, bag limit of 5 fish.

Bluegills and yellow perch were found to be the dominant prey species in Big Hills Lake. However, their numbers are low and growth rates above average. In order to increase panfish populations, the DNR recommend placing brush bundles or fallen trees or fish cribs in the lake as habitat.

Carp

Members of the District have identified carp in Big Hills Lake in recent years. The presence of carp was confirmed by the DNR during the fishery survey. It is unclear how or when the carp entered the lake. There are a limited number of options for managing carp in a lake like Big Hills Lake. There are piscicides (chemicals toxic to fish) commercially available, however, they will not selectively target one species. According to the current Wisconsin fishing regulations. Carp and other can be taken by hook and line, spear or bow and arrow. If captured by hook and like, they can be returned to the waterbody, however, it is not recommended, particularly carp in Big Hills Lake. Carp taken by spear or bow cannot be returned to the waterbody and instead should be disposed of properly. Anglers should not leave these fish on the shore or ice.

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Table 5. Fish stocking data from 1972 to 2010 for Big Hills Lake, Waushara County, Wisconsin.

Year	Species	Age Class	Number Fish Stocked	Avg Fish Length (in.)	Source Type
1972	Walleye	Yearling	1,350	10	Federal Hatchery
1987	Walleye	Fingerling	1,140	7	Field Transfer
1989	Walleye	Fingerling	5,400	7	DNR Hatchery
1990	Walleye	Fingerling	2,000	5	DNR Hatchery
1996	Walleye	Fingerling	693	5.6	DNR Co-op Ponds
1999	Golden Shiner	Large Fingerling	10,400	4.1	Private Hatchery
1999	Walleye	Large Fingerling	1,200	7.1	Private Hatchery
2000	Black Crappie	Large Fingerling	1,000	4.9	Private Hatchery
2000	Fathead Minnow	Adult	49,000	2.1	Private Hatchery
2000	Yellow Perch	Adult (Broodstock)	3,000	4.4	Field Transfer
2001	Fathead Minnow	Unknown	N/A	N/A	Private Hatchery
2001	Walleye	Large Fingerling	N/A	7.2	Private Hatchery
2002	Fathead Minnow	Adult (Broodstock)	60,000	1.5	Private Hatchery
2003	Fathead Minnow	Adult (Broodstock)	90,000	N/A	Private Hatchery
2003	Yellow Perch	Adult (Broodstock)	1,000	N/A	Private Hatchery
2004	Black Crappie	Fall Yearling	200	4.1	Private Hatchery
2004	Black Crappie	Unknown	500	8.2	Private Hatchery
2004	Walleye	Fall Yearling	1,200	7.2	Private Hatchery
2005	Fathead Minnow	Adult	60,000	N/A	Private Hatchery
2005	Walleye	Large Fingerling	1,000	6.5	Private Hatchery
2006	Fathead Minnow	Adult	120,000	N/A	Private Hatchery
2007	Black Crappie	Adult	1,200	7	Private Hatchery
2007	Fathead Minnow	Yearling	60,000	N/A	Private Hatchery
2008	Fathead Minnow	Adult	60,000	1.5	Private Hatchery
2008	Walleye	Large Fingerling	1,300	7	Private Hatchery
2009	Black Crappie	Adult	500	6	Private Hatchery
2009	Fathead Minnow	Adult	60,000	2	Private Hatchery
2010	Black Crappie	Adult	1,000	6	Private Hatchery
2010	Fathead Minnow	Adult	150,000	2	Private Hatchery
2010	Walleye	Fall Yearling	750	5	Private Hatchery

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 19 and 20**). 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. The shallow bay on the west end of the lake contains dense submergent vegetation rimmed by emergents. This area is an important nursery area for juvenile fish and forage production.

There are scattered areas of emergents elsewhere in the lake composed primarily of three-square bulrush. However these areas are limited. 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 Big Hills Lake.

Table 6 provides a list of habitat requirements and improvements for game fish species found in Big Hills 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 19. Shoreline variability on Big Hills Lake, Waushara County, Wisconsin







Fish Cribs

In March 2011 We Really Kare Inc., under the guidance of the Wisconsin DNR, placed six wooden fish cribs in Big Hills Lake. Each crib was comprised of pine logs and brush and measured 8' by 8' by 6' tall. Six additional cribs are scheduled to be placed in Big Hills Lake in the winter of 2011/2012.

Figure 20. Fish habitat availability in 2010 on Big Hills Lake, Waushara County

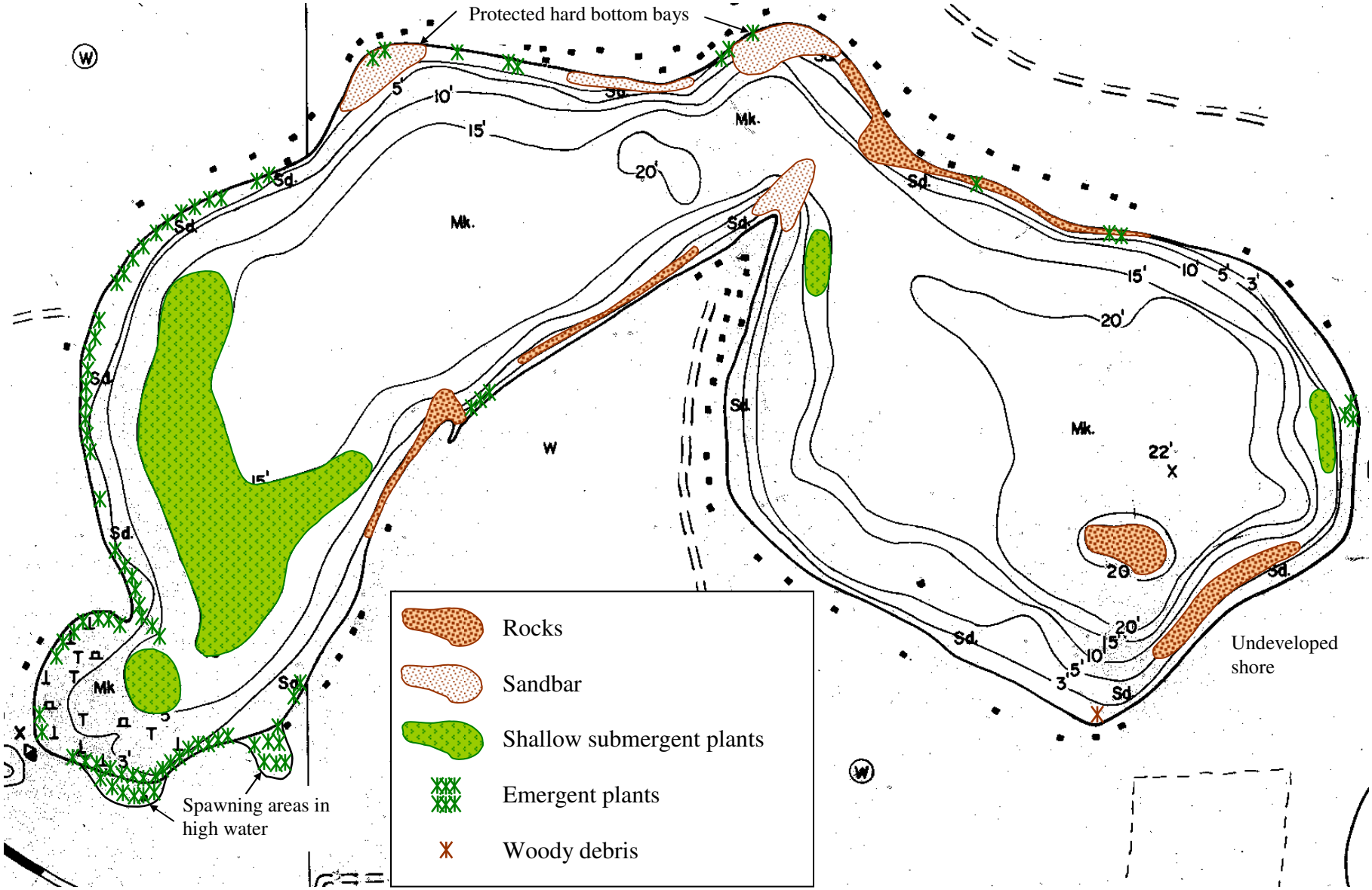

Table 6. Description of habitat requirements and improvements for fish species found in Big Hills Lake, Waushara County.

Species	Habitat Requirements			Habitat Improvements	Important Water Quality Parameters
	Spawning	Rearing	Foraging		
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 Big Hills 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 Big Hills 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 exists in Big Hills Lake and other exotic species like curly-leaf pondweed 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.

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 Big Hills Lake are very important to residents and largely the reason for owning property on the lake. Currently, Big Hills Lake has a below average diversity of submergent aquatic plants. This appears to have been the case prior to the large-scale milfoil treatment in 2004. It is likely this is the nature of Big Hills Lake and not a result of lake management practices in the past decade or so. Results of the aquatic plant survey conducted in 2010 support lake users comments that the aquatic plant community of Big Hills Lake does not greatly impact navigation or recreational use of the lake.

Exotic species monitoring
Survey results confirm that Eurasian watermilfoil continues to infest Big Hills Lake, albeit at low levels of occurrence. Over the past two years it has been confined to the bay adjacent to the public boat landing. Active management of milfoil has allowed the Distrtict to contain the milfoil thus far. Experience has shown that a proactive approach to the management of Eurasian watermilfoil is effective at maintaining this species at low levels. 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.

Management of Eurasian watermilfoil
After the large-scale treatment for Eurasian watermilfoil in 2004, a subsequent treatment was not needed until the spring of 2010. This treatment utilized Navigate® (granular 2,4-D) applied at a rate of 150 lbs per acre. Some survival and expansion took place following this most recent treatment. For this reason, it is recommended that the District continue to sponsor annual treatments as needed on Big Hills 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. As an example, the herbicide triclopyr has recently been used to treat Eurasian watermilfoil on both a large-scale and small scale approach on lakes in the Upper Peninsula of Michigan. Results of these treatments are

pending. If this or 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 Big Hills Lake Protection and Rehabilitation District does not have an active Clean Boats, Clean Water (CBCW) program. With a County park at the public landing, Big Hills 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 Big Hills Lake since Eurasian watermilfoil is 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 Big Hills 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 Big Hills 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 Big Hills 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 Big Hills 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).

When property owners were asked what they would change about Big Hills Lake, the top responses concerned boating. Respondents would like to see boat size restrictions and the removal of jet skis from the lake. Although the likelihood of this happening is low, 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.

Members of the District have expressed some concern in recent years about the possibility of pollutants, primarily nutrients, entering the lake through faulty or poorly maintained septic systems.

In October 2008, the Department of Commerce mandated that Wisconsin counties put all septic systems into a three-year maintenance program by 2012. This program would include pumping and visual inspections of septic systems. The Waushara County Zoning Office has computerized files pertaining to the septic system permits dating back to 1990 and paper files dating back to 1980. The County is confident that these systems dating back to 1980 were installed correctly and are currently functioning properly. They are also confident these systems do not pose a significant threat to the quality of the groundwater. Some systems were likely installed in the 1960's or 1970's. It is unclear from the files how old these systems are, whether they were properly installed or even if certain properties contain septic systems.

County staff is currently evaluating properties not currently in the system before capturing them in the three-year program. These evaluations should be conducted by certified soil testers, plumbing inspectors and/or Private Onsite Wastewater Treatment System (POWTS) inspectors.

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 Big Hills Lake have mostly collected water clarity data over this time frame. Volunteers can be trained to collect a variety of water quality data in order to gain a better understanding of lake conditions. 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 Big Hills 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.

Citizen Involvement and Management Planning

Input from members of the Big Hills Lake P & R District was gathered by Leede Research as part of this study. Results were compiled in the May 2010 and are presented in Apprendix A.

In addition, the results of this study were presented to the membership living on Big Hills Lake at the annual meeting held on July 23, 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 Big Hills 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 Big Hills 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 Big Hills 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 Big Hills 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 Big Hills 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: Continue with the stocking of game fish and the placement of fish cribs in Big Hills Lake.

Timeframe: Starting in 2011
Facilitator: District Board, We Really Kare Inc.
The District board will 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 Big Hills Lake, conducted by Leede Research, May 2010.



Bill Hills Lakes Management District Property Owners Study

Preliminary Report
May 2010

LEEDE RESEARCH
market with confidence

Leede Research

Who we are:

- Leede Research was founded in 1982 by current CEO, Dean Halverson based on computer software written as a college student.
- The company has grown to a staff of 85 information professionals with offices in Minneapolis and Manitowoc, Wisconsin. Leede offers full-service qualitative and quantitative research programs and is a nationally recognized leader in website usability testing. We also have experience in ethnography and persona development.
- Leede Research has a strong base in customer satisfaction, loyalty and marketing tracking systems.
- Leede Research has worked with a wide range of nationally recognized consumer packaged goods, financial services and healthcare. Our experience includes work with a variety of government entities and non-profit organizations.
- Leede's work is custom designed, bringing to the table over 27 years of market research experience.

