Muskellunge Lake

Lincoln County, Wisconsin

Comprehensive Management Plan

November 2012

Sponsored by:

Muskellunge Lake District
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Onterra, LLC
Lake Management Planning

Muskellunge Lake
Lincoln County, Wisconsin
Comprehensive Management Plan
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This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

Muskellunge Lake Planning Committee

Mike Atkinson	Robert Schuetthaun
Sue Warren	Nancy Voelker
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1.0 INTRODUCTION

Muskellunge Lake, Lincoln County, is a 159-acre headwater drained lake with a maximum depth of 23 feet. The Muskellunge Creek which flows from Muskellunge Lake, leads to the Wisconsin River through Lake Mohawksin. This upper mesotrophic/lower eutrophic lake has a relatively small watershed when compared to the size of the lake. In 2008, 50 native aquatic plant species were located, of which coontail was the most common. No non-native aquatic plant species are known to exist in the lake, and none were located in 2008.

Muskellunge Lake is in close proximity to the Rice Reservoir and upstream of Lake Mohawksin, both which have populations of Eurasian water milfoil (*Myriophyllum spicatum*). The Muskellunge Lake District (MLD) had concerns that this invasive plant was already present within Muskellunge Lake. The MLD entered into the management planning program for two main reasons: 1) to learn whether non-native aquatic plants were present within the lake and 2) gain a more comprehensive understanding of the Muskellunge Lake ecosystem. The data collected from the 2008 surveys will serve as a baseline set of data for which future management planning projects can call upon.

Lake at a Glance – Muskellunge Lake

Morphology	
Acreage	159 (WDNR Definition)
Maximum Depth (ft)	23
Mean Depth (ft)	10
Shoreline Complexity	5.1
Vegetation	
Curly-leaf Survey Date	June 30, 2008
Comprehensive Survey Date	July 16-17, 2008 & August 5, 2008
Number of Native Species	50
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	None
Simpson's Diversity	0.92
Average Conservatism	7.2
Water Quality	
Trophic State	Upper mesotrophic/Lower eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	6.8-8.1
Sensitivity to Acid Rain	Not Sensitive
Watershed to Lake Area Ratio	8:1

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa. The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee, the completion of a stakeholder survey, and updates within the lake group's newsletter.

The highlights of this component are described below in chronological order. Materials used during the planning process can be found in Appendix A.

Kick-off Meeting
On June 7, 2008 the MLPRD held a special meeting to inform district members about the lake management planning project the district was undertaking. During the meeting, Eddie Heath, an aquatic ecologist with Onterra, presented information about lake eutrophication, native and non-native aquatic plants, the importance of lake management planning, and the goals and components of the Muskellunge Lake management planning project.

Stakeholder Survey
During September 2008, a six-page, 24-question survey was mailed to 111 riparian property owners in the Muskellunge Lake watershed. Almost 60% of the surveys were returned and those results were entered into a spreadsheet by members of the Muskellunge Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan.

Planning Committee Meeting I
On March 12, 2009, Eddie Heath and Tim Hoyman of Onterra met with eight members of the Muskellunge Lake Planning Committee for nearly 2.5 hours. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. A few concerns were raised by the committee, including nuisance levels of aquatic plants and sediment build-up. Towards the end of the meeting a discussion of management goals began that was continued in the second planning committee meeting.

Planning Committee Meeting II
On April 6, 2009, Eddie Heath and Tim Hoyman met with ten members of the Planning Committee to discuss the stakeholder survey results and to continue developing management goals and actions for the Muskellunge Lake management plan.

Management Plan Review and Adoption Process

On April 10, 2010 a draft of the Muskellunge Lake Management Plan was supplied to the WDNR and the MLPRD Planning Committee Members for review. The WDNR returned comments on the plan to Onterra on July 10, 2012. Onterra addressed comments and finalized the management plan on November 21, 2012. Formal acceptance of the plan by the MLD Board of Commissioners will occur through a vote held at the next annual meeting.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, not all chemical attributes collected may have a direct bearing on the lake's ecology, but may be more useful as indicators of other problems. Finally, water quality values that may be considered poor for one lake may be considered good for another because judging water quality is often subjective. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water.

Many types of analysis are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the ecology of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

Comparisons with Other Datasets

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to similar lakes in the area. In this document, a portion of the water quality information collected in Muskellunge Lake are compared to other lakes in the region and state (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Muskellunge Lake water quality analysis:

> **Phosphorus** is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both *algae* and *macrophytes*. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.
>
> **Chlorophyll-*a*** is the green pigment in plants used during *photosynthesis*. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.
>
> **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by

lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are interrelated. Phosphorus controls algal abundance, which is measured by chlorophyll-*a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water (Canter et al. 1994, Dinius 2007, and Smith et al. 1991).

Lillie and Mason (1983) is an excellent source of data for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Lincoln County lakes are included within the study's Northeast Region (Figure 3.1-1) and are among 242 lakes randomly sampled from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data along with data corresponding to statewide natural lake means and historic data from Muskellunge Lake are displayed in Figures 3.1-2 – 3.1-4. Please note that the data in these graphs represent values collected only during the summer months (June-August) from the deepest location in Muskellunge Lake (Map 1). Furthermore, the phosphorus and chlorophyll-a data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments (see discussion under Internal Nutrient Loading on page 9). Surface samples in Muskellunge Lake were collected at a depth of 3 feet.

Figure 3.1-1. Location of Muskellunge Lake within the regions utilized by Lillie and Mason (1983).

Apparent Water Quality Index

Water quality, like beauty, is often in the eye of the beholder. A person from southern Wisconsin that has never seen a northern lake may consider the water quality of their lake to be good if the bottom is visible in 4 feet of water. On the other hand, a person accustomed to seeing the bottom in 18 feet of water may be alarmed at the clarity found in the southern lake.

Lillie and Mason (1983) used the extensive data they compiled to create the *Apparent Water Quality Index* (WQI). They divided the phosphorus, chlorophyll-*a*, and clarity data of the state's lakes into ranked categories and assigned each a "quality" label from "Excellent" to "Very Poor". The categories were created based upon natural divisions in the dataset and upon their experience. As a result, using the WQI as an assessment tool is very much like comparing a particular lake's values to values from many other lakes in the state. However, the use of terms like, “Poor”, “Fair”, and “Good” bring about a better understanding of the results than just comparing averages or other statistical values between lakes. The WQI values corresponding to the phosphorus, chlorophyll-*a*, and Secchi disk values for Muskellunge Lake are displayed on Figures 3.1-2 – 3.1-4.

Trophic State

Total phosphorus, chlorophyll-*a*, and water clarity values are directly related to the *trophic state* of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: *oligotrophic*, *mesotrophic*, and finally *eutrophic*. Every lake will naturally progress through these states and under natural conditions (i.e. not influenced by the activities of humans) this progress can take tens of thousands of years. Unfortunately, human influence has accelerated this natural aging process in many Wisconsin lakes. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the productivity of their lake over time. Yet, classifying a lake into one of three trophic states often does not give clear indication of where a lake really exists in its trophic progression because each trophic state represents a range of productivity. Therefore, two lakes classified in the same trophic state can actually have very different levels of production. However, through the use of a *trophic state index* (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake’s position within the eutrophication process. This allows for a more clear understanding of the lake’s trophic state while facilitating clearer long-term tracking.

> **Trophic states** describe the lake’s ability to produce plant matter (production) and include three continuous classifications: *Oligotrophic* lakes are the least productive lakes and are characterized by being deep, having cold water, and few plants. *Eutrophic* lakes are the most productive and normally have shallow depths, warm water, and high plant biomass. *Mesotrophic* lakes fall between these two categories.

Carlson (1977) presented a trophic state index that gained great acceptance among lake managers. Because Carlson developed his TSI equations on the basis of association among water clarity, chlorophyll-*a*, and total phosphorus values of a relatively small set of Minnesota Lakes, researchers from Wisconsin (Lillie et. al. 1993), developed a new set of relationships and equations based upon the data compiled in Lillie & Mason (1983). This resulted in the Wisconsin Trophic State Index (WTSI), which is essentially a TSI calibrated for Wisconsin lakes. The WTSI is used extensively by the WDNR and is reported along with lake data collected by Citizen Lake Monitoring Network volunteers.

Limiting Nutrient

The *limiting nutrient* is the nutrient which is in shortest supply and controls the growth rate of algae and some macrophytes within the lake. This is analogous to baking a cake that requires four eggs, and four cups each of water, flour, and sugar. If the baker would like to make four cakes, he needs 16 of each ingredient. If he is short two eggs, he will only be able to make three cakes even if he has sufficient amounts of the other ingredients. In this scenario, the eggs are the limiting nutrient (ingredient).

In most Wisconsin lakes, phosphorus is the limiting nutrient controlling the production of plant biomass. As a result, phosphorus is often the target for management actions aimed at controlling plants, especially algae. The limiting nutrient is determined by calculating the nitrogen to phosphorus ratio within the lake. Normally, total nitrogen and total phosphorus values from the surface samples taken during the summer months are used to determine the ratio. Results of this ratio indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 15:1, the lake is considered phosphorus limited; if it is less than 10:1, it is considered nitrogen limited. Values between these ratios indicate a transitional limitation between nitrogen and phosphorus.

Temperature and Dissolved Oxygen Profiles

Temperature and dissolved oxygen profiles are created simply by taking readings at different water depths within a lake. Although it is a simple procedure, the completion of several profiles over the course of a year or more provides a great deal of information about the lake. Much of this information relates to whether the lake thermally stratifies or not, which is determined primarily through the temperature profiles. Lakes that show strong stratification during the summer and winter months need to be managed differently than lakes that do not. Normally, deep lakes stratify to some extent, while shallow lakes (less than 17 feet deep) do not.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fishkills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical process that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The *epiliminion* is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The *hypolimnion* is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The *metalimnion*, often called the thermocline, is the middle layer containing the steepest temperature gradient.

Internal Nutrient Loading In lakes that support strong stratification, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. months at a time).
- Lakes with hypolimnetic total phosphorus values less than 200 μg/L.