Some of Our Consumer Goods Clients



May 2010

Study Methodology

The following are the details of the study:

- The Big Hills Lake Management District is coordinating a comprehensive lake study being completed by Cason Associates. This study will evaluate the health and usage of our lake and help identify issues that will be addressed in a management plan for the lake. This is an important tool in maintaining the quality of the lake and feel about key issues.
- Custom designed quantitative program developed through work between Leede Research, Cason Associates and the Lake District.
- Surveys were gathered through a direct mail and online format managed by Leede Research.
- A total of 100 completed interviews were conducted in this study. This indicates a maximum error in the study of $\pm$ 4.9% based on 95% confidence. The return on the survey is considered outstanding and one of the higher rates in Leede's experience with such organizations.
- All reporting, analysis and presentation materials were completed by Leede Research

Executive Summary

Executive Summary

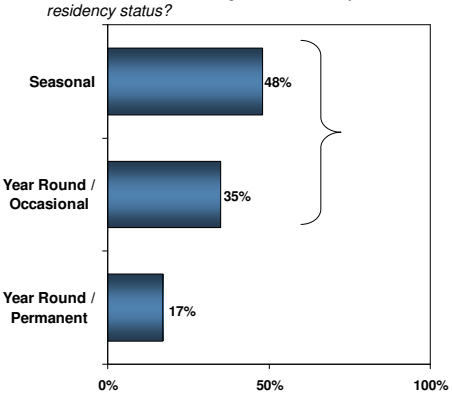
The following are what Leede Research sees as the key findings of the the overall study:

- xxx

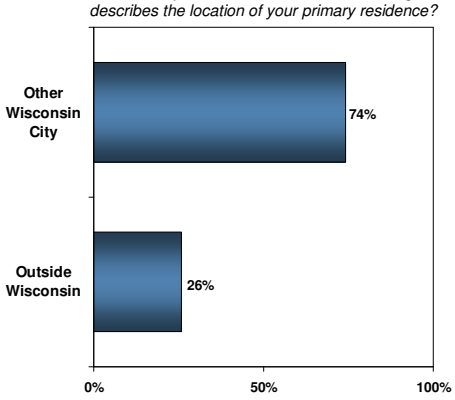
Study Details

Residency Status

Q1. Which of the following best describes your residency status?



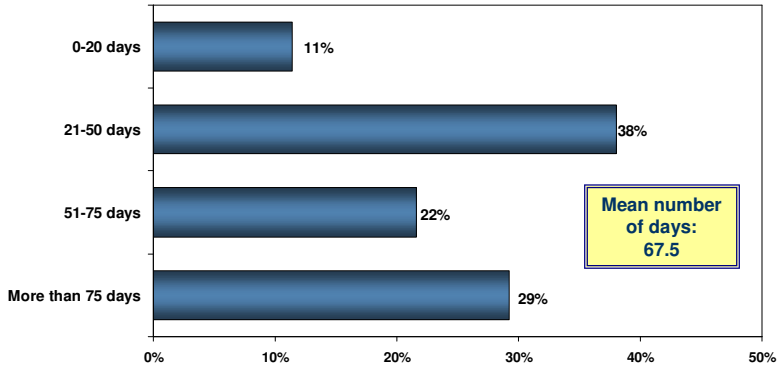
Q1b. If not permanent, Which of the following best describes the location of your primary residence?



- Respondents were primarily Seasonal Residents but there is a significant portion that are Year Round Occasional. There are 17% of respondents who consider themselves Permanent. Most are from some area of Wisconsin, though a full quarter are from outside.

Number of Days at Property

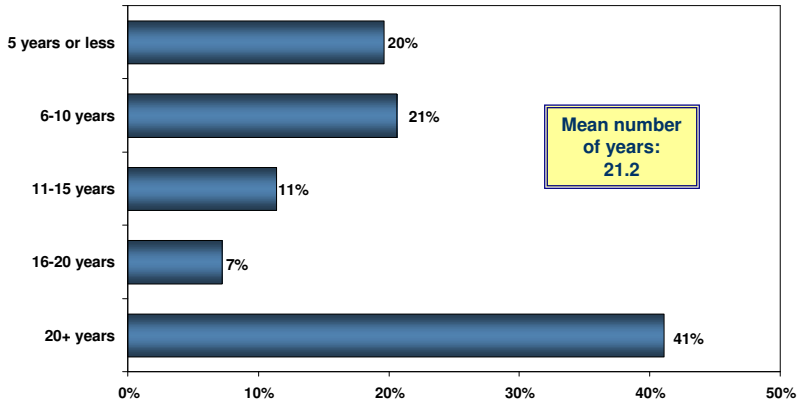
Q1a. Approximately how many days per year are you at the property?



➢ There is a significant variation in the number of days spent on the respondent's properties. The mean is 67 days with almost 30% of respondents spending more than 75 days per year at their property.

Length of Ownership

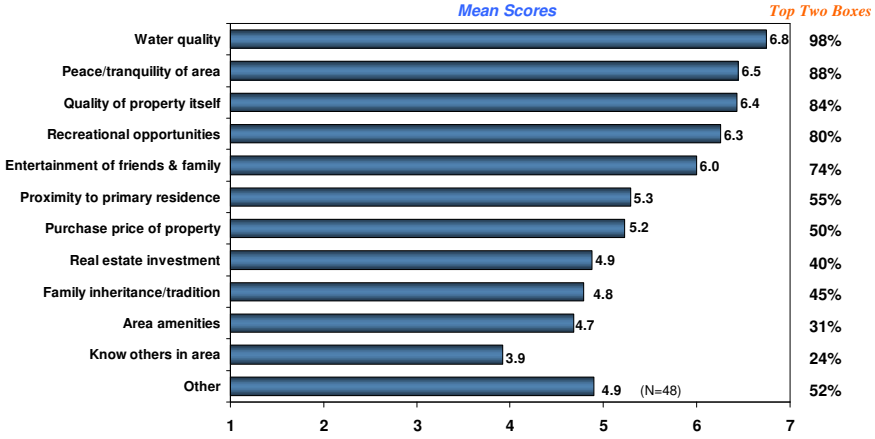
Q2. How long have you owned the property?



➢ There are many long-term property owners generating a mean response of 21years. This means there were as many respondents above that number as below. We see there are about one in five respondents who are recent owners and have been on the lake five years or less. This may be a factor of further analysis.

Attribute Importance

Q3. The following is a list of factors that may have been important to you in selecting your property on Big Hills Lake. Please rate the importance of each item from 1 to 7, with 1 being Not at All Important, to 7 being Very Important to you:



➢ The respondents indicate Water Quality, Tranquility, Quality of Property and Recreational Opportunities are the top reasons they purchased their property. These items generated the top two box scores in excess of 80%. This means they offered either a 6 or 7 rating.

Other Important Factors

Q3. What other factors are important:

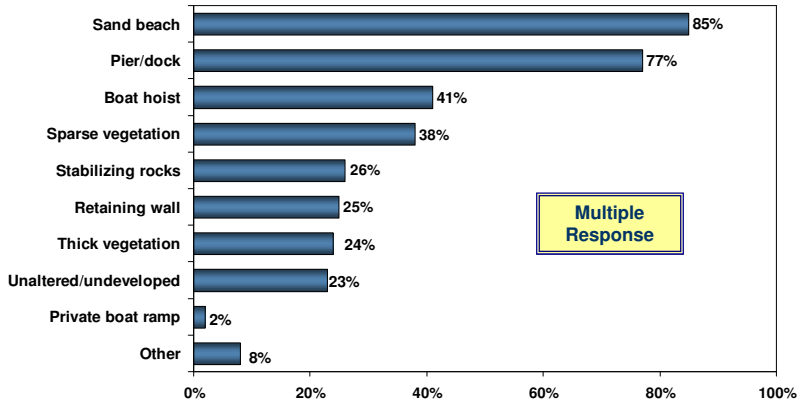
1. Accessibility to other lakes. We are not on the lake. We do have lake access.
2. Close to owned recreational land.
3. Family summer home since 1952
4. Had to check every line, think the list has it pretty well covered. Tranquil, woodsy, very nice lake, beautiful nighttime skies; close enough to amenities, though I often park the car for the entire visit; scout camp to east is a nice buffer and fine neighbors; attitude of all our neighbors is great.
5. I find the larger motored boats very invasive to this smaller lake and mostly the ski machines that have no clue about rules...now these may be coming off the public landing but a survey on my part in my quiet boat shows many newer homes own them. Also there should be rules about dogs running loose on other peoples property. We have a leash on ours all the time even when playing in the water as a safety feature, however on the south side of the lake dogs run loose and visit whomever they please. I love our lake/lake home and the purity of the water...my husband died two years ago but when we bought this property together in 58 we rented a boat and looked at the lake...and that's what sold us, the clean lake. Thanks for helping out with this survey. Dorothy
6. Nice, sandy beach
7. No tavern
8. No wake to remain the way it is, fishing quality, shoreline beauty
9. Non wake hours
10. Northern Wisconsin feel without the drive. Size of lake (wanted 100 acre minimum).
11. Property has been in my wife's family since the mid 1950's. My father-in-law inherited from his father and we purchased it from my father-in-law. We intend to keep it in the family.
12. Retirement location, interrupted by death of spouse.
13. Sandy beach

Other Important Factors, continued

14. Swim-able, sandy bottom, little to no weeds
15. Swimming area/sandy beach
16. The beauty of the setting
17. The cottage was income property when we purchased it. Rented it out for 17 years.
18. The lake home offers a sanctuary from the complexities of modern life and a bridge to a simpler time and way of life, even on summer weekends when the lake is vibrating with the force or dozens of water crafts.
19. Tree quality
20. Upkeep of the lake
21. Water ski lake
22. Water ski/wakeboard lake
23. Water-skiing/sports
24. We inherited this property, and before that we owned the cottage next door, which my grandfather and his sons built in 1929 and which is still owned by family. Some of our roots are here in this land and in this lake.
25. When purchased, the property was near where we worked. We chose a place to work and live that provided a rural lifestyle.
26. Wildlife
27. Wonderful friendly neighbors next to us and also around the lake who observe lake rules. What a blessing!

Type of Lake Frontage

Q4. Which of the following describes your lake frontage within 25 feet of the waters edge?



➢ This table indicates that Sand Beach is a key feature as are Piers. There is a strong penetration of Boat Hoists and Sparse Vegetation. This should be compared against other lakes that Cason has worked with.

Best Feature of Big Hills Lake

Q5. What do you think is the best feature of Big Hills Lake? – Open Responses

The most often mentioned responses were:

Water Quality / Clear Water – 54 Responses

Beauty / Peaceful – 11 Responses

Please see all of the responses in the "Open Responses" section of the report.

- These items, though in an open format, tie to the earlier measurement of why the respondent selected their property. Water is clearly a key component and the results indicate the need for activities of the Lake District to focus on the protection and development of the water.

Change About Big Hills Lake

Q6. If you were in charge of the lake and could change one thing, what would it be? – Open Responses

The most often mentioned responses were:

Have Boat Size Restrictions – 16 responses

Allow no jet skis – 10 responses

More fish stocked – 7 responses

Close public beach / landing – 7 responses

More enforcement – 6 responses

Raise water levels – 6 responses

Change no wake hours – 6 responses

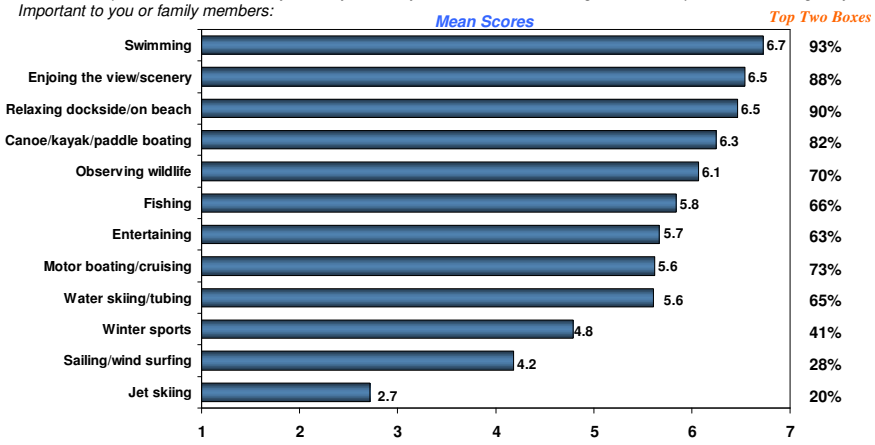
Clean up beach / properties – 3 responses

Please see all of the responses in the "Open Responses" section of the report.

- The results indicate concern with a variety of issues but there does appear to be some issue with the size and types of watercraft that are accessing the lake.