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations exceeding 200 μg/L.

- Lakes with epilimnetic phosphorus concentrations that cannot be accounted for in watershed phosphorus load modeling.

Specific to the final bullet-point, during the watershed modeling assessment, the results of the modeled phosphorus loads are used to estimate in-lake phosphorus concentrations. If these estimates are much lower than those actually found in the lake, another source of phosphorus must be responsible for elevating the in-lake concentrations. Normally, two possibilities exist; 1) shoreland septic systems, and 2) internal phosphorus cycling.

If the lake is considered a candidate for internal loading, modeling procedures are used to estimate that load.

Muskellunge Lake Water Quality Analysis

Muskellunge Lake Long-term Trends

Little historic water quality data exists for Muskellunge Lake, making beneficial long-term trend analysis impossible. However, sporadic data does exist for the lake beginning in the late 1970's. Figure 3.1-2 contains average total phosphorus data collected from Muskellunge Lake. With a superficial look, there appears to be a trend within these data; for example that the phosphorus levels increased dramatically between the late 70's and 90's and then tapered back down by 2008. That observation is really not a trend as its validity is largely nullified by the large data gap between 1979 and 1997. Between those years, we do not know if the phosphorus levels increased beyond those found in 1997 and/or fell below those in 1979. In fact, it is likely that the levels fluctuated greatly between those years. The observation that phosphorus levels have steadily fallen since 1997 is supported even though there are three to four-year gaps within the means. The cause of this perceived decline is unknown, but may be related to increased macrophyte biomass within the lake or changes within the watershed leading to lower phosphorus loads during this time span.

The available chlorophyll-*a* and Secchi disk clarity values (Figures 3.1-3 and 3.1-4, respectively) follow the same general pattern as the phosphorus data, indicating a strong relationship, as discussed above, between these three parameters.

Overall, the data displayed in Figures 3.1-2 – 3.1-4 indicate that at least for the last five years, the water quality of Muskellunge Lake is considered "Good" and better than that found in most other lakes within the state and Northeast Region.

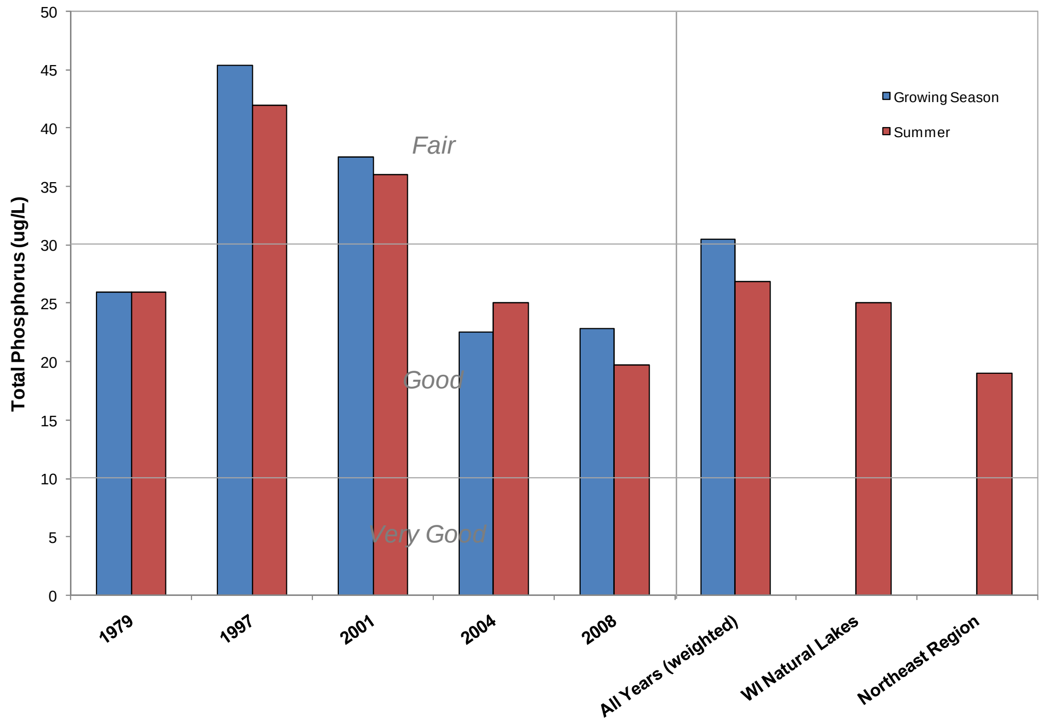

Figure 3.1-2. Muskellunge Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

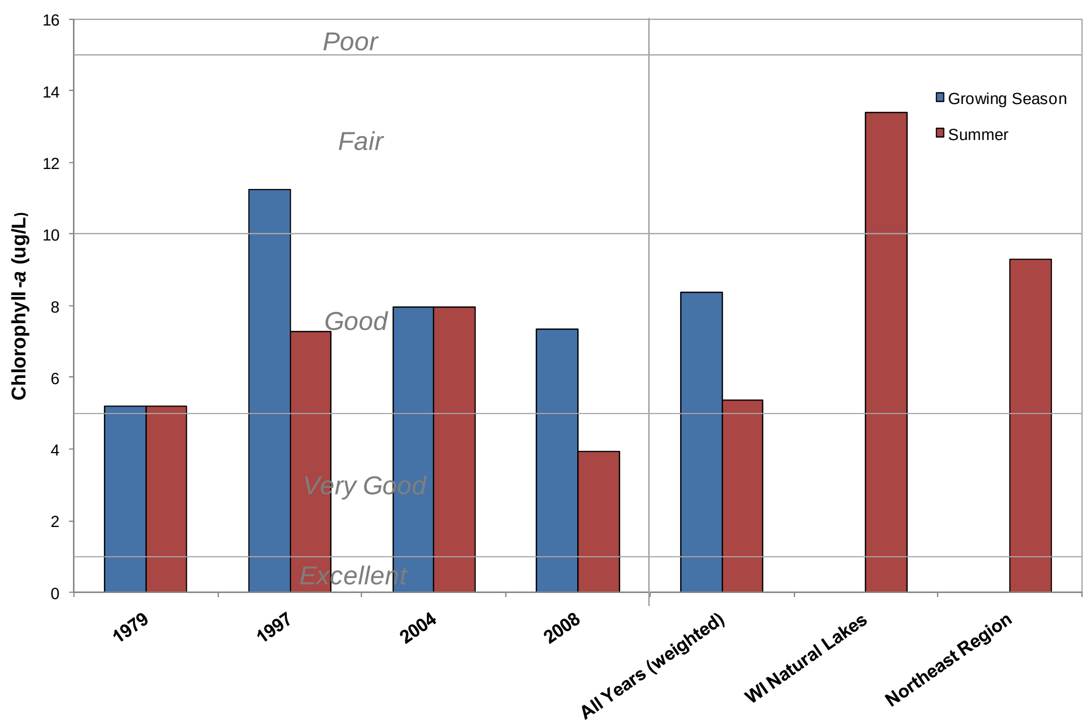

Figure 3.1-3. Muskellunge Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

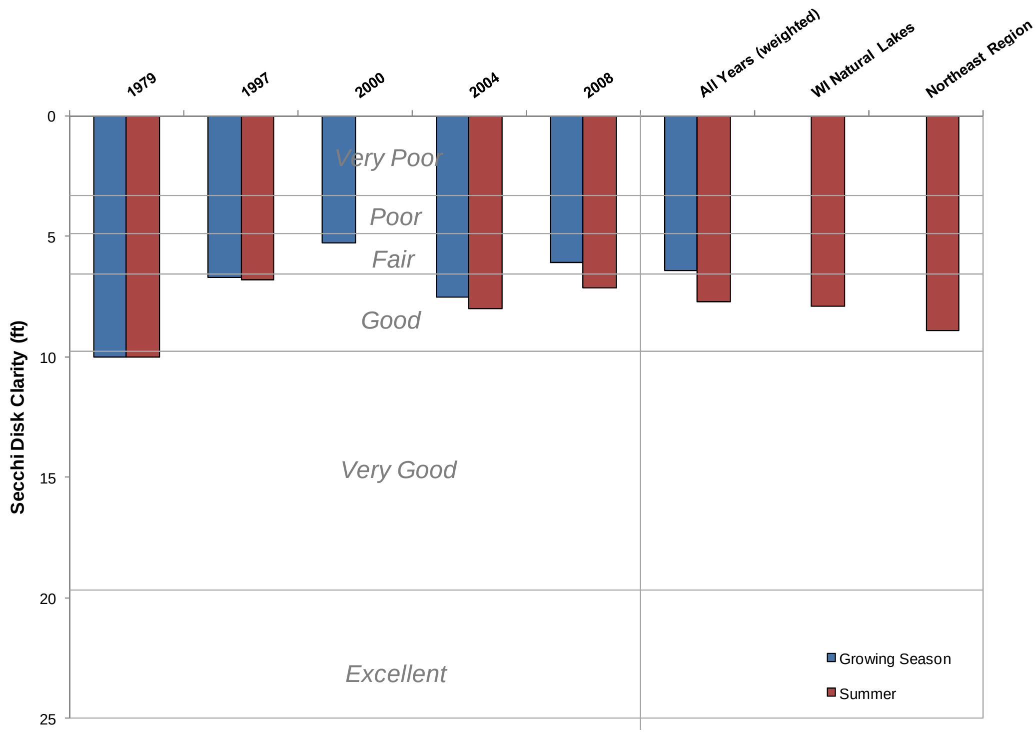

Figure 3.1-4. Muskellunge Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

Limiting Plant Nutrient of Muskellunge Lake

Using average summer nitrogen and phosphorus concentrations from Muskellunge Lake, a nitrogen:phosphorus ratio of 21:1 was calculated. This finding indicates that Muskellunge Lake is indeed phosphorus limited as are the vast majority of Wisconsin Lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Muskellunge Lake Trophic State

Figure 3.1-5 contains the WTSI values for Muskellunge Lake. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values from the last five years range in values spanning from lower eutrophic to middle mesotrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* WTSI values, it can be concluded that Muskellunge Lake is in an upper mesotrophic to very low eutrophic state.

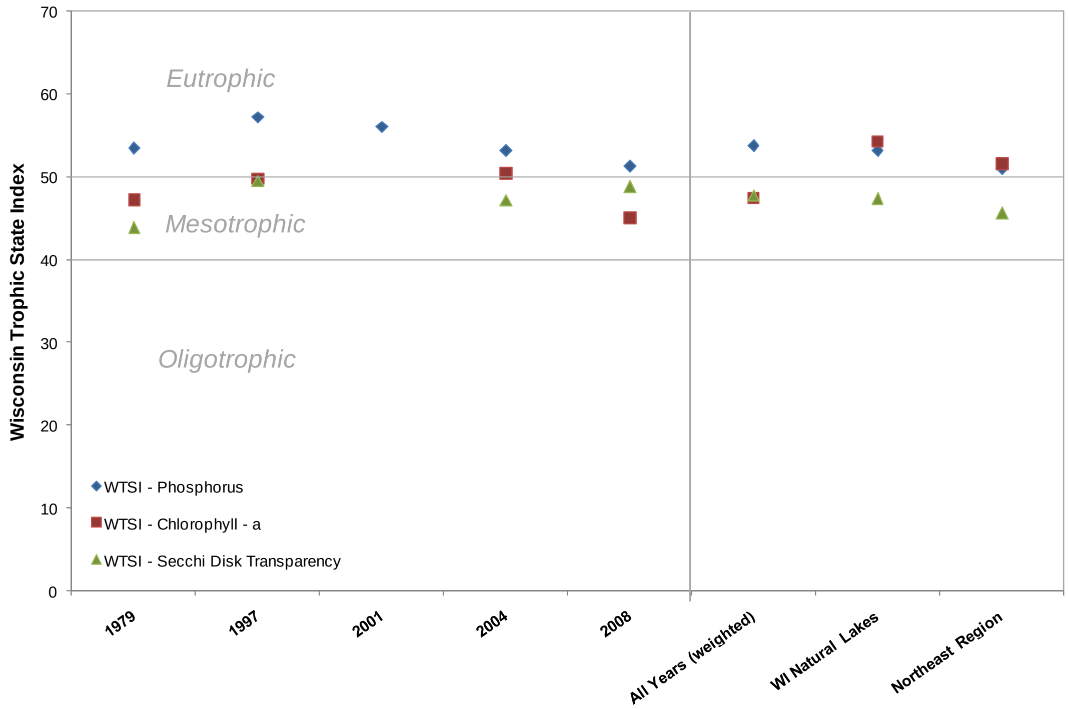

Figure 3.1-5. Muskellunge Lake, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

Dissolved Oxygen and Temperature in Muskellunge Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling event at Muskellunge Lake during 2008 (Figure 3.1-6). The profiles indicate that the lake stratifies during the winter with ice cover and during the summer months, but very little of the water column becomes anoxic. This means that even though the lake supports a healthy plant population with a lush littoral zone, the decomposition of the plant mass does not adversely impact the water quality or the harm the fishery.

Additional Water Quality Data Collected at Muskellunge Lake

Alkalinity, pH, and calcium analysis were also performed on some of the water quality samples collected from Muskellunge Lake. Alkalinity values ranged between 33 and 36 mg/l as $CaCO_3$ during the summer months indicating that the lake has a high buffering capacity against acid rain. During the same time, the lake's pH hovered around 7.6-8.0 or slightly above neutral. The pH value is normal for a lake such as Muskellunge Lake and is well within the optimal range for zebra mussels. However, calcium analysis from a sample collected during June 2007 returned a value of 10.8 mg/l, which is well below the optimal range for zebra mussels.

Internal Nutrient Loading in Muskellunge Lake

Internal nutrient loading is not believed to be significant in Muskellunge Lake. This is supported by the fact that hypolimnetic phosphorus levels reached only 111 μg/l during summer stratification, which is well below the threshold of concern as discussed in the introduction to this section.

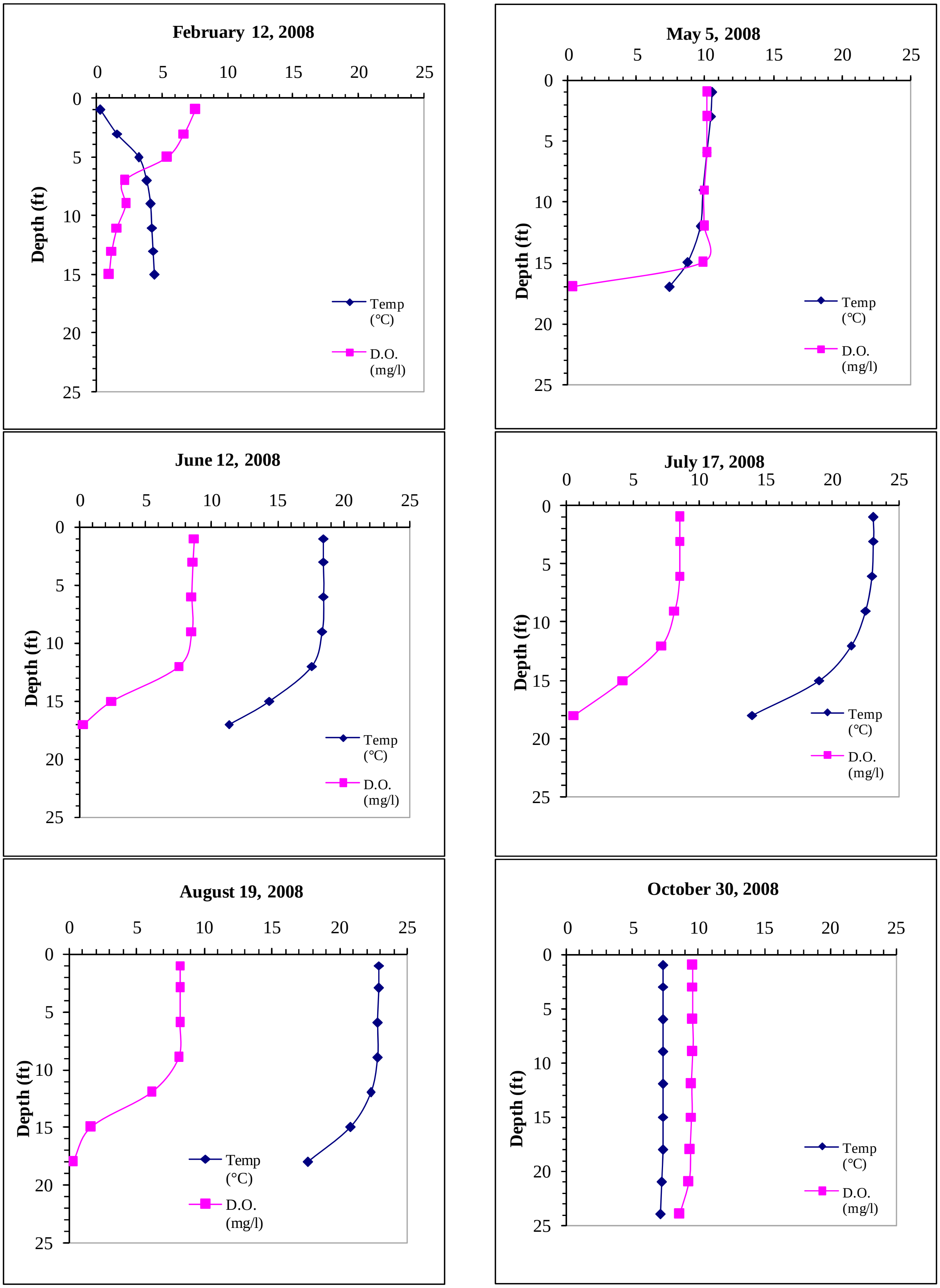

Figure 3.1-6. Muskellunge Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected from Muskellunge Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Muskellunge Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw et al. 2004). The pH of the water in Muskellunge Lake was found to be acidic with surface values ranging from 6.8 to 8.1.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Muskellunge Lake was measured at 34.3 (mg/L as $CaCO_3$), indicating that the lake has a high capacity to resist fluctuations in pH and is not sensitive to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Muskellunge Lake's pH values fall within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Muskellunge Lake was found to be 10.8 mg/L, indicating Muskellunge Lake has a *very low* susceptibility to zebra mussel establishment.

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, Muskellunge Lake was considered not suitable for mussel establishment. Plankton tows were completed by Onterra staff during the summer of 2008 and these samples were processed by the WDNR for larval zebra mussels. Their analysis did not locate any larval zebra mussels.

3.2 Watershed Assessment

A lake's **flushing rate** is simply a determination of the time required for the lake's water volume to be completely exchanged. **Residence time** describes how long a volume of water remains in the lake and is expressed in days, months, or years. The parameters are related and both determined by the volume of the lake and the amount of water entering the lake from its watershed. Greater flushing rates equal shorter residence times.

Two aspects of a lake's watershed are the key factors in determining the amount of phosphorus the watershed exports to the lake; 1) the size of the watershed, and 2) the land cover (land use) within the watershed. The impact of the watershed size is dependent on how large it is relative to the size of the lake. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drains to each surface-acre of the lake. Larger ratios result in the watershed having a greater role in the lake's annual water budget and phosphorus load.

The type of land cover that exists in the watershed determines the amount of phosphorus (and sediment) that runs off the land and eventually makes its way to the lake. The actual amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Vegetated areas, such as forests, grasslands, and meadows, allow the water to permeate the ground and do not produce much surface runoff. On the other hand, agricultural areas, particularly row crops, along with residential/urban areas, minimize infiltration and increase surface runoff. The increased surface runoff associated with these land cover types leads to increased phosphorus and pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations.

In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grass or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g. reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

In systems with high WS:LA ratios, like those exceeding 10-15:1, the impact of land cover may be tempered by the sheer amount of land draining to the lake. Situations actually occur where lakes with completely forested watersheds have sufficient phosphorus loads to support high rates of plant production. In other systems with high ratios, the conversion of vast areas of row crops to vegetated areas (grasslands, meadows, forests, etc.) may not reduce phosphorus loads sufficiently to see a change in plant production. Both of these situations occur frequently in impoundments.