Attribute Importance of Participation

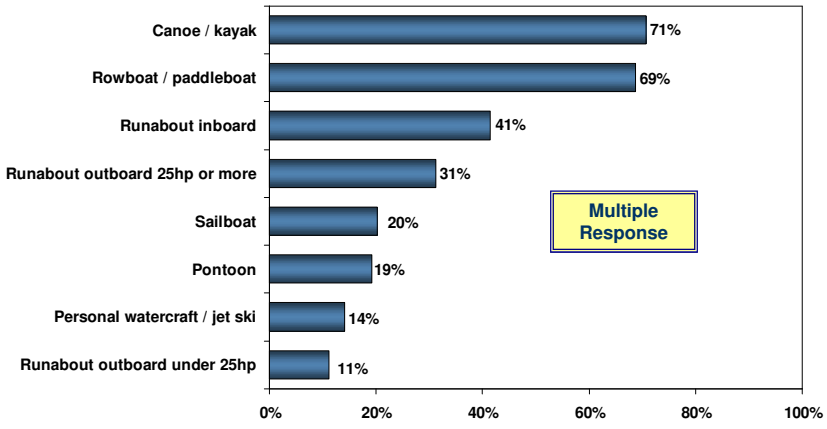
Q7. The following is a list of activities that you or members of your household may participate in on Big Hills Lake. For each item please indicate whether you have done that in the past year. If you have participated in an activity please rate the overall importance of that item to you and your family from 1 to 7, with 1 being Not at All Important, to 7 being Very Important to you or family members:



➢ The results indicate the items respondents participate in tie strongly to the water and related quality. It is interesting to note that non-powered boat travel is higher than motored forms.

Types of Watercraft Use

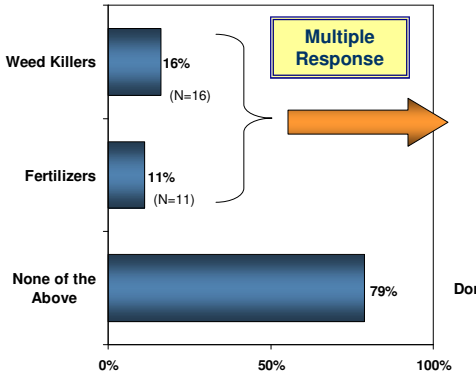
Q8. What types of watercraft do you use on Big Hills Lake?



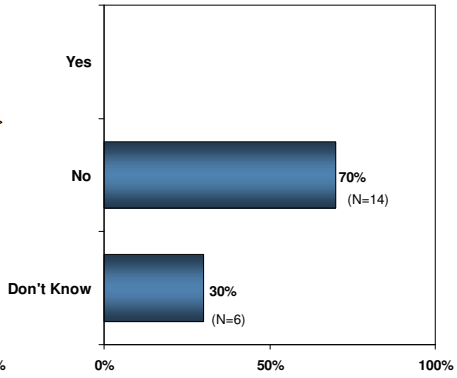
➢ This response ties well to the prior question and indicates that respondents have a high degree of non-powered watercraft. This may also be a factor in concerns over the size of boats on the lake and outside access.

Use Products

Q9. Do you use any of the following on your property?



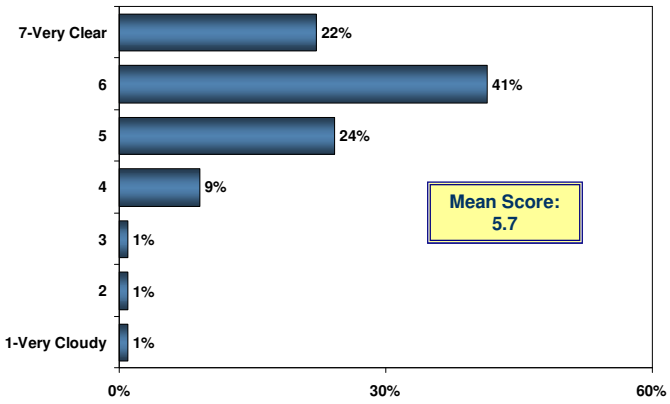
Q9a. Does the product(s) used contain phosphorus?



➢ It is positive to see only limited use of weed killers or fertilizers. Those using such products do not believe them to contain phosphorus. It should be noted this is based on self reporting and does not guarantee that such products are not being used.

Water Clarity

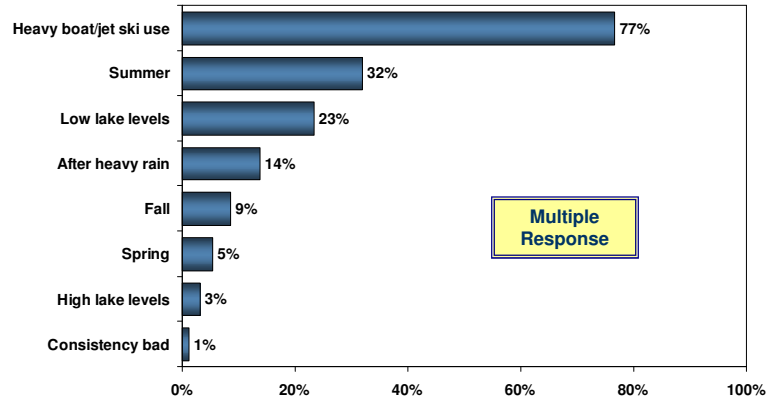
Q10. On a scale from 1 to 7, with 1 being Very Cloudy, to 7 being Very Clear, how would you describe the water clarity in Big Hills Lake during the summer months?



➢ The respondents view the clarity of the lake to be a 5.7 on the 7 point rating scale. The largest single response is a 6 rating. There are almost two-thirds of respondents that give one of the top two ratings. This is strong and ties well to earlier items related to water quality.

When Water Clarity is Poor

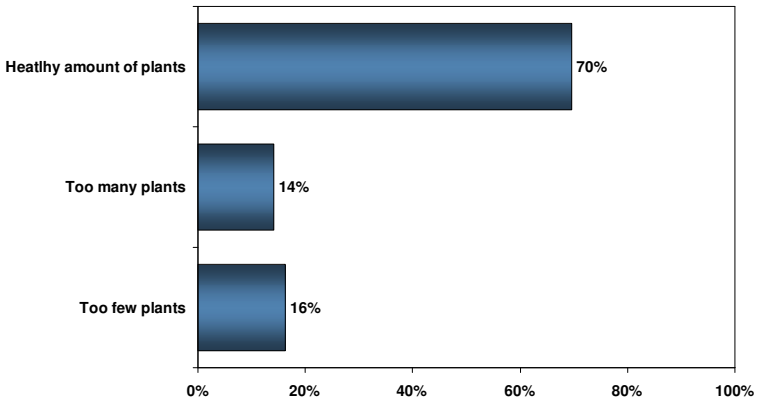
Q11. When is water clarity on the lake poor?



➢ The results indicate property owners feel that heavy boat traffic has the most significant impact on water clarity. This is consistent with earlier findings on concerns for the size and number of boats that are coming onto the lake.

Aquatic Plant Growth

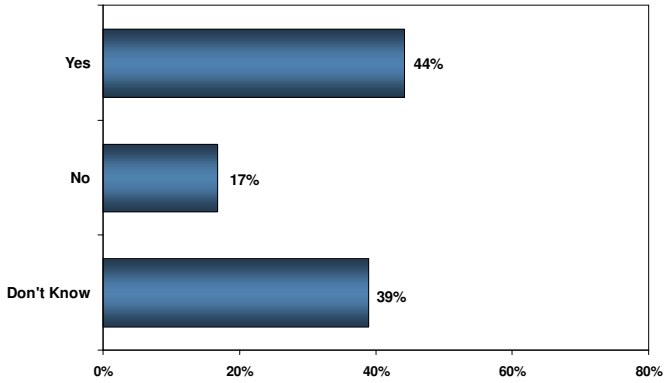
Q12. Overall, how would you describe the Aquatic Plant growth in Big Hills Lake?



➢ The vast majority of respondents indicate they feel there is a healthy amount of weeds in the lake under current conditions. This would most likely be based on weed levels seen during the 2009 season as weeds would not have been in full growth at the actual time of the survey.

Need for Aquatic Plant Control

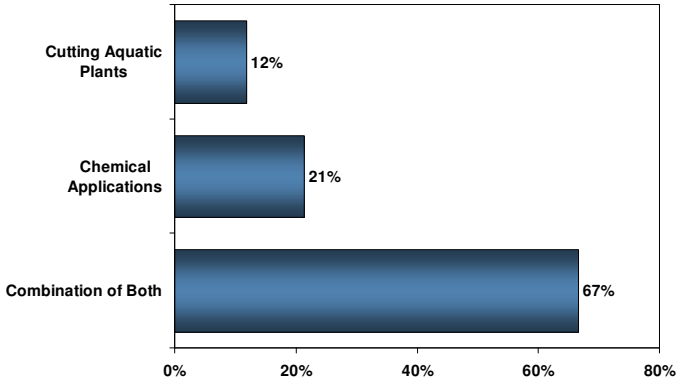
Q13. Do you feel there is a need for an aquatic plant control program on Big Hills Lake?



➢ There are mixed feelings on the need for weed control on the lake. We see that while only 17% feel there is no need for a control program the balance is split between seeing the need and not being sure. This may indicate that the Lake District needs to make decisions and inform and educate property owners on issues related to control.

Options for Aquatic Plant Control

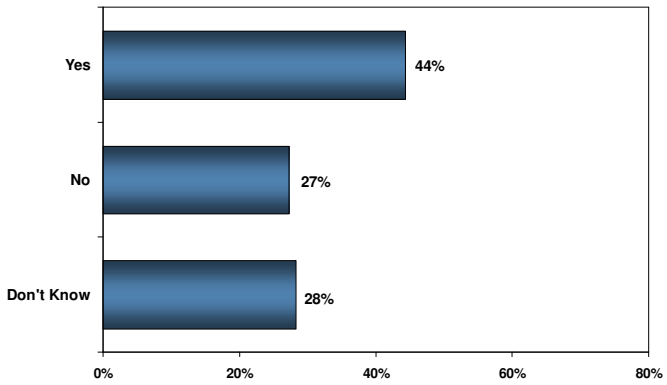
Q14. When there is a need for aquatic plant control on Big Hills Lake please indicate which of the following options should be considered to control the problem?



➢ It is clear that when control programs are used the respondents feel that both cutting and chemicals should be part of the program. This give the district the option of conducting programs to meet specific situations and needs.

Adequate Law Enforcement

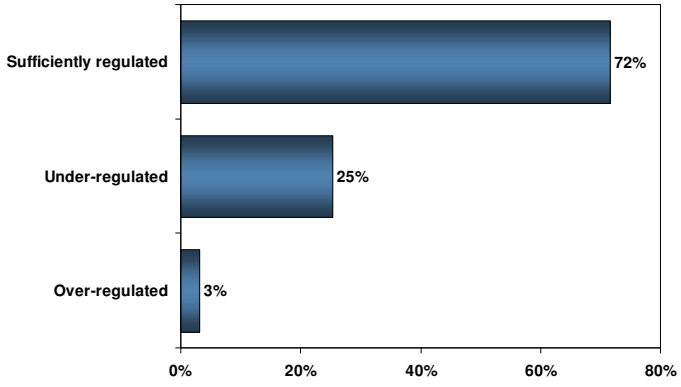
Q15. Do you feel that there is adequate law enforcement on Big Hills Lake?



➢ There are some mixed feelings on law enforcement on Big Hills Lake but the largest single response is for Yes, indicating that there IS adequate enforcement on the water. This should be considered by district management.

Lake Use Regulations

Q16. What is your opinion regarding lake use regulations on Big Hills Lake in general?



➢ The vast majority of respondents feel that the lake regulations are generally sufficient in meeting the needs of property owners on the lake. There are a quarter of respondents that feel further action is needed.

Like to See Changed in Rules

Q16. If Under or Over Regulated: What would you like to see changed in the rules? – Open Responses

The most often mentioned responses were:

UNDER REGULATED:

Have boat size restrictions – 9 responses

Change no wake hours – 4 responses

More enforcement – 5 responses

Allow no jet skis – 3 responses

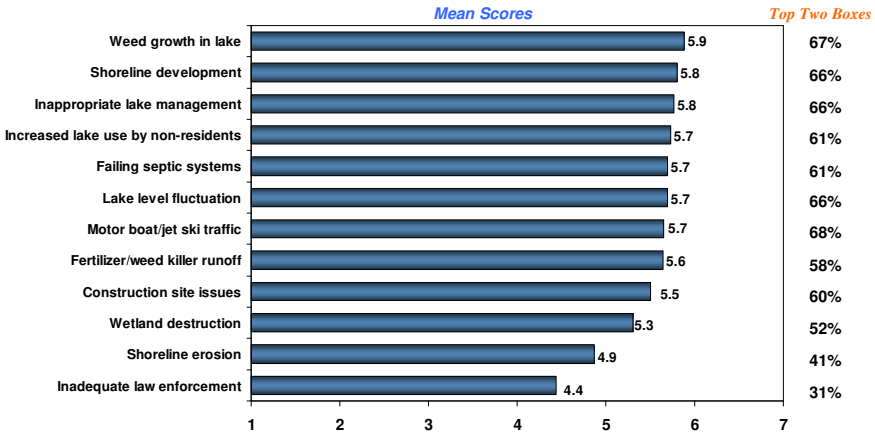
OVER-REGULATED – Change no wake hours – 3 responses

Please see all of the responses in the "Open Responses" section of the report.