Regardless of the size of the watershed or the makeup of its land cover, it must be remembered that every lake is different and other factors, such as flushing rate, lake volume, sediment type, and many others, also influence how the lake will react to what is flowing into it. For instance, a deeper lake with a greater volume can dilute more phosphorus within its waters than a less voluminous lake and as a result, the production of a lake is kept low. However, in that same lake, because of its low flushing rate (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. On the contrary, a lake with a higher flushing rate (low residence time, i.e., days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

A reliable and cost-efficient method of creating a general picture of a watershed's affect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS). Certain morphological attributes of a lake and its watershed can be entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface. WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

Muskellunge Lake's 1,494 acre watershed is largely dominated by forest (60% or 902.7 acres) and wetland (20% or 305.7 acres) with pasture/grass and row crop agriculture making up smaller quantities of the watershed (Figure 3.2-1). The lake itself covers 11% of the watershed, which equates to a watershed to lake ratio of about 8:1. This ratio indicates that land cover located within this watershed plays an important role in the lake's water quality. Furthermore, it likely indicates that land use changes within this watershed could be fairly effective at changing aspects of Muskellunge Lake's water quality.

Input of the watershed land cover data (Figure 3.2-1) within WiLMS produced a loading estimate of 178.6 lbs of phosphorus annually (Figure 3.2-2 and Appendix D) to Muskellunge Lake, which is relatively low for a watershed of this size. Forested land, which occupies 60% of the watershed, is responsible for 41% of the phosphorus load. Muskellunge Lake itself (11% of the watershed) is responsible for 23% of the phosphorus load, which occurs as a result of atmospheric deposition. The land uses of special concern may be pasture/grass and row crop agriculture, which make up small percentages of the watershed (8% and 1% respectively) but export a combined 21% phosphorus load (Figure 3.2-2).

Further WiLMS modeling indicated that converting the 7.7 acres of row crop agriculture to forested land would essentially reduce the entire 6.6 annual lbs of phosphorus (Appendix D, Scenario 1). However, although this is an easy conservation measure to make because of the small acreage of this land type, the reduction (6.6 lbs of phosphorus) would have little impact on the lake's water quality. Conservation or restoration measures are likely better focused upon other areas, such as the lake's immediate shoreline.

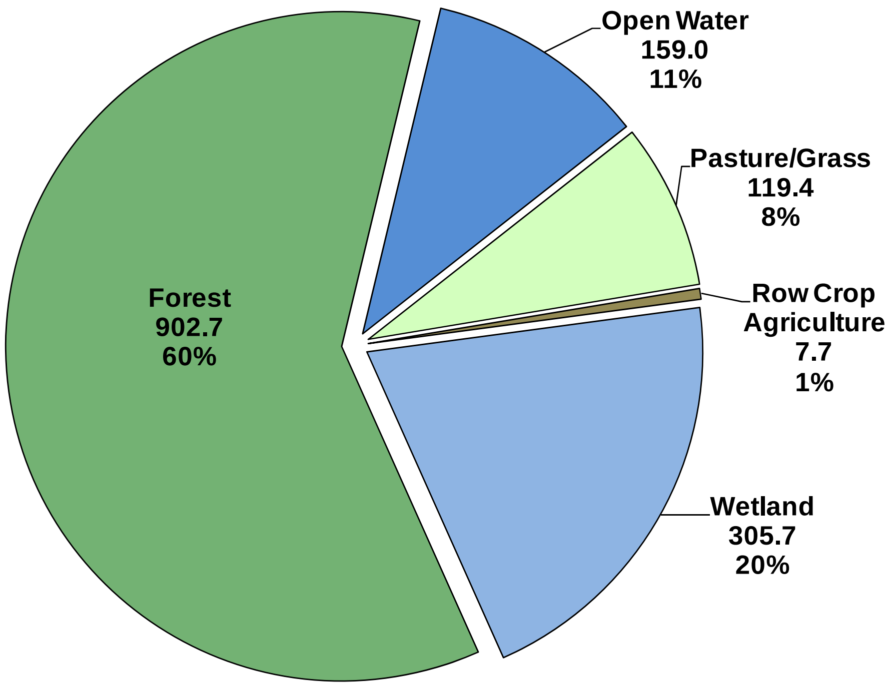

Figure 3.2-1. Muskellunge Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998).

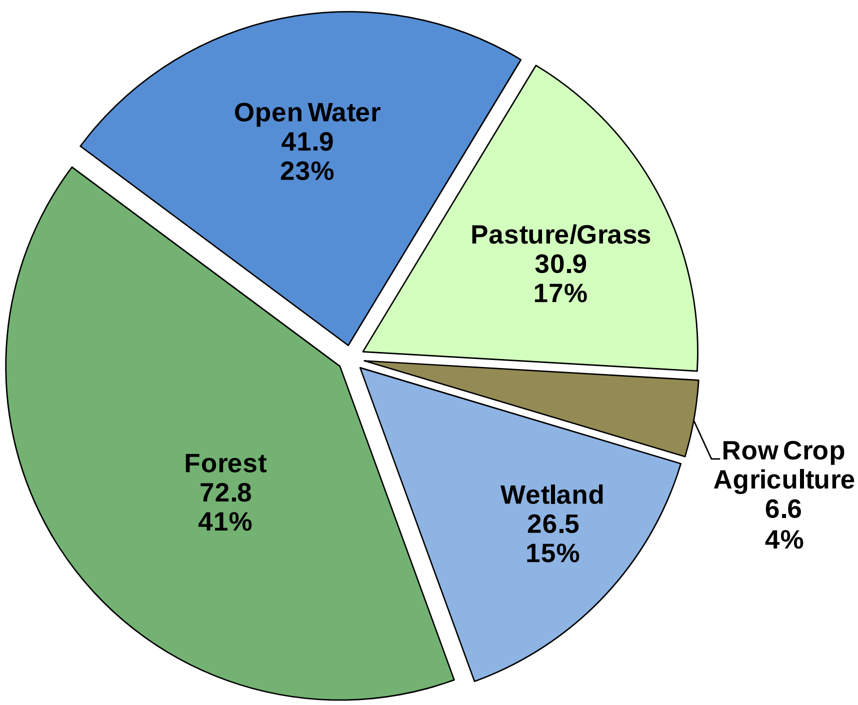

Figure 3.2-2. Muskellunge Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 Aquatic Plants

Introduction

Although the occasional lake user considers aquatic macrophytes to be "weeds" and a nuisance to the recreational use of the lake, the plants are actually an essential element in a healthy and functioning lake ecosystem. It is very important that lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative effects on it.

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*) In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the *periphyton* attached to them as their primary food source. The plants also provide cover for feeder fish and *zooplankton*, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by *phytoplankton*, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced numbers of predator fish and a stunted pan-fish population. *Exotic* plant species, such as Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing *native* plants and reducing *species diversity*. These *invasive* plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

When plant abundance negatively affects the lake ecosystem and limits the use of the resource, plant management and control may be necessary. The management goals should always include the control of invasive species and restoration of native communities through environmentally sensitive and economically feasible methods. No aquatic plant management plan should only contain methods to control plants, they should also contain methods on how to protect and possibly enhance the important plant communities within the lake. Unfortunately, the latter is often neglected and the ecosystem suffers as a result.

Aquatic Plant Management and Protection

Important Note:
Even though most of these techniques are not applicable to Muskellunge Lake, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake. The techniques applicable to Muskellunge Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Many times an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyngodon idella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice. Unfortunately, there are no “silver bullets” that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that 30 feet. This action can be conducted up to 150 feet from shore. Please note that a permit is needed in all instances if wild rice is to be removed. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR.

Permits are required for chemical and mechanical manipulation of native and non-native plant communities. Large-scale protocols have been established for chemical treatment projects covering >10 acres or areas greater than 10% of the lake littoral zone and more than 150 feet from shore. Different protocols are to be followed for whole-lake scale treatments (≥160 acres or ≥50% of the lake littoral area). Additionally, it is important to note that local permits and U.S. Army Corps of Engineers regulations may also apply. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

\Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreline. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreline sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake (. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a *shoreland buffer zone.* The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function.

Enhancement activities also include additions of *submergent*, *emergent*, and *floating-leaf* plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Cost

The cost of native, aquatic and shoreland plant restorations is highly variable and depend on the size of the restoration area, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include extensive grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), and protective measures used to guard the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,200.

- The single site used for the estimate indicated above has the following characteristics:
  - An upland buffer zone measuring 35’ x 100’.
  - An aquatic zone with shallow-water and deep-water areas of 10’ x 100’ each.
  - Site is assumed to need little invasive species removal prior to restoration.
  - Site has a moderate slope.
  - Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
  - Plant spacing for the aquatic zone would be 3 feet.
  - Each site would need 100’ of biolog to protect the bank toe and each site would need 100’ of wavebreak and goose netting to protect aquatic plantings.
  - Each site would need 100’ of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
  - There is no hard-armor (rip-rap or seawall) that would need to be removed.
  - The property owner would maintain the site for weed control and watering.

Advantages	***Disadvantages***
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake from developed properties. • Reduces bottom sediment re-suspension and shoreline erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • Many educational and volunteer opportunities are available with each project.	• Property owners need to be educated on the benefits of native plant restoration before they are willing to participate. • Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in. • Monitoring and maintenance are required to assure that newly planted areas will thrive. • Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Manual Removal

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width. Please note that the use of powered cutters may require a mechanical harvesting permit to be issued by the WDNR.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15th.

Cost

Commercially available hand-cutters and rakes range in cost from $85 to $150. Power-cutters range in cost from $1,200 to $11,000.

Advantages	***Disadvantages***
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if treatment is conducted after June 15th. • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area. • Plant biomass is removed from waterbody.	• Labor intensive. • Impractical for larger areas or dense plant beds. • Subsequent treatments may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb *benthic* organisms and fish-spawning areas. • Risk of spreading invasive species if fragments are not removed.