➢ Results indicate there are issues with the current no wake hours on both sides of the regulation question. The results indicate that boat size and jet ski issues are also a factor that should be considered.

Potential Impact

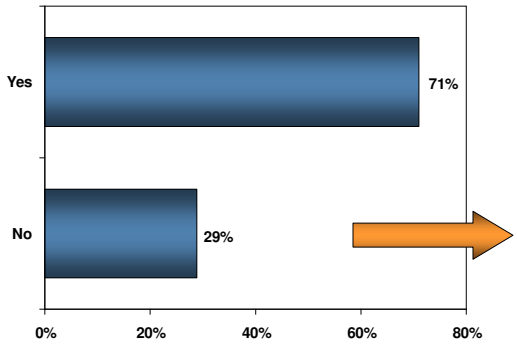
Q17. The following is a list of issues that could have future impact on Big Hills Lake. Please rate the potential impact of each issues on the lake from1 to 7, with 1 being No Impact, to 7 being a Very Strong Impact for each issues:



➢ This question may be the most meaningful in terms of the very narrow range of response seen in the results. Both Mean and Top Two Box scores fall in a very narrow range and indicate that respondents feel that most of the items have the potential to be issues. This should be considered in future planning along with open-ended responses.

Offer Input Into Matters

Q18. Do you feel that you can offer input into matters regarding the management of Big Hills Lake?



*Q4a. **If No**: Please explain why you feel that way? – Open Response Coded*

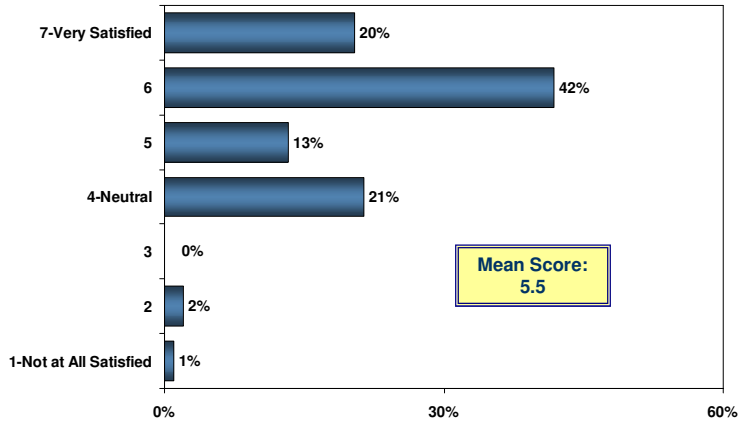
My age – 7 responses

Do not live here – 6 responses

➢ There are over 70% of respondents who feel they are able to offer input to the district and its management. There do not appear to be significant issues that are barriers to the balance of respondents.

Satisfaction With Management of Lake

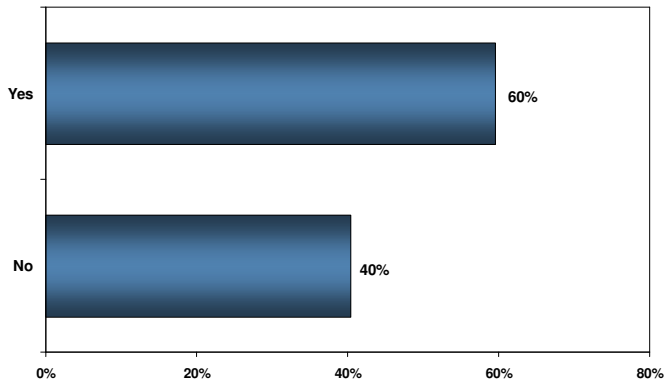
Q19. On a scale from 1 to 7, with 1 being Not at All Satisfied, to 7 being Very Satisfied, how satisfied are you with the overall management of Big Hills Lake?



➢ Overall satisfaction shows a mean score of 5.5 on the 7 point rating scale. There are 62% of respondents who give one of the top two ratings. This is generally an indication of solid satisfaction but there is still some room for improvement. There are only 3% of respondents that fall below average ratings.

Attended Annual Meeting

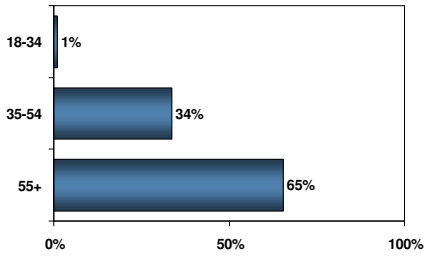
20. Have you attended an Annual Meeting of the Big Hills Lake Association in the past 3 years?



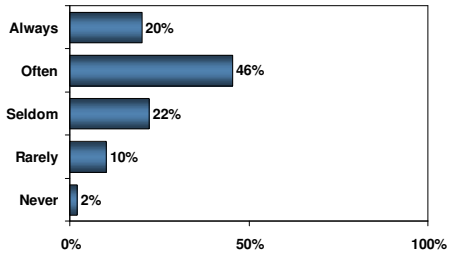
➢ There were six in ten respondents who had attended an Annual Meeting of the Lake District. This may be an area for further analysis to determine if there are differences between the groups and the information they receive. There could also be differences in needs that could be addressed through matters other than the meetings.

Age of Primary Owner/Have Children

Q21. Please check the age(s) of the primary owners of the property on Big Hills Lake.



Q22. Which of the following best describes how often you have children on your property?



➢ The majority of owners are over 55 years of age. This should be noted in reviewing the results and ties to the length of ownership seen earlier in the results. The results also indicate that there are commonly children present at the properties and that fact should be considered in actions taken by district management.


Thanks for Your Participation
LEEDE RESEARCH
market with confidence

Appendix B

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

Site	Latitude	Longitude	Site	Latitude	Longitude	Site	Latitude	Longitude
0	44.1487	-89.1717	51	44.1505	-89.1692	102	44.1537	-89.1672
1	44.1483	-89.1712	52	44.1508	-89.1692	103	44.1540	-89.1672
2	44.1487	-89.1712	53	44.1512	-89.1692	104	44.1544	-89.1671
3	44.1490	-89.1712	54	44.1515	-89.1692	105	44.1515	-89.1667
4	44.1508	-89.1712	55	44.1519	-89.1692	106	44.1519	-89.1667
5	44.1512	-89.1712	56	44.1523	-89.1692	107	44.1522	-89.1667
6	44.1516	-89.1712	57	44.1526	-89.1692	108	44.1526	-89.1667
7	44.1483	-89.1707	58	44.1530	-89.1692	109	44.1530	-89.1667
8	44.1487	-89.1707	59	44.1533	-89.1692	110	44.1533	-89.1667
9	44.1490	-89.1707	60	44.1494	-89.1687	111	44.1537	-89.1667
10	44.1498	-89.1707	61	44.1497	-89.1687	112	44.1540	-89.1667
11	44.1501	-89.1707	62	44.1501	-89.1687	113	44.1544	-89.1666
12	44.1505	-89.1707	63	44.1505	-89.1687	114	44.1519	-89.1662
13	44.1508	-89.1707	64	44.1508	-89.1687	115	44.1522	-89.1662
14	44.1512	-89.1707	65	44.1512	-89.1687	116	44.1526	-89.1662
15	44.1516	-89.1707	66	44.1515	-89.1687	117	44.1530	-89.1662
16	44.1519	-89.1707	67	44.1519	-89.1687	118	44.1533	-89.1662
17	44.1523	-89.1707	68	44.1523	-89.1687	119	44.1537	-89.1662
18	44.1526	-89.1707	69	44.1526	-89.1687	120	44.1540	-89.1662
19	44.1483	-89.1702	70	44.1530	-89.1687	121	44.1544	-89.1661
20	44.1487	-89.1702	71	44.1533	-89.1687	122	44.1519	-89.1657
21	44.1490	-89.1702	72	44.1494	-89.1682	123	44.1522	-89.1657
22	44.1494	-89.1702	73	44.1497	-89.1682	124	44.1526	-89.1657
23	44.1497	-89.1702	74	44.1501	-89.1682	125	44.1530	-89.1657
24	44.1501	-89.1702	75	44.1505	-89.1682	126	44.1533	-89.1657
25	44.1505	-89.1702	76	44.1508	-89.1682	127	44.1537	-89.1657
26	44.1508	-89.1702	77	44.1512	-89.1682	128	44.1540	-89.1657
27	44.1512	-89.1702	78	44.1515	-89.1682	129	44.1522	-89.1652
28	44.1515	-89.1702	79	44.1519	-89.1682	130	44.1526	-89.1652
29	44.1519	-89.1702	80	44.1523	-89.1682	131	44.1530	-89.1652
30	44.1523	-89.1702	81	44.1526	-89.1682	132	44.1533	-89.1652
31	44.1526	-89.1702	82	44.1530	-89.1682	133	44.1537	-89.1652
32	44.1530	-89.1702	83	44.1533	-89.1682	134	44.1540	-89.1652
33	44.1487	-89.1697	84	44.1537	-89.1682	135	44.1522	-89.1647
34	44.1490	-89.1697	85	44.1541	-89.1682	136	44.1526	-89.1647
35	44.1494	-89.1697	86	44.1512	-89.1677	137	44.1529	-89.1647
36	44.1497	-89.1697	87	44.1515	-89.1677	138	44.1533	-89.1647
37	44.1501	-89.1697	88	44.1519	-89.1677	139	44.1537	-89.1647
38	44.1505	-89.1697	89	44.1523	-89.1677	140	44.1540	-89.1647
39	44.1508	-89.1697	90	44.1526	-89.1677	141	44.1526	-89.1642
40	44.1512	-89.1697	91	44.1530	-89.1677	142	44.1529	-89.1642
41	44.1515	-89.1697	92	44.1533	-89.1677	143	44.1533	-89.1642
42	44.1519	-89.1697	93	44.1537	-89.1677	144	44.1537	-89.1642
43	44.1523	-89.1697	94	44.1541	-89.1677	145	44.1540	-89.1641
44	44.1526	-89.1697	95	44.1544	-89.1676	146	44.1529	-89.1637
45	44.1530	-89.1697	96	44.1515	-89.1672	147	44.1533	-89.1637
46	44.1487	-89.1692	97	44.1519	-89.1672	148	44.1537	-89.1637
47	44.1490	-89.1692	98	44.1522	-89.1672	149	44.1540	-89.1636
48	44.1494	-89.1692	99	44.1526	-89.1672	150	44.1544	-89.1636
49	44.1497	-89.1692	100	44.1530	-89.1672	151	44.1511	-89.1632
50	44.1501	-89.1692	101	44.1533	-89.1672	152	44.1515	-89.1632