Bottom Screens

Bottom screens are very much like landscaping fabric used to block weed growth in flowerbeds. The gas-permeable screen is placed over the plant bed and anchored to the lake bottom by staking or weights. Only gas-permeable screen can be used or large pockets of gas will form under the mat as the result of plant decomposition. This could lead to portions of the screen becoming detached from the lake bottom, creating a navigational hazard. Normally the screens are removed and cleaned at the end of the growing season and then placed back in the lake the following spring. If they are not removed, sediments may build up on them and allow for plant colonization on top of the screen.

Cost

Material costs range between $.20 and $1.25 per square-foot. Installation cost can vary largely, but may roughly cost $750 to have 1,000 square feet of bottom screen installed. Maintenance costs can also vary, but an estimate for a waterfront lot is about $120 each year.

Advantages	*Disadvantages*
• Immediate and sustainable control. • Long-term costs are low. • Excellent for small areas and around obstructions. • Materials are reusable. • Prevents fragmentation and subsequent spread of plants to other areas.	• Installation may be difficult over dense plant beds and in deep water. • Not species specific. • Disrupts benthic fauna. • May be navigational hazard in shallow water. • Initial costs are high. • Labor intensive due to the seasonal removal and reinstallation requirements. • Does not remove plant biomass from lake. • Not practical in large-scale situations.

Water Level Drawdown

The primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation and either heating or freezing depending on the timing of the treatment. Winter drawdowns are more common in temperate climates like that of Wisconsin and usually occur in reservoirs because of the ease of water removal through the outlet structure. An important fact to remember when considering the use of this technique is that only certain species are controlled and that some species may even be enhanced. Furthermore, the process will likely need to be repeated every two or three years to keep target species in check.

Cost

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive. If a hydro-electric facility is operating on the system, the costs associated with loss of production during the drawdown also need to be considered, as they are likely cost prohibitive to conducting the management action.

Advantages	***Disadvantages***
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian water-milfoil for a few years. • Allows some loose sediment to consolidate, increasing water depth. • May enhance growth of desirable emergent species. • Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.	• May be cost prohibitive if pumping is required to lower water levels. • Has the potential to upset the lake ecosystem and have significant affects on fish and other aquatic wildlife. • Adjacent wetlands may be altered due to lower water levels. • Disrupts recreational, hydroelectric, irrigation and water supply uses. • May enhance the spread of certain undesirable species, like common reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*). • Permitting process may require an environmental assessment that may take months to prepare. • Unselective.

Mechanical Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Costs

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages	***Disadvantages***
• Immediate results. • Plant biomass and associated nutrients are removed from the lake. • Select areas can be treated, leaving sensitive areas intact. • Plants are not completely removed and can still provide some habitat benefits. • Opening of cruise lanes can increase predator pressure and reduce stunted fish populations. • Removal of plant biomass can improve the oxygen balance in the littoral zone. • Harvested plant materials produce excellent compost.	• Initial costs and maintenance are high if the lake organization intends to own and operate the equipment. • Multiple treatments are likely required. • Many small fish, amphibians and invertebrates may be harvested along with plants. • There is little or no reduction in plant density with harvesting. • Invasive and exotic species may spread because of plant fragmentation associated with harvester operation. • Bottom sediments may be re-suspended leading to increased turbidity and water column nutrient levels.

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

1. *Contact herbicides* act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. *Systemic herbicides* spread throughout the entire plant and often result in complete mortality if applied at the right time of the year.

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to both the applicator and the environment, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

Applying herbicides in the aquatic environment requires special considerations compared with terrestrial applications. WDNR administrative code states that a permit is required if “you are standing in socks and they get wet.” In these situations, the herbicide application needs to be completed by an applicator licensed with the Wisconsin Department of Agriculture, Trade and Consumer Protection. All herbicide applications conducted under the ordinary high water mark require herbicides specifically labeled by the United States Environmental Protection Agency.

Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to reduce herbicide concentration within aquatic systems. Understanding concentration exposure times are important considerations for aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Some herbicides are applied at a high dose with the anticipation that the exposure time will be short. Granular herbicides are usually applied at a lower dose, but the release of the herbicide from the clay carrier is slower and increases the exposure time.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

Fluridone (Sonar®, Avast!®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters were dilution can be controlled. Required length of contact time makes this chemical inapplicable for use in flowages and impoundments. Irrigation restrictions apply.

Diquat (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.

Endothall (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothall (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, DMA IV®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions may apply.

Triclopyr (Renovate®) Selective, systemic herbicide that is effective on broad leaf plants and, similar to 2,4 D, will not harm native monocots. Triclopyr is available in liquid or granular form, and can be combined with Endothal in small concentrations (<1.0 ppm) to effectively treat Eurasian water-milfoil. Triclopyr has been used in this way in Minnesota and Washington with some success.

Glyphosate (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a *surfactant* to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species. This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*). Glyphosate is also marketed under the name Roundup®; this formulation is not permitted for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic organisms.

Imazapyr (Habitat®) Broad spectrum, system herbicide, slow-acting liquid herbicide used to control emergent species. This relatively new herbicide is largely used for controlling common reed (giant reed, *Phragmites*) where plant stalks are cut and the herbicide is directly applied to the exposed vascular tissue.

Cost

Herbicide application charges vary greatly between $400 and $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • Some herbicides can be used effectively in spot treatments.	• Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many herbicides are nonselective. • Most herbicides have a combination of use restrictions that must be followed after their application. • Many herbicides are slow-acting and may require multiple treatments throughout the growing season. • Overuse may lead to plant resistance to herbicides

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

Cost

Stocking with adult weevils costs about $1.20/weevil and they are usually stocked in lots of 1000 or more.

Advantages	***Disadvantages***
• Milfoil weevils occur naturally in Wisconsin. • Likely environmentally safe and little risk of unintended consequences.	• Stocking and monitoring costs are high. • This is an unproven and experimental treatment. • There is a chance that a large amount of money could be spent with little or no change in Eurasian water-milfoil density.

Wisconsin has approved the use of two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These beetles were imported from Europe and used as a biological control method for purple loosestrife. Many cooperators, such as county conservation departments or local UW-Extension locations, currently support large beetle rearing operations. Beetles are reared on live purple loosestrife plants growing in kiddy pools surrounded by insect netting. Beetles are collected with aspirators and then released onto the target wild population. For more information on beetle rearing, contact your local UW-Extension location.

In some instances, beetles may be collected from known locations (*cella* insectaries) or purchased through private sellers. Although no permits are required to purchase or release beetles within Wisconsin, application/authorization and release forms are required by the WDNR for tracking and monitoring purposes.

Cost

The cost of beetle release is very inexpensive, and in many cases is free.

Advantages	***Disadvantages***
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods is required. • Augmenting populations many lead to long-term control.	• Although considered “safe,” reservations about introducing one non-native species to control another exist. • Long range studies have not been completed on this technique.

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, like variable water levels or negative, like increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways; there may be a loss of one or more species, certain life forms, such as emergents or floating-leaf communities may disappear from certain areas of the lake, or there may be a shift in plant dominance between species. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Muskellunge Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of Muskellunge Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, relative frequency of occurrence is used to describe how often each species occurred in the plots that contained vegetation. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

In the end, this analysis indicates the species that dominate the plant community within the lake. Shifts in dominant plants over time may indicate disturbances in the ecosystem. For instance, low water levels over several years may increase the occurrence of emergent species while decreasing the occurrence of floating-leaf species. Introductions of invasive exotic species may result in major shifts as they crowd out native plants within the system.

Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

A lake with high species diversity is much more stable than a lake with a low diversity. This is analogous to a diverse financial portfolio in that a diverse lake plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity.

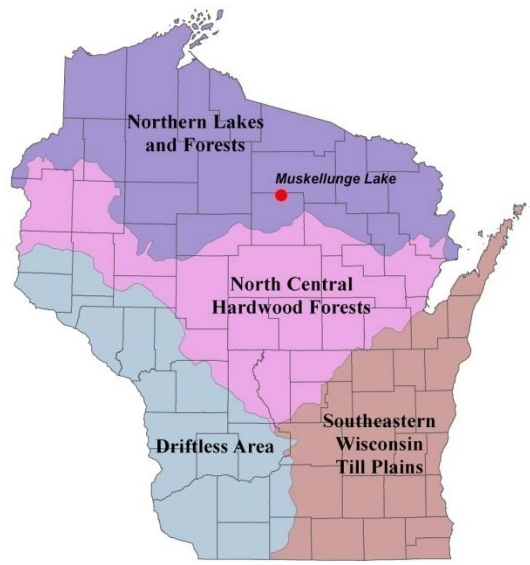

Figure 3.3-1. Location of Muskellunge Lake within the ecoregions of Wisconsin. After Nichols 1999.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Pesobic Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.3-1).

> **Ecoregions** are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states.

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept survey and does not include incidental species or those encountered during other aquatic plant surveys.

Community Mapping

A key component of the aquatic plant survey is the creation of an aquatic plant community map. The map represents a snapshot of the important plant communities in the lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with surveys completed in the future. A mapped community can consist of submergent, floating-leaf, or emergent plants, or a combination of these life-forms. Examples of submergent plants include wild celery and pondweeds; while emergents include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergents and floating-leaf communities lend themselves well to mapping because there are distinct boundaries between communities. Submergent species are often mixed throughout large areas of the lake and are seldom visible from the surface; therefore, mapping of submergent communities is more difficult and often impossible.