Site	Latitude	Longitude
153	44.1519	-89.1632
154	44.1529	-89.1632
155	44.1533	-89.1632
156	44.1537	-89.1632
157	44.1540	-89.1631
158	44.1544	-89.1631
159	44.1504	-89.1627
160	44.1508	-89.1627
161	44.1511	-89.1627
162	44.1515	-89.1627
163	44.1519	-89.1627
164	44.1522	-89.1627
165	44.1526	-89.1627
166	44.1529	-89.1627
167	44.1533	-89.1627
168	44.1537	-89.1627
169	44.1540	-89.1626
170	44.1544	-89.1626
171	44.1497	-89.1622
172	44.1501	-89.1622
173	44.1504	-89.1622
174	44.1508	-89.1622
175	44.1511	-89.1622
176	44.1515	-89.1622
177	44.1519	-89.1622
178	44.1522	-89.1622
179	44.1526	-89.1622
180	44.1529	-89.1622
181	44.1533	-89.1622
182	44.1537	-89.1622
183	44.1540	-89.1621
184	44.1544	-89.1621
185	44.1497	-89.1617
186	44.1500	-89.1617
187	44.1504	-89.1617
188	44.1508	-89.1617
189	44.1511	-89.1617
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191	44.1518	-89.1617
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195	44.1533	-89.1617
196	44.1536	-89.1617
197	44.1540	-89.1616
198	44.1493	-89.1612
199	44.1497	-89.1612
200	44.1500	-89.1612
201	44.1504	-89.1612
202	44.1508	-89.1612
203	44.1511	-89.1612
204	44.1515	-89.1612
205	44.1518	-89.1612
206	44.1522	-89.1612
207	44.1526	-89.1612
208	44.1529	-89.1612
209	44.1533	-89.1612
210	44.1493	-89.1607
211	44.1497	-89.1607
212	44.1500	-89.1607
213	44.1504	-89.1607
214	44.1508	-89.1607
215	44.1511	-89.1607
216	44.1515	-89.1607
217	44.1518	-89.1607
218	44.1522	-89.1607
219	44.1526	-89.1607
220	44.1529	-89.1607
221	44.1533	-89.1607
222	44.1493	-89.1602
223	44.1497	-89.1602
224	44.1500	-89.1602
225	44.1504	-89.1602
226	44.1508	-89.1602
227	44.1511	-89.1602
228	44.1515	-89.1602
229	44.1518	-89.1602
230	44.1522	-89.1602
231	44.1526	-89.1602
232	44.1529	-89.1602
233	44.1533	-89.1602
234	44.1490	-89.1597
235	44.1493	-89.1597
236	44.1497	-89.1597
237	44.1500	-89.1597
238	44.1504	-89.1597
239	44.1508	-89.1597
240	44.1511	-89.1597
241	44.1515	-89.1597
242	44.1518	-89.1597
243	44.1522	-89.1597
244	44.1526	-89.1597
245	44.1529	-89.1597
246	44.1486	-89.1592
247	44.1489	-89.1592
248	44.1493	-89.1592
249	44.1497	-89.1592
250	44.1500	-89.1592
251	44.1504	-89.1592
252	44.1507	-89.1592
253	44.1511	-89.1592
254	44.1515	-89.1592
255	44.1518	-89.1592
256	44.1522	-89.1592
257	44.1525	-89.1592
258	44.1529	-89.1592
259	44.1486	-89.1587
260	44.1489	-89.1587
261	44.1493	-89.1587
262	44.1497	-89.1587
263	44.1500	-89.1587
264	44.1504	-89.1587
265	44.1507	-89.1587
266	44.1511	-89.1587
267	44.1515	-89.1587
268	44.1518	-89.1587
269	44.1522	-89.1587
270	44.1525	-89.1587
271	44.1529	-89.1587
272	44.1489	-89.1582
273	44.1493	-89.1582
274	44.1497	-89.1582
275	44.1500	-89.1582
276	44.1504	-89.1582
277	44.1507	-89.1582
278	44.1511	-89.1582
279	44.1515	-89.1582
280	44.1518	-89.1582
281	44.1522	-89.1582
282	44.1525	-89.1582
283	44.1529	-89.1582
284	44.1493	-89.1577
285	44.1497	-89.1577
286	44.1500	-89.1577
287	44.1504	-89.1577
288	44.1507	-89.1577
289	44.1511	-89.1577
290	44.1515	-89.1577
291	44.1518	-89.1577
292	44.1522	-89.1577
293	44.1525	-89.1577
294	44.1497	-89.1572
295	44.1500	-89.1572
296	44.1504	-89.1572
297	44.1507	-89.1572
298	44.1511	-89.1572
299	44.1515	-89.1572
300	44.1518	-89.1572
301	44.1522	-89.1572
302	44.1525	-89.1572
303	44.1500	-89.1567
304	44.1504	-89.1567
305	44.1507	-89.1567

Site	Latitude	Longitude
306	44.1511	-89.1567
307	44.1514	-89.1567
308	44.1518	-89.1567
309	44.1522	-89.1567
310	44.1504	-89.1562
311	44.1507	-89.1562
312	44.1511	-89.1562
313	44.1514	-89.1562
314	44.1518	-89.1562

Appendix C

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

Aquatic plant species key:

FILA	filamentous algae
BRSC	*Brasenia schreberi*, Watershield
CHAR	*Chara* , Muskgrasses
ELCA	*Elodea canadensis*, Common waterweed
MYSP	*Myriophyllum spicatum*, Eurasian water-milfoil
NAFL	*Najas flexilis*, Bushy pondweed
POFO	*Potamogeton foliosus*, Leafy 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
STPE	*Stuckenia pectinata*, Sago pondweed
VAAM	*Vallisneria americana*, Wild celery

sampling point	Depth (ft)	comments	FILA	BRSC	CHAR	ELCA	MYSP	NAFL	POFO	POGR	POIL	PONA	POPU	POZO	STPE	VAAM
0	3.3				1	1		1	1							
1	2.3	No Plants														
2	5				1	1										v
3	2.7				1	1	v	1		1						v
4	3.3				v											
5	4.2	No Plants														
6	3.3	No Plants														
7	3.4				1											
8	6	No Plants														
9	7.6				1											
10	5.2	No Plants														
11	6.1	No Plants														
12	9.2				1											
13	9.9													1		
14	10.5													1		
15	11.4													1		
16	10.3					1									1	
17	7.7															
18	4.7	No Plants														
19	2.4				1			v								
20	5.4	No Plants														
21	7.3													3		
22	8.3									1				3		
23	9.2													2		
24	9.7													1		
25	11.6				1			1	1						1	
26	12.8									1						
27	13	No Plants														
28	12.9													1		
29	13	No Plants														
30	12.9	No Plants														
31	11.2				1						1			1		
32	3.6	No Plants														
33	3.4				1											
34	9					1				1						
35	10.1													3		
36	11.9													1		
37	12.4	No Plants														
38	12.9				1											
39	13.7				1					1						
40	14				1				1							
41	14.2				1											
42	14				2				1							
43	13.7								1							
44	12.8				1					1						
45	7.8	No Plants														
46	1.5															

sampling point	Depth (ft)	comments	FILA	BRSC	CHAR	ELCA	MYSP	NAFL	POFO	POGR	POIL	PONA	POPU	POZO	STPE	VAAM
47	5.6	No Plants														
48	9													3		1
49	11	No Plants														
50	12.5				3											
51	13.5	No Plants														
52	14.2	No Plants														
53	14	No Plants														
54	15				2											
55	14.3				3											
56	14.4				1				1					1		
57	13.7							1		1						
58	11.6							1		1				2		
59	4.5	No Plants														
60	5.5									1						v
61	8.8															
62	12.6	No Plants														
63	13.4	No Plants														
64	13.8				1			1								
65	14.5	No Plants														
66	14.6	No Plants														
67	15.3				1								1			
68	14.2				1											
69	13.9				1					1						
70	13.9	No Plants														
71	8.4	No Plants														
72	4.4	No Plants														
73	6.1	No Plants														
74	8.4									1						1
75	11.4				1			1		1						
76	12.7	No Plants														
77	15	No Plants														
78	15.3								1							
79	14.9				2				1							
80	15.1				2											
81	15.1				1											
82	14				3								1			
83	13.9								1	1						
84	10.8				1											1
85	7.3				1											
86	8.8															
87	14.8				1											
88	16.4	No Plants														
89	15.2	No Plants														
90	15.2	No Plants														
91	14.7				2											
92	14.6				1				1	1						
93	13.8									1						

sampling point	Depth (ft)	comments	FILA	BRSC	CHAR	ELCA	MYSP	NAFL	POFO	POGR	POIL	PONA	POPU	POZO	STPE	VAAM
94	13.9					1								2		
95	3.7					1						1				
96	12.2	No Plants														
97	15.1								1				1			
98	16.1								1							
99	14.9												1			
100	15.5	No Plants														
101	15		2													
102	14.1	No Plants														
103	14.5	No Plants														
104	5	No Plants														
105	5.5		1					v								
106	15.1	No Plants														
107	16		1													
108	16.2	No Plants														
109	15.5		1													
110	15.3	No Plants														
111	14.5		1										1			
112	14.1	No Plants														
113	3.5	No Plants														
114	11.6														1	
115	15.8	No Plants														
116	16	No Plants														
117	15.5		1						1							
118	15.3									1						
119	15.1		1							1						
120	11.7	No Plants														
121	2									v						
122	11.4	No Plants														
123	15.4				1											
124	16.3	No Plants														
125	16.2		3													
126	15.9		1													
127	15								1							
128	8.5	No Plants														
129	14.1	No Plants														
130	15.6				1											
131	16.6	No Plants														
132	16.4	No Plants														
133	14.1									1						
134	8.2	No Plants														
135	3.1									1						
136	14.2				1								1			
137	16.5	No Plants														
138	17	No Plants														
139	14.1	No Plants														
140	5.8	No Plants														

sampling point	Depth (ft)	comments	FILA	BRSC	CHAR	ELCA	MYSP	NAFL	POFO	POGR	POIL	PONA	POPU	POZO	STPE	VAAM
141	5.8	No Plants														
142	14				1											
143	16.9	No Plants														
144	16.2				2											
145	13.2	No Plants														
146	11.3	No Plants														
147	16.5	No Plants														
148	16.2				1											
149	15.5	No Plants														
150	10.2													1		
151	5.1	No Plants														
152	5.4	No Plants														
153	5.4	No Plants														
154	1.2	No Plants														
155	17.8	No Plants														
156	16.5								1							
157	16.2	No Plants														
158	14.7									2				1		
159	5.7	No Plants														
160	9.1														1	1
161	10.6				1					1					1	
162	12				1									1		
163	10									1					2	v
164	10	No Plants														
165	11.5				1											
166	12				1											
167	17.5	No Plants														
168	17.3	No Plants														
169	16.3	No Plants														
170	12	No Plants														
171	1.6							v								
172	5.9				1											
173	10.4				1											
174	13							1		1						
175	13.5				1											
176	13.3				1											
177	15	No Plants														
178	15.1				1											
179	15.1	No Plants														
180	17				3											
181	18.1	No Plants														
182	17.7	No Plants														
183	13.1	No Plants														
184	8	No Plants														
185	7				1											
186	12.3	No Plants														
187	14.3	No Plants														

sampling point	Depth (ft)	comments	FILA	BRSC	CHAR	ELCA	MYSP	NAFL	POFO	POGR	POIL	PONA	POPU	POZO	STPE	VAAM
188	13.5				1					1						
189	14.9	No Plants														
190	15								1							
191	15.8	No Plants														
192	16.3	No Plants														
193	17				1											
194	17.3													1		
195	17.3	No Plants														
196	10				1											
197		Terrestrial														
198	3.1	No Plants														
199	7.8				1											
200	14.1	No Plants														
201	14.8	No Plants														
202	15.1				3											
203	16.1				1											
204	16.1	No Plants														
205	17					1			1							
206	17												1			
207	17.1	No Plants														
208	17.3	No Plants														
209	13.9	No Plants														
210	5	No Plants														
211	6.4				1											
212	15.1	No Plants														
213	15.5				1											
214	15.9				1								1			
215	16.5				3											
216	16.9				1											
217	17.1	No Plants														
218	18.5	No Plants														
219	17.5	No Plants														
220	16.2	No Plants														
221	11.5					1				1			1			
222	6				1											
223	10.8	No Plants														
224	15.5				3											
225	16.5				1			1	1							
226	17				1				1							
227	17.9				1											
228	17.8	No Plants														
229	18.5	No Plants														
230	18.6	No Plants														
231	17.1	No Plants														
232	14.3	No Plants														
233	5.6	No Plants														
234	4.1	No Plants														

sampling point	Depth (ft)	comments	FILA	BRSC	CHAR	ELCA	MYSP	NAFL	POFO	POGR	POIL	PONA	POPU	POZO	STPE	VAAM
235	5.1				1											
236	15	No Plants														
237	16				1											
238	16.6				1								1			
239	17.7								1							
240	18.1	No Plants														
241	18.3	No Plants														
242	18.7	No Plants														
243	17.7	No Plants														
244	17.4								1							
245	9.3	No Plants														
246	4.1							1								
247	9.7				1											
248	11.5	No Plants														
249	15.7	No Plants														
250	16.8	No Plants														
251	16.7	No Plants														
252	17.6	No Plants														
253	18.1	No Plants														
254	18.6	No Plants														
255	18.7	No Plants														
256	18.4	No Plants														
257	17.2								1							
258	11				1			1								
259	3.1	No Plants														
260	11.5				1											
261	17.2	No Plants														
262	17.5				2											
263	17.8	No Plants														
264	18.3				1											
265	18.1								1							
266	18.8	No Plants														
267	18.1	No Plants														
268	19	No Plants														
269	18	No Plants														
270	16.3	No Plants														
271	9.6	No Plants														
272	4.8				1											
273	10.3	No Plants														
274	18				3											
275	19.1				1											
276	19.1	No Plants														
277	18.9	No Plants														
278	19	No Plants														
279	19	No Plants														
280	18.5	No Plants														
281	17.5	No Plants														

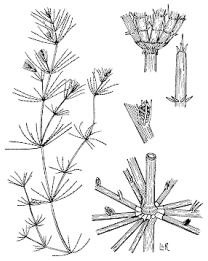
sampling point	Depth (ft)	comments	FILA	BRSC	CHAR	ELCA	MYSP	NAFL	POFO	POGR	POIL	PONA	POPU	POZO	STPE	VAAM
282	15				1											
283	0.5	No Plants														
284	4.2				1											
285	16.6	No Plants														
286	19.7	No Plants														
287	19.5	No Plants														
288	18.5				1											
289	18.6	No Plants														
290	18.4	No Plants														
291	17.2				2											
292	14.8	No Plants														
293	6.1				1											
294	5				1											
295	8	No Plants														
296	20	No Plants														
297	19.5	No Plants														
298	18.8	No Plants														
299	18.5												1			
300	17.3	No Plants														
301	10.5	No Plants														
302	2.9	No Plants														
303	4.8				1											
304	18.8	No Plants														
305	19.4	No Plants														
306	18.3	No Plants														
307	14.5	No Plants														
308	8.2	No Plants														
309	2.7				1											
310	3.8	No Plants														
311	6.4											1				1
312	9.5											1				1
313	3.9	No Plants														
314	2.4	No Plants														

Appendix D

- The Importance of Aquatic Plants

The Importance of Aquatic Plants

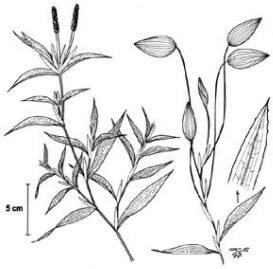
Plant information was gathered from Borman et al. (1997), Eggers and Reed (1997), Fasset (1940), Fink (1994), Nichols and Vennie (1991), and Whitley et al. (1999).



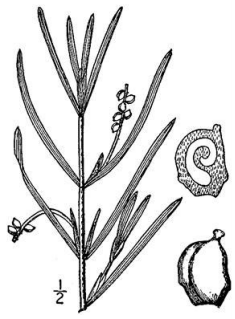
Muskgrass (*Chara* spp.) is a complex algae that resemble higher plants. Muskgrass is identified by its pungent, skunk-like odor with whorls of branched leaves. Ecologically, musk grass provides shelter for juvenile fish and is associated with black crappie spawning sites. Waterfowl love to feast on 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.



Bushy pondweed (*Najas flexilis*) also known as s**lender naiad** 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.



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.



Small pondweed (*Potamogeton pusillus*) and the closely related leafy pondweed (Potamogeton foliosus) and Frie's pondweed (Potamogeton friesii) have long with has slender stems which emerge form slight rhizomes that branch repeatedly. Submersed leaves are linear and attach directly to the stem. These species can be a valuable food source for waterfowl and a number of mammals. They can also provide a home for fish and invertebrates.

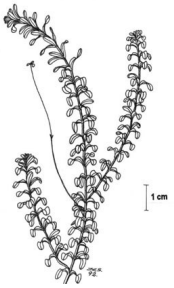
Wild Celery (*Vallisneria americana*) also known as **eelgrass** has long ribbon-like leaves that emerge in clusters. Leaves have a prominent central stripe and leaf tips tend to float gracefully at the water's surface. In the fall, a vegetative portion of the rhizome will break free and float to other 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.



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 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 Big Hills Lake, Waushara County, WI.

DATE	Chlorophyll ug/L	Chlorophyll TSI	Total Phosphorus mg/L	Phosphorus TSI	Secchi depth m	Secchi TSI	Average TSI
5/10/1987	--	--	--	--	4.80	*37.39*	*37.39*
5/24/1987	--	--	--	--	4.80	*37.39*	*37.39*
7/1/1987	--	--	--	--	3.66	*41.31*	*41.31*
7/31/1987	--	--	--	--	3.75	*40.96*	*40.96*
8/11/1987	--	--	--	--	2.67	*45.86*	*45.86*
9/6/1987	--	--	--	--	2.74	*45.46*	*45.46*
9/26/1987	--	--	--	--	2.78	*45.26*	*45.26*
11/14/1987	--	--	--	--	4.42	*38.59*	*38.59*
5/15/1988	--	--	--	--	4.53	*38.22*	*38.22*
5/30/1988	--	--	--	--	5.18	*36.29*	*36.29*
7/17/1988	--	--	--	--	3.81	*40.72*	*40.72*
7/31/1988	--	--	--	--	3.77	*40.87*	*40.87*
8/7/1988	--	--	--	--	2.82	*45.06*	*45.06*
8/14/1988	--	--	--	--	2.74	*45.46*	*45.46*
10/15/1988	--	--	--	--	3.89	*40.44*	*40.44*
5/14/1989	--	--	--	--	4.42	*38.59*	*38.59*
6/17/1989	--	--	--	--	4.27	*39.09*	*39.09*
7/16/1989	--	--	--	--	3.58	*41.62*	*41.62*
7/29/1989	--	--	--	--	4.80	*37.39*	*37.39*
8/5/1989	--	--	--	--	4.65	*37.86*	*37.86*
10/23/1989	--	--	--	--	5.45	*35.57*	*35.57*
5/28/1990	--	--	--	--	4.72	*37.63*	*37.63*
7/8/1990	--	--	--	--	3.92	*40.30*	*40.30*
7/25/1990	--	--	--	--	4.23	*39.22*	*39.22*
8/12/1990	--	--	--	--	3.89	*40.44*	*40.44*
6/16/1991	--	--	--	--	5.18	*36.29*	*36.29*
6/29/1991	--	--	--	--	5.07	*36.62*	*36.62*
7/2/1991	--	--	--	--	3.05	*43.94*	*43.94*
7/15/1991	--	--	--	--	3.66	*41.31*	*41.31*
7/30/1991	--	--	--	--	2.90	*44.68*	*44.68*
9/2/1991	--	--	--	--	3.89	*40.44*	*40.44*
10/13/1991	--	--	--	--	4.72	*37.63*	*37.63*
5/31/1992	--	--	--	--	5.37	*35.77*	*35.77*
6/20/1992	--	--	--	--	5.34	*35.86*	*35.86*
8/16/1992	--	--	--	--	4.23	*39.22*	*39.22*
5/29/1993	--	--	--	--	5.87	*34.50*	*34.50*
7/3/1993	--	--	--	--	4.57	*38.10*	*38.10*
7/10/1993	--	--	--	--	3.66	*41.31*	*41.31*
7/21/1993	--	--	--	--	3.20	*43.24*	*43.24*
8/21/1993	--	--	--	--	3.35	*42.57*	*42.57*
8/28/1993	--	--	--	--	3.20	*43.24*	*43.24*
7/5/1994	--	--	--	--	2.59	*46.28*	*46.28*
7/30/1994	--	--	--	--	2.44	*47.16*	*47.16*
7/7/1995	--	--	--	--	3.35	*42.57*	*42.57*
7/13/1995	--	--	--	--	2.74	*45.46*	*45.46*
7/21/1995	--	--	--	--	3.81	*40.72*	*40.72*
7/29/1995	--	--	--	--	4.57	*38.10*	*38.10*
8/14/1995	--	--	--	--	3.96	*40.16*	*40.16*
8/22/1995	--	--	--	--	3.96	*40.16*	*40.16*

DATE	Chlorophyll ug/L	Chlorophyll TSI	Total Phosphorus mg/L	Phosphorus TSI	Secchi depth m	Secchi TSI	Average TSI
8/26/1995	--	--	--	--	3.81	*40.72*	*40.72*
9/3/1995	--	--	--	--	3.01	*44.12*	*44.12*
9/8/1995	--	--	--	--	2.97	*44.31*	*44.31*
7/3/1996	--	--	--	--	2.86	*44.87*	*44.87*
7/13/1996	--	--	--	--	4.04	*39.89*	*39.89*
7/24/1996	--	--	--	--	3.05	*43.94*	*43.94*
8/2/1996	--	--	--	--	2.74	*45.46*	*45.46*
8/16/1996	--	--	--	--	2.59	*46.28*	*46.28*
7/28/1997	--	--	--	--	2.67	*45.86*	*45.86*
5/10/1998	--	--	--	--	3.66	*41.31*	*41.31*
5/31/1998	--	--	--	--	3.54	*41.77*	*41.77*
6/21/1998	--	--	--	--	3.51	*41.93*	*41.93*
7/15/1998	--	--	--	--	2.63	*46.07*	*46.07*
8/16/1998	--	--	--	--	2.40	*47.38*	*47.38*
9/30/1998	--	--	--	--	2.44	*47.16*	*47.16*
4/24/1999	8	*51.00*	0.008	*34.14*	3.09	*43.76*	*42.97*
5/22/1999	--	--	--	--	4.27	*39.09*	*39.09*
5/30/1999	--	--	--	--	4.11	*39.62*	*39.62*
6/17/1999	4.5	*45.35*	0.01	*37.35*	--	--	*41.35*
6/26/1999	--	--	--	--	2.59	*46.28*	*46.28*
7/3/1999	--	--	--	--	2.44	*47.16*	*47.16*
7/23/1999	1.25	*32.79*	0.007	*32.21*	--	--	*32.50*
8/7/1999	--	--	--	--	3.66	*41.31*	*41.31*
8/18/1999	3.86	*43.85*	0.013	*41.14*	--	--	*42.49*
8/20/1999	--	--	--	--	3.66	*41.31*	*41.31*
6/17/2000	--	--	--	--	3.66	*41.31*	*41.31*
6/25/2000	--	--	--	--	5.45	*35.57*	*35.57*
7/4/2000	--	--	--	--	5.52	*35.37*	*35.37*
8/4/2000	--	--	--	--	3.09	*43.76*	*43.76*
8/19/2000	--	--	--	--	3.12	*43.58*	*43.58*
9/4/2000	--	--	--	--	3.20	*43.24*	*43.24*
10/21/2000	--	--	--	--	3.20	*43.24*	*43.24*
6/17/2001	--	--	--	--	3.20	*43.24*	*43.24*
6/30/2001	--	--	--	--	3.58	*41.62*	*41.62*
7/8/2001	--	--	--	--	2.93	*44.49*	*44.49*
7/20/2001	--	--	--	--	3.05	*43.94*	*43.94*
7/29/2001	--	--	--	--	3.05	*43.94*	*43.94*
8/12/2001	--	--	--	--	3.01	*44.12*	*44.12*
9/8/2001	--	--	--	--	3.09	*43.76*	*43.76*
10/6/2001	--	--	--	--	3.20	*43.24*	*43.24*
2/14/2002	--	--	0.009	*35.83*	--	--	*35.83*
3/4/2002	--	--	0.012	*39.98*	--	--	*39.98*
4/16/2002	2	*37.40*	0.01	*37.35*	--	--	*37.38*
6/9/2002	--	--	--	--	5.49	*35.47*	*35.47*
6/17/2002	1	*30.60*	0.035	*55.42*	--	--	*43.01*
7/1/2002	--	--	--	--	3.66	*41.31*	*41.31*
7/7/2002	--	--	--	--	3.96	*40.16*	*40.16*
7/13/2002	--	--	--	--	4.11	*39.62*	*39.62*
7/21/2002	--	--	--	--	4.15	*39.48*	*39.48*

DATE	Chlorophyll ug/L	Chlorophyll TSI	Total Phosphorus mg/L	Phosphorus TSI	Secchi depth m	Secchi TSI	Average TSI
7/24/2002	1.61	*35.27*	0.0235	*49.67*	--	--	*42.47*
8/2/2002	--	--	--	--	3.35	*42.57*	*42.57*
8/18/2002	--	--	--	--	2.86	*44.87*	*44.87*
8/23/2002	5.5	*47.32*	0.01	*37.35*	--	--	*42.34*
9/1/2002	--	--	--	--	3.35	*42.57*	*42.57*
9/15/2002	--	--	--	--	3.58	*41.62*	*41.62*
10/22/2002	3.57	*43.08*	0.011	*38.73*	--	--	*40.91*
5/24/2003	--	--	--	--	5.45	*35.57*	*35.57*
5/31/2003	--	--	--	--	5.41	*35.67*	*35.67*
6/21/2003	--	--	--	--	5.49	*35.47*	*35.47*
6/26/2003	--	--	--	--	5.41	*35.67*	*35.67*
7/6/2003	--	--	--	--	5.26	*36.08*	*36.08*
7/14/2003	--	--	--	--	5.64	*35.08*	*35.08*
7/19/2003	--	--	--	--	5.26	*36.08*	*36.08*
8/16/2003	--	--	--	--	4.08	*39.75*	*39.75*
9/1/2003	--	--	--	--	4.08	*39.75*	*39.75*
9/20/2003	--	--	--	--	4.04	*39.89*	*39.89*
10/10/2003	--	--	--	--	4.57	*38.10*	*38.10*
5/19/2004	--	--	--	--	5.98	*34.22*	*34.22*
6/12/2004	--	--	--	--	3.16	*43.41*	*43.41*
6/26/2004	--	--	--	--	2.97	*44.31*	*44.31*
7/4/2004	--	--	--	--	3.20	*43.24*	*43.24*
7/16/2004	--	--	--	--	3.39	*42.40*	*42.40*
7/24/2004	--	--	--	--	3.62	*41.46*	*41.46*
8/27/2004	--	--	--	--	2.90	*44.68*	*44.68*
9/17/2004	--	--	--	--	3.05	*43.94*	*43.94*
10/9/2004	--	--	--	--	3.31	*42.73*	*42.73*
4/9/2005	--	--	--	--	5.94	*34.32*	*34.32*
5/21/2005	--	--	--	--	4.19	*39.35*	*39.35*
5/27/2005	--	--	--	--	4.19	*39.35*	*39.35*
6/17/2005	--	--	--	--	5.87	*34.50*	*34.50*
7/2/2005	--	--	--	--	4.57	*38.10*	*38.10*
7/9/2005	--	--	--	--	3.89	*40.44*	*40.44*
8/14/2005	--	--	--	--	5.33	*35.88*	*35.88*
9/11/2005	--	--	--	--	3.66	*41.31*	*41.31*
9/24/2005	--	--	--	--	3.85	*40.58*	*40.58*
10/16/2005	--	--	--	--	4.88	*37.17*	*37.17*
10/29/2005	--	--	--	--	4.88	*37.17*	*37.17*
4/22/2006	--	--	--	--	5.37	*35.77*	*35.77*
5/13/2006	--	--	--	--	5.22	*36.19*	*36.19*
5/28/2006	--	--	--	--	5.18	*36.29*	*36.29*
6/10/2006	--	--	--	--	5.37	*35.77*	*35.77*
6/18/2006	--	--	--	--	4.61	*37.98*	*37.98*
6/24/2006	--	--	--	--	4.04	*39.89*	*39.89*
7/4/2006	--	--	--	--	3.70	*41.16*	*41.16*
7/9/2006	--	--	--	--	3.35	*42.57*	*42.57*
7/27/2006	--	--	--	--	3.01	*44.12*	*44.12*
8/9/2006	--	--	--	--	3.20	*43.24*	*43.24*
8/27/2006	--	--	--	--	3.39	*42.40*	*42.40*