Exotic Plants

Because of their tendency to upset the natural balance of an aquatic ecosystem, exotic species are paid particular attention to during the aquatic plant surveys. Two exotics, curly-leaf pondweed and Eurasian water milfoil are the primary targets of this extra attention.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.3-2). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

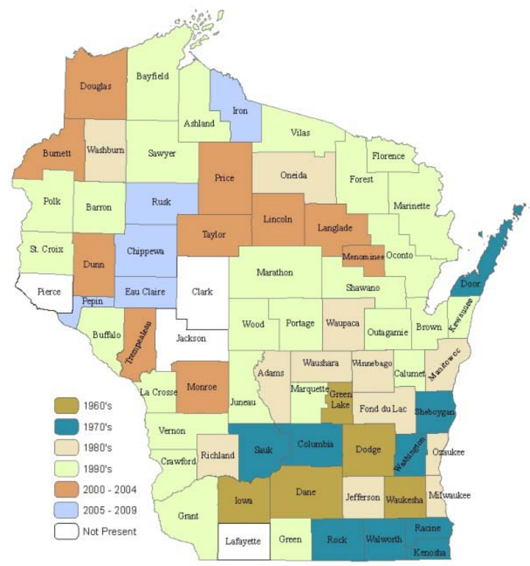

Figure 3.3-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2009 mapped by Onterra.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. Curly – leaf pondweed begins growing almost immediately after ice-out and by mid-June is at peak biomass. While it is growing, each plant produces many turions (asexual reproductive shoots) along its stem. By mid-July most of the plants have senesced, or died-back, leaving the turions

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in the sediment. The turions lie dormant until fall when they germinate to produce winter foliage, which thrives under the winter snow and ice. It remains in this state until spring foliage is produced in early May, giving the plant a significant jump on native vegetation. Like Eurasian water-milfoil, curly-leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.

Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian water milfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer.

Aquatic Plant Survey Results

As mentioned above, numerous plant surveys were completed as a part of this project. In June 2008, a survey was completed Muskellunge Lake that focused upon curly-leaf pondweed. This meander-based survey did not locate any occurrences of curly-leaf pondweed. It is believed that this aquatic invasive species either does not occur in Muskellunge Lake or exists at an undetectable level.

The point intercept survey was conducted on Muskellunge Lake in July 2008 by Onterra. Additional surveys were completed by Onterra on Muskellunge Lake to create the aquatic plant community maps (Map 3) during August 2008.

Median Value This is the value that roughly half of the data are smaller and half the data are larger. A median is used when a few data are so large or so small that they skew the average value to the point that it would not represent the population as a whole.

During the point-intercept and aquatic plant mapping surveys, 50 species of plants were located in Muskellunge Lake (Table 3.3-1), including Vasey's pondweed, a species of special concern in Wisconsin. Although this species is secure globally, it is "imperiled" in Wisconsin because of rarity (WDNR 2010). Vasey's pondweed populations are quite health in Muskellunge Lake, as evidenced by being the seventh most common species located during the point-intercept survey (Figure 3.3-3).

The results of a stakeholder survey sent to MLPRD members in 2008 indicate that approximately 24% of respondents believe that aquatic invasive species are present in Muskellunge Lake. Before aquatic plant surveys were conducted in 2008, numerous reports of Eurasian water milfoil infestations were conveyed to Onterra ecologists. Actually, one of the auspices for the MLPRD to conduct a management planning project was to better understand the extents of the perceived infestation.

No Eurasian water milfoil or any other exotic invasive species were located within the system during the aquatic plant surveys. Many nearby lakes contain Eurasian water milfoil, so there is a good chance that Muskellunge Lake has been exposed to fragments of this species carried in by transient boaters. Healthy plant communities, like those found in Muskellunge Lake, make establishment of aquatic invasive species difficult.

Table 3.3-1. Aquatic plant species located on Muskellunge Lake during July-August 2008 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	Onterra 2008
Emergent	*Calla palustris*	Water arum	9	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Equisetum fluviatile	Water horsetail	7	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Typha spp.	Cattail spp.	1	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elatine minima	Waterwort	9	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes echinospora	Spiny-spored quilwort	8	X
	Lobelia dortmanna	Water lobelia	10	X
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum heterophyllum	Various-leaved water milfoil	7	I
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Myriophyllum tenellum	Dwarf water milfoil	10	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton strictifolius	Stiff pondweed	8	I
	*Potamogeton vaseyi**	Vasey's pondweed	10	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Ranunculus flammula	Creeping spearwort	9	X
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	X
	Utricularia gibba	Creeping bladderwort	9	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
FF	*Lemna trisulca*	Forked duckweed	6	X
	Lemna turionifera	Turion duckweed	2	I
	Spirodela polyrhiza	Greater duckweed	5	X
S/E	*Juncus pelocarpus*	Brown-fruited rush	8	X

FL = Floating-leaf; FL/E = Floating-leaf/Emergent; FF = Free-floating; S/E = Submergent/Emergent
X = Species present on rake during point-intercept survey; I = Incidental species
** = Listed as a species of 'special conern' in Wisconsin*

Three milfoil species (genus *Myriophyllum*), were located from Muskellunge Lake. Dwarf water milfoil is morphologically much different from the other 6 milfoil species known to occur in Wisconsin waters. The other milfoil species, including the exotic Eurasian water milfoil, have feathery foliage with individual leaves resembling a candelabra being arranged in whorls around the stem. An incidental occurrence of various-leaved milfoil was located in the northwestern shallow bay of Muskellunge Lake.

Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and high water clarity. These conditions can be observed in Muskellunge Lake and likely explain why northern water milfoil is the sixth most common plant within the lake. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the 'reddish' appearance of Eurasian water milfoil as the plant reacts to increased sun exposure as the growing season progresses and is exacerbated by lowering water levels. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

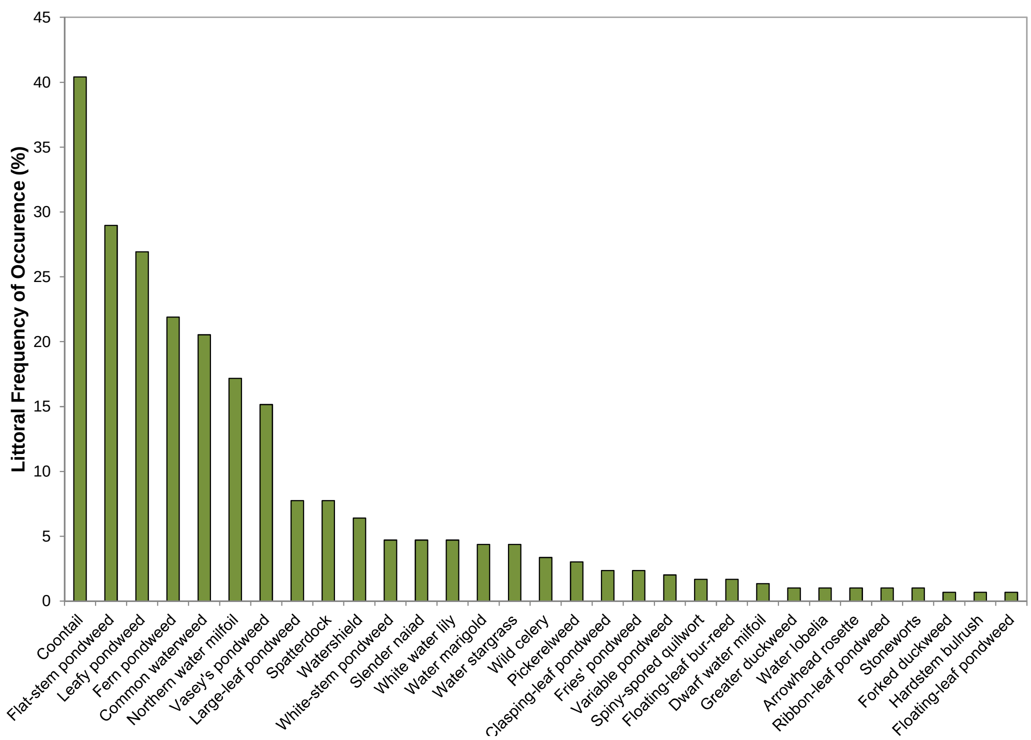

Figure 3.3-3 Muskellunge Lake aquatic plant occurrence analysis. Created using data from 2008 surveys.

Several aquatic plant surveys have been conducted on Muskellunge Lake. A 1998 report authored by Rand Atkinson of Aquatic Resources, Inc. includes information relating to surveys conducted in 1979, 1993, and 1997 (Atkinson 1998). It is important to note that field identification of particular plant species can be quite difficult at times, especially if the plant species are lacking key characteristics (e.g. flowers, seeds, winter buds). As a part of the current project, representatives of all plant species located during the plant surveys were collected, prepared, and had their identifications vouchered (confirmed and stored in a state-wide database) by the University of Wisconsin – Steven's Point Herbarium. This was not the case for the previous studies; therefore comparisons with the current study cannot truly be made.

For instance, the 1997 survey indicates that Hill's pondweed was the third most common species encountered in Muskellunge Lake. This NHI listed Species of Special Concern has only been confirmed from a single Wisconsin county with individuals found growing in beaver pond wetlands. It is possible that this 'small' pondweed was actually leafy-pondweed, the third most common plant species found during the current survey. Because the current study located five 'small' pondweeds (leafy, fries', spiral-fruited, small, and Vasey's pondweeds) it is also likely that these individuals were also included within the misidentification.

However, coontail was listed as the most dominant plant species from the 1979 and 1997, consistent with the findings of the current study (Figure 3.3-3). Identification of this species is relatively straight-forward and it is likely that coontail has been remained the dominant plant in Muskellunge Lake for the past 3 decades. It also appears that water lilies continue to comprise a dominant part of the plant community of the lake.

In addition to Muskellunge Lake containing a very high number of aquatic plants species, these species are found to be in relatively 'even' distribution. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The high diversity index for Muskellunge Lake's plant community (0.92) shows that the lake has a relatively even distribution (relative frequency) of plant species throughout the lake and no plant species overwhelmingly dominate the plant community. Figure 3.3-3 shows that coontail is most prevalent species in the lake. Due to their lack of developed root structures, the locations of coontail are largely influenced by water movement and their tendency to become entangled in plants, rocks, or debris. Muskellunge Lake contains a large amount of submergent plant species which at certain times of the year, can be found growing to the surface and likely provide the substrate needed for coontail to become entangled. Coontail also can be found growing along the bottom of the lake.

Data collected from the 2008 aquatic plant surveys indicate that the average conservatism values in Muskellunge Lake are much higher than the state and Northern Lakes Ecoregion medians (Figure 3.3-4). This indicates that many of the species present in the lake are indicative of a healthy, undisturbed system. The establishment of aquatic invasive species could certainly be viewed as a disturbance and would likely cause a shift of the aquatic plant community, particularly in respect to those species with higher coefficients of conservatism (Table 3.3-1).

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were solely encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total of 50 native aquatic plant species were located in Muskellunge Lake during the 2008 surveys, 39 were encountered on the rake during the point-intercept survey. The native species encountered on the rake and their conservatism values were used to calculate the FQI of Muskellunge Lake's aquatic plant community (equation shown below).

FQI = Average Coefficient of Conservatism (7.2) * √ Number of Native Species (39)
FQI = 44.7

Figure 3.3-4 compares the FQI components from Muskellunge Lake calculated from the 2008 point-intercept survey to median values of lakes within the Northern Lakes and Forests Ecoregion in Wisconsin. As displayed, the native species richness and average conservatism values for Muskellunge Lake exceed median values for both the ecoregion and the state. Combining Muskellunge Lake's native species richness and average conservatism values yields an exceptionally high FQI value of 44.7, greatly exceeding the ecoregional and state medians (Figure 3.3-5). This analysis indicates that the aquatic plant community of Muskellunge Lake is of higher quality than the majority of lakes within the Northern Lakes and Forests Ecoregion and the entire state of Wisconsin.

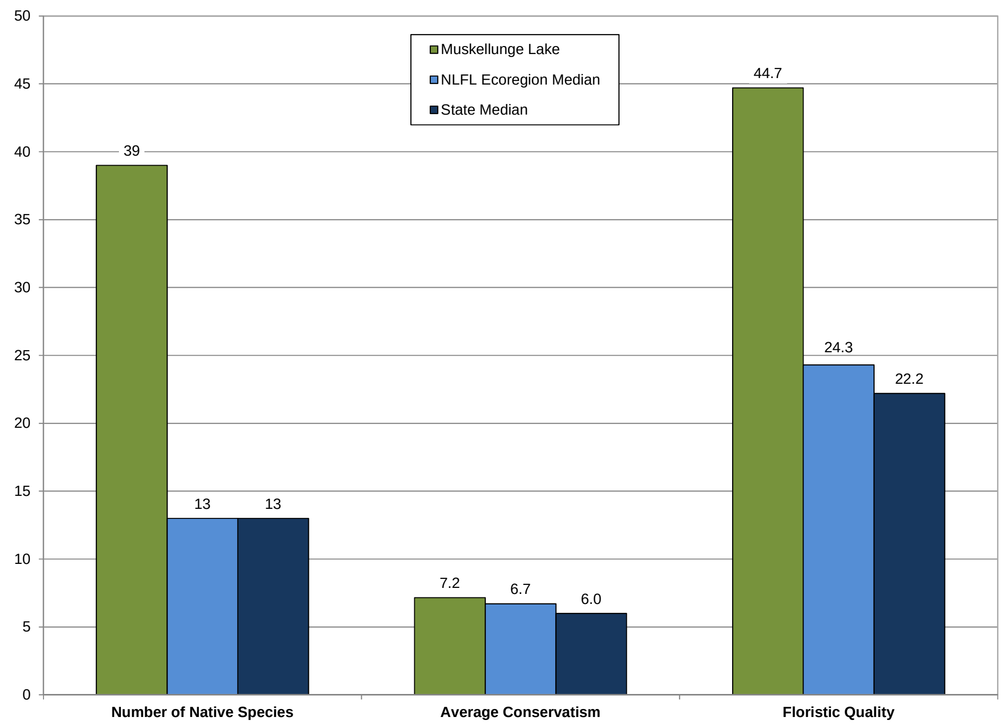

Figure 3.3-4. Muskellunge Lake Floristic Quality Assessment. Created using data from 2008 surveys. Analysis following Nichols (1999).

The quality is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. A total of 15 emergent and floating-leaf species are known to exist in Muskellunge Lake (Table 3.3-1). The 2008 community map indicates that about 20% of the surface area (31 acres) of the lake contains these types of plant communities (Table 3.3-2, Map 3). Each of these areas provides valuable fish and wildlife habitat important to the ecosystem of the lake, particularly since structural habitat of fallen trees and other forms of coarse-woody debris are quite sparse along the shoreline of Muskellunge Lake.

Table 3.3-2. Muskellunge Lake acres of plant community types from the 2008 community mapping survey.

Plant Community	Acres
Floating-leaf	1.2
Mixed Floating-leaf and Emergent	29.8
Total	31.0

Continuing the analogy that the community map represents a 'snapshot' of the important plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Muskellunge Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Along with human development of the lake's shoreline, motorboat traffic is a major disturbance factor affecting Wisconsin lakes. Respondents to the 2008 stakeholder survey ranked passive activities as the top four most important or enjoyable. These activities likely have little negative impacts on the lake. However, motor boating and water skiing/tubing were the fifth and sixth highest ranked activities, respectively, indicating that the lake is exposed to these active forms of recreation (Appendix B, Question #9). It must be noted that these enjoyable activities can have adverse effects on the lake. Many studies have shown that higher turbidity were associated with motorboat traffic (e.g. Murphy and Eaton 1983, Vermaat and de Bruyne 1993, Mumma et al. 1996, Asplund and Cook 1997).

The 1998 report indicated that one of the most pressing issues facing Muskellunge Lake at that time was boat traffic causing an increased suspension of bottom sediments. During this timeframe, a short stakeholder survey sent to district members indicated that 70% of the respondents were at least moderately supportive of dredging activities being conducted on their lake (Atkinson 1998). The stakeholder survey sent to district members in 2008 showed that those at least moderately in favor of dredging have reduced to approximately 54% (Appendix B, Question #18). Sedimentation/silt build up was viewed as the second-most pressing issue facing Muskellunge Lake, with the most pressing issue being excessive aquatic growth (Appendix B, Question #15). The decomposition of these plants is likely the source of the organic matter that is accumulating as silt within the lake.

Respondents to the 1998 survey also indicated excessive aquatic growth as being a major concern, particularly within the shallow bays of the lake. Floating-leaf and emergent plant species appear to be those that are most concerning to MLPRD members, especially the threat of these communities expanding lakeward. As stated above, replication of the community mapping survey will allow an understanding if these communities are expanding over time. Riparians are able to maintain reasonable access to the lake within these areas and these activities are outlined within the Implementation Plan Section of this document.

3.4 Fisheries Overview

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR (WDNR 2010).

Table 3.4-1. Gamefish present in Muskellunge Lake with corresponding biological information (Becker, 1983).

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead	*Ictalurus melas*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Bowfin	*Amia calva*	30	Late April - Early June	Vegetated areas from 2 - 5 ft with soft rootlets, sand or gravel	Fish, crayfish, small rodents, snakes, frogs, turtles
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	*Lepomis gibbosus*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass	*Micropterus dolomieu*	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)

Table 3.4-1 cont.

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Walleye	*Sander vitreus*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Warmouth	*Lepomis gulosus*	13	Mid May - Early July	Shallow water 0.6 - 0.8 m, with rubble slightly covered with silt	Crayfish, small fish, odonata, and other invertebrates
Yellow Bullhead	*Ameiurus natalis*	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Table 3.4-2. Non-gamefish present in Muskellunge Lake with corresponding biological information (Becker, 1983).

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Blackchin Shiner	*Notropis heterodon*	3	June - August	Sand and Gravel	Aquatic invertebrate adults and larvae
Bluntnose Minnow	*Pimephales notatus*	3	May - August	Sand or Gravel Shoals	Diatoms, filamentous algae, aquatic invertebrates
Creek Chub	*Semotilus atromaculatus*	5	May - July	Littoral areas of gravel	Fish, insects, vegetation
Emerald Shiner	*Notropis atherinoides*	5	Late May - Early August	Gravel shoals, rounded boulders, and sand	Terrestrial insects, algae, aquatic invertebrates
Fathead Minnow	*Pimephales promelas*	2	Late May – June	Sand, marl or gravel; hard surfaces	Algae, plant fragments, insect larvae
Johnny Darter	*Etheostoma nigrum*	3	April - June	Rocks, logs or other hard surfaces	Insect larvae, algae
Golden Shiner	*Notemigonus crysoleucas*	5	May - August	Over areas of Submerged Vegetation	Aquatic Invertebrates
White Sucker	*Catostomus commersoni*	8	April - Early May	Swift water or rapids, occasionally over gravel in lakes	Fish, fish eggs, plants, mollusks, insects, crustaceans and protazoans

Muskellunge Lake Fishing Activity

Based on data collected from the stakeholder survey, fishing was the second highest ranked important or enjoyable activity on Muskellunge Lake (Appendix B, Question #9). Approximately 92% of these same respondents believed that the quality of fishing on the lake was either fair or poor (Appendix B, Question #6); and approximately 91% believe that the quality of fishing has remained the same or gotten worse since they have obtained their property (Appendix B, Question #7).