DATE	Chlorophyll ug/L	Chlorophyll TSI	Total Phosphorus mg/L	Phosphorus TSI	Secchi depth m	Secchi TSI	Average TSI
9/8/2006	--	--	--	--	3.39	*42.40*	*42.40*
9/15/2006	--	--	--	--	2.63	*46.07*	*46.07*
10/1/2006	--	--	--	--	3.70	*41.16*	*41.16*
4/15/2007	--	--	--	--	5.22	*36.19*	*36.19*
4/28/2007	--	--	--	--	4.72	*37.63*	*37.63*
5/12/2007	--	--	--	--	3.66	*41.31*	*41.31*
5/27/2007	--	--	--	--	2.86	*44.87*	*44.87*
6/15/2007	--	--	--	--	2.29	*48.09*	*48.09*
6/30/2007	--	--	--	--	1.87	*51.00*	*51.00*
7/8/2007	--	--	--	--	1.83	*51.30*	*51.30*
7/21/2007	--	--	--	--	1.68	*52.56*	*52.56*
8/11/2007	--	--	--	--	1.68	*52.56*	*52.56*
9/1/2007	--	--	--	--	1.68	*52.56*	*52.56*
9/15/2007	--	--	--	--	1.83	*51.30*	*51.30*
10/13/2007	--	--	--	--	2.78	*45.26*	*45.26*
5/18/2008	--	--	--	--	3.85	*40.58*	*40.58*
5/26/2008	--	--	--	--	5.72	*34.88*	*34.88*
6/28/2008	--	--	--	--	4.72	*37.63*	*37.63*
7/3/2008	--	--	--	--	3.81	*40.72*	*40.72*
7/22/2008	--	--	--	--	3.96	*40.16*	*40.16*
7/27/2008	--	--	--	--	4.27	*39.09*	*39.09*
8/9/2008	--	--	--	--	3.81	*40.72*	*40.72*
8/24/2008	--	--	--	--	3.81	*40.72*	*40.72*
9/1/2008	--	--	--	--	3.39	*42.40*	*42.40*
9/19/2008	--	--	--	--	3.66	*41.31*	*41.31*
10/4/2008	--	--	--	--	4.00	*40.02*	*40.02*
5/25/2009	--	--	--	--	5.79	*34.69*	*34.69*
6/12/2009	--	--	--	--	6.10	*33.95*	*33.95*
7/12/2009	--	--	--	--	5.33	*35.88*	*35.88*
7/19/2009	--	--	--	--	4.34	*38.84*	*38.84*
8/2/2009	--	--	--	--	2.44	*47.16*	*47.16*
8/28/2009	--	--	--	--	3.20	*43.24*	*43.24*
9/5/2009	--	--	--	--	3.05	*43.94*	*43.94*
9/18/2009	--	--	--	--	3.05	*43.94*	*43.94*
9/27/2009	--	--	--	--	3.81	*40.72*	*40.72*
4/20/2010	1.44	*34.18*	0.009	*35.83*	5.85	*34.54*	*34.85*
6/9/2010	4.13	*44.51*	0.012	*39.98*	4.48	*38.39*	*40.96*
6/30/2010	--	--	--	--	2.93	*44.53*	*44.53*
7/7/2010	3.79	*43.67*	0.011	*38.73*	--	--	*41.20*
7/28/2010	5.75	*47.76*	0.015	*43.20*	2.53	*46.63*	*45.86*
8/24/2010	5.45	*47.23*	0.015	*43.20*	2.38	*47.52*	*45.98*
9/21/2010	9.74	*52.93*	0.017	*45.00*	2.29	*48.09*	*48.67*
11/1/2010	16.3	*57.98*	0.014	*42.21*	3.11	*43.65*	*47.95*

Big Hills Lake
Deepest Point: N 44º 9.037' W 89º 9.427'

Date	April 20, 2010		
Depth (m)	Temp (ºF)	D.O. (mg/l)	% Sat.
0	57.2	11.16	111.1
0.5	56.8	11.28	109.4
1	56.2	11.31	108.3
1.5	56.1	10.78	103.2
2	55.9	11.09	105.8
2.5	55.9	11.30	108.0
3	55.9	11.06	105.4
3.5	55.8	10.83	103.3
4	55.8	10.68	101.9
4.5	55.8	11.09	106.0
5	55.7	11.20	106.8
5.5	55.7	10.74	102.2

Depth 19.2 feet

Date	June 9, 2010		
Depth (m)	Temp (ºF)	D.O. (mg/l)	% Sat.
0	72.2	10.92	125.7
0.5	72.1	10.75	123.8
1	71.9	10.55	120.6
1.5	71.4	10.52	119.2
2	71.1	10.23	116.4
2.5	71.0	10.44	118.5
3	70.9	10.42	118.7
3.5	70.8	10.51	119.0
4	70.5	9.76	109.3
4.5	70.3	9.89	110.7
5	70.2	9.17	103.5
5.5	70.2	9.37	105.0

Depth 18.8 feet

Date	June 30, 2010		
Depth (m)	Temp (ºF)	D.O. (mg/l)	% Sat.
0	77.5	8.99	108.8
0.5	77.3	8.91	109.1
1	77.1	8.36	101.1
1.5	77.1	8.99	107.8
2	77.0	8.66	106.6
2.5	76.9	8.70	110.2
3	76.8	9.49	114.3
3.5	76.7	9.62	116.0
4	76.6	9.47	112.4
4.5	76.0	8.50	102.0
5	73.8	9.39	111.3
5.5	71.9	9.20	106.7

Depth 18.6 feet

Date	July 28, 2010		
Depth (m)	Temp (ºF)	D.O. (mg/l)	% Sat.
0	81.3	8.05	101.0
0.5	81.3	7.98	99.8
1	81.3	8.08	102.3
1.5	81.3	7.92	101.7
2	81.3	7.97	101.2
2.5	81.2	7.54	95.9
3	81.2	7.86	99.7
3.5	81.2	7.79	98.2
4	81.2	7.75	98.3
4.5	81.2	8.01	101.0
5	80.9	7.14	90.8
5.5	80.0	3.68	44.1

Depth 19.4 feet

Big Hills Lake
Deepest Point: N 44º 9.037' W 89º 9.427'

Date	August 24, 2010		
Depth (m)	Temp (ºF)	D.O. (mg/l)	% Sat.
0	78.6	8.29	101.7
0.5	78.6	7.80	92.0
1	78.6	7.75	94.6
1.5	78.6	7.35	91.4
2	78.6	8.14	100.1
2.5	78.6	7.65	93.6
3	78.6	7.38	94.0
3.5	78.6	8.19	100.9
4	78.5	7.79	96.2
4.5	78.1	7.34	89.5
5	77.8	6.81	83.2
5.5	77.5	6.31	77.3
6	77.2	3.58	44.6

Depth 20.7 feet

Date	September 21, 2010		
Depth (m)	Temp (ºF)	D.O. (mg/l)	% Sat.
0	65.4	9.51	101.9
0.5	65.3	8.93	94.8
1	65.3	8.39	89.4
1.5	65.3	8.79	93.7
2	65.2	8.56	91.3
2.5	65.2	8.47	90.4
3	65.2	8.83	94.0
3.5	65.2	8.31	88.3
4	65.2	8.43	89.9
4.5	65.2	8.58	91.3
5	65.2	8.61	91.8
5.5	65.2	8.64	91.4
6	65.2	8.18	87.4

Depth 19.9 feet

Date	November 1, 2010		
Depth (m)	Temp (ºF)	D.O. (mg/l)	% Sat.
0	49.5	10.64	93.8
0.5	49.5	10.18	90.9
1	49.5	10.20	89.4
1.5	49.4	10.01	88.3
2	49.4	10.07	88.1
2.5	49.4	9.85	86.6
3	49.4	9.62	84.3
3.5	49.4	9.52	83.9
4	49.4	9.39	82.1
4.5	49.4	9.20	81.0
5	49.4	9.32	81.5
5.5	49.2	9.43	82.0
6	49.7	9.24	81.2

Depth 21.2 feet

Appendix F

- Threat of exotic aquatic species to Big Hills Lake

Exotic Species

It is important that members of the Big Hills Lake Management 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

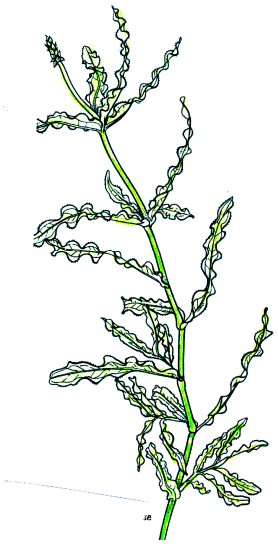
Wisconsin. A twelve-lake study called "The Wisconsin Milfoil Weevil Project" (Jester et al., 1999) conducted by the University of Wisconsin, Stevens Point in conjunction with the Wisconsin DNR researched the efficacy of weevil stocking. This report concluded that milfoil weevil densities were not elevated, 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.

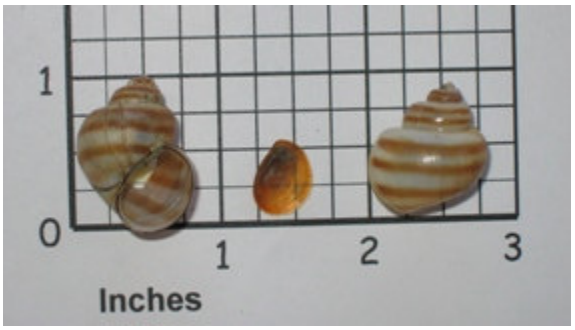
Some success has been achieved by manually removing mussels from a lake. Although this method can dramatically reduce populations, it does not eradicate the mussels. In addition, it should be noted that this option is also very labor intensive.

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.

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.



Chinese Mystery Snail

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.

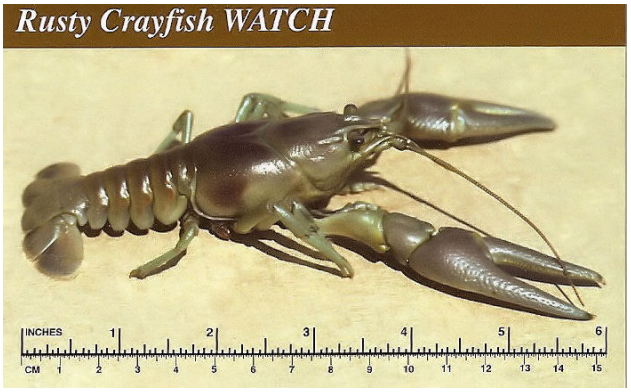
Current research is focused on the life-cycle of these snails and the environmental conditions under which population growth is hindered or promoted.

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.

Appendix G

- Big Hills Lake Fisheries Survey Summary Report – 2010 (Wisconsin DNR).

Big Hills Lake Fisheries Survey
Summary Report – 2010

In 2010, the Department of Natural Resources conducted a fish survey of Big Hills Lake in order to assess the fish community and provide some direction for the future fisheries management of this lake. The following report is a brief summary of all activities conducted and data taken this past year. If you have any questions, please contact: Dave Bartz, Fisheries Biologist, Hwy. 22N, 363 Church St. Montello, WI. 53949. Phone: 608-297-7058 or Scott Bunde, Fisheries Technician 920-787-4686 ext.3018.

Comprehensive Fish Survey – What is it?

A comprehensive fish survey is an assessment of the entire fish community in a lake. Different survey methods are used to sample all the different fish species that inhabit a lake (including the smaller forage fish). Fyke-netting and boomshocking are the primary fish capture methods; however, seines and other gear are also utilized. Once fish are captured, information can be collected as it relates to species composition, abundance, size structure, age classes, growth, survival, and reproductive success. The following report provides some of this information for most major species.

This past year the following surveys were conducted on Big Hills Lake.

Spring Fyke-Netting: Larger fyke nets were used to sample the spawning population of northern pike and walleye. Nets were placed in spawning locations; fish were measured, weighed, sexed and given an appropriate mark, then returned to the water. A formula is used comparing the number of new fish caught in a net daily to the number of marked fish (recap).

Spring Boomshocking: Two nights of boomshocking took place in the spring. The first run is done to assess the walleye and northern pike spawning stock. The second is done a little later in the spring to assess the rest of the fishery, primarily bass and panfish.





Numerous 10 inch Largemouth Bass

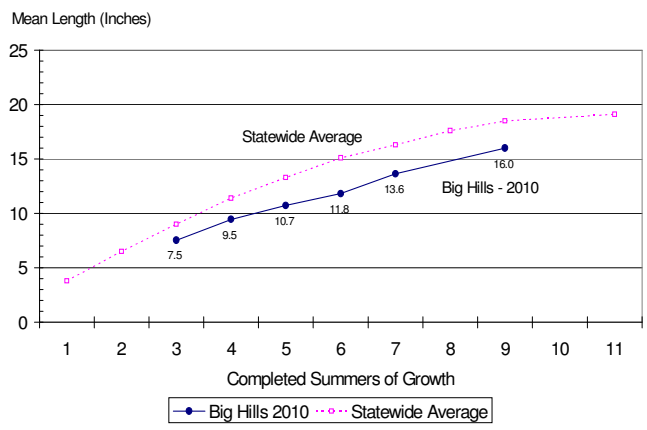
Gamefish Summary

Largemouth bass are the dominant gamefish (or predator) in Big Hills Lake. Walleye and northern pike are also present but in lesser numbers.

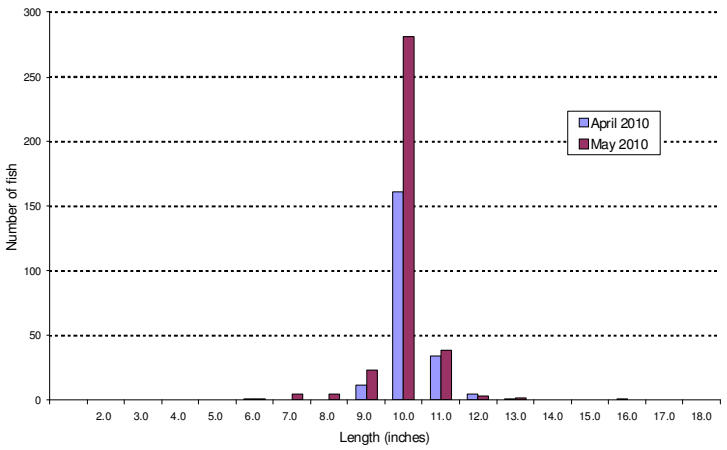
Largemouth Bass

Abundance: **Abundant.** CPE=286/hr 8 inches and larger. Total population = 2711 (20 bass/acre). This population is high for this lake.
Size Structure: **Poor.** Length Range = 6.0 – 16.0 in. Average Length = 10.6 inches Only 1 fish was sampled larger than 14 in (legal harvestable size). RSD14=0 (9% in 1997). PSD12 = 1 (1% of the population larger than 8 inches was also greater than 12 inches).
Growth and Condition: **Poor.** Growth rates are below average with fish not attaining legal size (14 inches) until after their 7th year of life. Condition is poor. Little near shore habitat results in less food (prey fish) and ambush sites for predators.

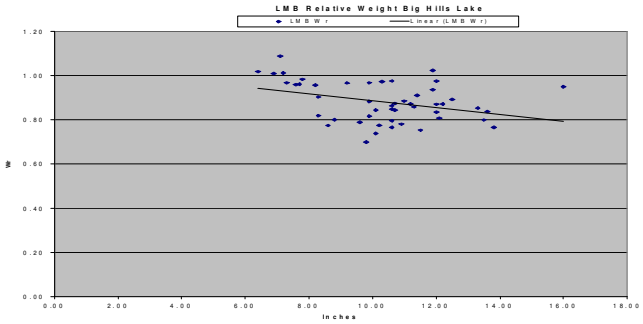
Largemouth Bass Growth Rates
Big Hills Lake, Waushara Co.



Big Hills Largemouth Bass



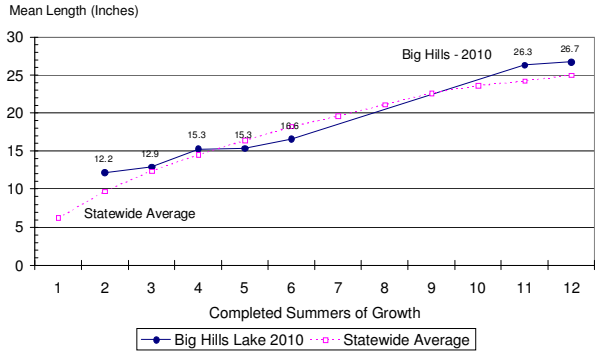
Northern Pike



Abundance: Low. Only 2 fish sampled the entire survey. (15.0 & 20.3 inches)
Northern pike have made up a small part of the fishery according to surveys since 1986. A total of 7 NP (25-28.5 inches) sampled in **1986** and 3 NP (26.2, 28.7, 36.3 inches) in **1997**. Suitable spawning habitat is the limiting factor for the northern pike fishery. Near shore vegetation is a must for successful northern pike reproduction. The top picture with the net is a good example.

Walleye

Walleye Growth Rates
Big Hills Lake, Waushara Co.



Abundance: Low. Total adult population = 169 (1.3/acre). Walleyes are present as a result of stocking by a local fishing club. A total of 53 walleyes were sampled in the nets.
Size Structure: Fair. Size ranged from 10.5 – 27.5 inches. Average length = 14.3 inches.
Growth and Condition: Average. Growth rates from the small number of fish sampled showed average growth with fish reaching 15 inches in length after their 4th summer. Fish were in fair – good condition.

Panfish

Bluegill and yellow perch are the dominant panfish (or prey) in Big Hills. The populations were found at below average abundance and exhibited above average growth and good size structure. Other species found were black crappie, green sunfish, white sucker, yellow bullhead, bluntnose minnow and common carp.

Bluegill



Abundance: Low. Electrofishing Catch: 23/hour (199/hour in 1997) larger than 3 inches. Only 5 fish sampled with shocker boat. Combined with netting survey we sampled 193 bluegills. Size ranged from 3.0 - 10.0 inches.

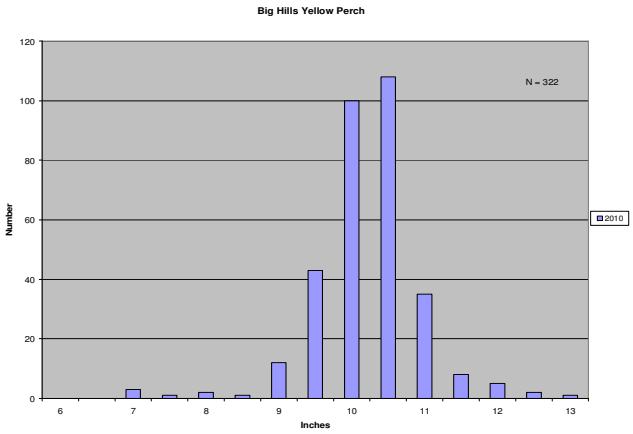
Growth and Condition: Above Average. Growth rates from the small number of fish sampled are well above average with most bluegill attaining quality size (6 inches) after their 3rd year of life. Low numbers of panfish in general results in less competition for food and better growth rates and condition.

Yellow Perch

Abundance: Fair for adults. **Low** overall. Total adult population was 785 fish, 5.9 adults/acre. We sampled a total of 317 fish.

Size Structure: Length Range = 7.0 – 13.0 inches. Average length = 10.4 inches. No young of year or yearling fish observed.

Growth and Condition: Above Average. Growth rates were well above average with fish attaining 9 inches after 3 summers of growth. Low numbers of panfish in general results in less competition for food and better growth rates.





Black Crappie

Abundance: We sampled 32 fish.

Size Structure: Length Range = 4.5 – 12.0 inches

Other Panfish and Forage Species

Other panfish and forage species captured during the survey include: green sunfish, white sucker, bluntnose minnow, common carp and yellow bullheads.

PSD =(number of fish ≥ minimum quality length ÷ number of fish ≥ minimum stock length) × 100

RSD =(number of fish ≥ specified length ÷ number of fish ≥ minimum stock length) × 100

	Stock Length	Quality Length
Northern Pike	14 inches	21 inches
Largemouth Bass	8 inches	12 inches
Bluegill	3 inches	6 inches

CPE (Catch Per unit Effort) - The number of a given species caught during a defined sampling effort. When shocking the shoreline of a lake we keep track of how much time it takes. We then count the number of a certain species we caught during that time and convert to a number caught **per hour** of shocking. These catch rates are then compared in future surveys.

History

Big Hills Lake is a 133 acre seepage lake located in the township of Mount Morris, Waushara County, Wisconsin. The lake has a maximum depth of 22 feet. Big Hills is a highly developed lake with very little near shore fish habitat remaining. Substrate consist of sand, silt, marl with some good gravel areas. Primary usage of the lake is swimming, fishing and boating.

Fish surveys have taken place on Big Hills Lake in the following years 1968, 1969, 1973, 1979, 1986, 1988, 1997 and 2003. Historically, Big Hills has supported an excellent bass and panfish fishery. With largemouth bass and walleye being the most abundant gamefish and bluegill, yellow perch and black crappie the most abundant panfish. Northern pike have always made up a small part of the fishery in Big Hills Lake. A walleye stocking survival study was done on Big Hills Lake. Fingerling and yearling walleyes were clipped and stocked in Big Hills from 1968-1972. In 1979 a spring survey revealed a 12 fold higher survival rate in the yearling fish that were stocked. A feasibility study done on Big Hills Lake in 1983 makes mention of "macrophytes are abundant around much of the lake and are somewhat impairing recreational usage of the lake." This is not the case today. White Bass were sampled in both the 1986 (21 fish) and 1997 (50 fish) surveys. These fish were likely stocked by local anglers. Reminder: It is illegal to transfer live fish from one body of water to another without the proper permits.

Management Recommendations

A healthy plant community provides cover for all fish species and is one component of a healthy fishery. A healthy natural shoreline is also important to the health of a lakes aquatic ecosystem. Property owners should be encouraged to maintain a portion of their shoreline in a natural state. Recommendations should be made to all shoreline property owners on protection and/or enhancement of their shoreline. Protection of near shore emergent vegetation and woody debris is critical to the health of a lake. Little cover/habitat has resulted in an overabundance of largemouth bass and a panfish fishery that is holding on by a string. The DNR in agreement with the Big Hills Lake Association recommend removal of the 14 inch size limit on bass and replace it with a no size limit, bag limit of 5 fish. The DNR will continue to monitor the lake with a boom shocking run in the spring. The goal is to have a CPE of bass 8 inches and larger of ~ 100 fish/hour, a PSD around 40 and growth rates closer to the statewide average. We would also like to see people voluntarily limit their harvest of panfish until bluegill CPE in the spring run is ~ 400 fish larger than 3 inches/hour. The yellow perch population is made up of a couple year classes of larger fish. It's concerning that no young of year and yearling fish were sampled. Spawning habitat is likely the main cause of this decline. Spawning yellow perch targeted our nets to spawn on because they where the closest thing to resemble habitat. Yellow perch need stiff vegetation or woody debris to deposit their ribbon of eggs on. Temporary brush bundles or trees could be placed in the near shore area immediately after ice out to aid in perch reproduction. They could then be moved under a dock or raft once they are installed. Cribs can also be installed to provide deeper water habitat. Groups of at least 4 cribs in a specific area are recommended as to not concentrate all the fish on one crib. Tree drops are another option for property owners interested in helping out the lakes fishery. Please contact Dave or Scott before under taking any of these recommendations. Northern pike populations have historically been small on this system and habitat again is the limiting factor. Walleyes are present in this system, strictly due to stocking. The DNR will continue to accept applications for stocking of this species, in low numbers, as it appears that it has resulted in a low density population and may contribute a small return to the angler.