Tables 3.4-1 and 3.4-2 (above) show the popular game fish and non-game fish that are present in the system. According to the stakeholder survey data, residents of the lake stated that they believed excessive aquatic plant growth and sedimentation/silt build up were the top two factors that are negatively impacting the lake (Appendix B). These factors also ranked as the primary and secondary concerns regarding Muskellunge Lake, and 83% of survey respondents stated that aquatic plant growth sometimes or always affects their enjoyment of the lake. If any actions are taken to address plant growth or sedimentation in Muskellunge Lake, it will be important to understand potential impacts this will have on the fish community, and plan their implementations accordingly. Specifically, the alteration of these elements may impact spawning habitat for fish species. Yellow perch is a species that could potentially be affected by early season herbicide applications, as the treatments could eliminate nursery areas for the emerged fry of these species. Muskellunge is another species that may be impacted by early season treatments as water temperatures and spawning locations often overlap. If mechanical harvesting of plants is to occur, a general rule of thumb is to begin harvesting after June 1st, which would allow the vast majority of fish species to complete their spawning season.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.4-1). Muskellunge Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. GLIFWC and WDNR fisheries biologist believe that approximately 35% of a lake's walleye or muskellunge population can be removed annually without adversely affecting the ability of the population to maintain itself. This 35% exploitation rate is called the total allowable catch. The safe harvest level is set at approximately one third (33%) of the total allowable catch (GLIFWC 2004). The six Wisconsin Chippewa Tribes declare a tribal quota based on a percent of the estimated safe harvest each year by March 15. The tribal declaration will influence the daily bag limits for hook-and-line anglers. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

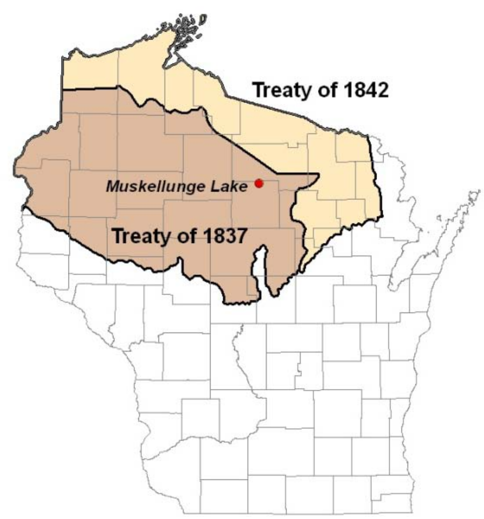

Figure 3.4-1. Location of Muskellunge Lake within the Native American Ceded Territory (GLIFWC 2007). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2004). With respect to walleye, tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2007). This regulation limits the harvest of the larger, spawning female walleye. Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly quota is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the quota is met or the season ends.

In 2009, the estimated safe harvest for Muskellunge Lake was set at 23 walleye. Tribal declaration is usually set at 50-80% of the estimated safe harvest for a given lake. Muskellunge Lake was not declared as a spear harvest lake in 2009 and has not been harvested in the past. A combination of a low estimated safe harvest for walleye and the availability to spear other lakes in the region with higher estimated safe harvest have likely contributed to Muskellunge Lake not being declared a spear harvest lake. With several larger waterbodies nearby, (Lake Nokomis and Lake Mohawksin) this is likely the case.

Because Muskellunge Lake is located within ceded territory, special fisheries regulations may occur, specifically in terms of largemouth and smallmouth bass. Because the lake is located in the Northern Bass Management Zone of Wisconsin, fishing for this species is limited to catch-and-release from May 1st to the third Friday of June. Following the catch-and-release season, harvests of both bass species is limited to fish over 18 inches, with a daily bag limit of 1 fish until the first Saturday of March in which the season ends. This is a regulation specific to Muskellunge Lake, and took effect in 2007.

In a 2004 fish survey of Muskellunge Lake, it was discovered that the lake held numerous small, slow-growing bluegill. Dave Seibel, WDNR fisheries biologist, recommended at the time that the lake be managed primarily for largemouth bass and bluegill and an appropriate management strategy for the system would be to increase the length limit and decrease the daily bag limit for bass, while encouraging harvest of bluegill. This regulation would work towards building bass abundance and size quality, which will in turn decrease the population but increase the size of bluegill. Mr. Seibel's presentation of these materials to the MLPRD is included provided as Appendix F.

There are no special regulations for or other game fish species in Muskellunge Lake besides those set for the Northern Bass, Muskellunge, and Pike Management Zones. For Muskellunge, a daily bag limit is set at one fish over 34". There is no minimum length limit on northern pike, and the daily bag limit is five fish. The statewide bluegill daily bag limit is 25 fish, with no minimum length.

Muskellunge Lake Fish Stocking

Muskellunge Lake has not been stocked by the WDNR, however Mr. Seibel has stated that historical stocking by stakeholders has occurred. Table 3.4-3 displays these efforts by both the Muskellunge Lake District and Tomahawk Fishing Unlimited, Inc. Based upon the results of WDNR surveys, there is little evidence supporting that the stocked fish have survived in Muskellunge Lake. Mr. Seibel does not recommend stocking the lake, particularly for walleye. WDNR surveys indicate that the lake is not a "walleye lake" and efforts to manage a walleye fishery on the lake will only create a larger imbalance between the largemouth bass and bluegill relationship. This is because walleye are not an effective predator of bluegill, but will prey on largemouth bass. Again, Mr. Seibel's 2004 presentation data and management recommendations are included as Appendix F.

Table 3.4-3. Historical fish stocking data for Muskellunge Lake. Stocking was supported through the Muskellunge Lake District and Tomahawk Fishing Unlimited, Inc. Data provided by Dave Seibel, 2010.

Date	Species	Number Stocked	Size
1938	Bluegill	1,250	Adult
1938	Crappie	500	Adult
1941	Muskellunge	5,000	Fry
1942	Muskellunge	10,000	Fry
1945	Muskellunge	24,000	Fry
1946	Muskellunge	1,146	Fingerling
1947	Muskellunge	60,000	Fry
1948	Largemouth Bass	5,000	Fingerling
1949	Largemouth Bass	300	Fingerling
1949	Muskellunge	1,500	Fingerling
1950	Largemouth Bass	2,300	Fingerling
1952	Muskellunge	630	Fingerling
1953	Muskellunge	315	Fingerling
1954	Muskellunge	116	
1955	Muskellunge	151	
1956	Muskellunge	30	
1957	Muskellunge	600	
1959	Muskellunge	100	
1960	Muskellunge	620	
1961	Muskellunge	150	
1962	Muskellunge	460	Fingerling
1982	Muskellunge	160	8-10"
1983	Muskellunge	150	12"
1985	Muskellunge	500-600	5"
1985	Walleye	1,000	2-3"
1985	Largemouth Bass	400	1"
1986	Muskellunge	300-400	8-10"
1990	Muskellunge	150	10-13"
1990	Walleye	750	5-7"
1991	Walleye	1,075	4-10"
1992	Walleye	1,000	4-9"
1995	Walleye	1,300	5-7"
2000	Walleye	1,300	5-7"

Muskellunge Lake Substrate Type

According to the point-intercept survey conducted by Onterra, 88% of the substrate sampled in the littoral zone on Muskellunge Lake was muck, 11% sand and only one location (<1%) having a rocky substrate (Map 4). Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so they do not get buried in sediment and suffocate. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment.

Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well. Largemouth bass prefer habitats very similar to that of bluegill, and prefer to both occupy and spawn in substrates of sand and gravel but like bluegill will spawn in softer substrates if necessary (Becker 1983).

4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill three objectives:

1) Collect baseline data to increase the general understanding of the Muskellunge Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake with a primary focus on Eurasian water milfoil.
3) Collect sociological information from Muskellunge Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current conditions of the lake and its management.

The three objectives were fulfilled during the project and have lead to a good understanding of the Muskellunge Lake ecosystem, the folks that care about the lake, and what needs to be completed to protect and enhance it.

Three primary aspects of the Muskellunge Lake ecosystem were studied as a part of this management planning project; the system's water quality, its aquatic plant community, and the watershed that supplies a small portion of system's water. In general, the studies indicate that the lake is in exceptionally good health. The paragraphs that follow cover the highlights of the studies that were completed and further, they elaborate on the conclusions that were drawn from them.

The watershed of Muskellunge Lake is largely comprised of forested (60%) and wetland (20%) areas. Forested areas export very little phosphorus and other pollutants within runoff as most of the precipitation that falls on them infiltrates the ground. Because so much of the lake's drainage basin is comprised of forested land cover means that little phosphorus enters the lakes through surface runoff. The large percentage of wetland area within Muskellunge Lake also contributes to the healthy condition of the lake. In addition to providing valuable wildlife habitat, wetland plants are excellent at utilizing nutrients, filtering the water of nutrients and pollutants before entering lake.

With a watershed to lake area ratio of 8:1, land use changes in the Muskellunge Lake watershed could be fairly effective at influencing water quality conditions. As demonstrated through the modeling exercise listed with the watershed section, reforesting the small amount (approximately 7.7 acres) of row crops within the Muskellunge Lake watershed had little benefit in terms of phosphorus reduction (6.6 lbs per year). However, if large amounts of development occur within the watershed, the impacts will likely be observed in terms of increased phosphorus levels and increased plant and algae productivity. Furthermore, continued impacts in the shoreland areas of the lake will most likely result in higher nutrient loads entering the lake and those higher loads will first be seen in decreased water clarity. These impacts include shoreland development, overcutting of trees, fertilizer use, faulty septic systems, and increases in impervious surfaces. Control of these impacts is required to maintain the water quality and habitat value within the lake.

The water quality of the lake is considered 'good.' Trophic analysis indicates that the lake is moderately productive, upper mesotrophic to lower eutrophic lake. Limited historic water quality data suggests that the conditions have largely remained the same since 1979. The limited data may suggest a reduction in total phosphorus concentrations since 1997. If this phenomenon is occurring, it is likely a result of 1) alterations of the watershed, or 2) increases in aquatic plant biomass. Because Muskellunge Lake lacks channelized inlets to the lake, the addition or modification of roads within wetlands systems without properly placed culverts have a greater ability to alter the size of the watershed. Also, the measured phosphorus values of a lake do not incorporate the quantities of this nutrient that are contained within the rooted aquatic plant community and therefore may under represent the amount of phosphorus entering the lake.

The aquatic plant community of Muskellunge is in very good condition, as evidence by almost 50 different plant species inhabiting the lake, all of which are native. Frequency analysis shows that these species are in relatively even distribution and not overly dominated by any one species. The health of this plant community is likely the reason why Muskellunge Lake does not currently contain any non-native species. With many nearby lakes that contain Eurasian water milfoil and curly-leaf pondweed, Muskellunge Lake likely has and will continue to be exposed to fragments of these species that enter the lake through unintentional introductions on transient boats and trailers. Invasive species thrive in disturbance situation and once established in a productive lake, can have devastating impacts on its health.

Many stakeholders have expressed concerns related to increases in aquatic plants, especially encroachment of floating-leaf and emergent communities across some of the shallow bays. While there is an obvious justification for riparians to have access to the lake, it also must be understood that a lake is a functioning system and will change over time. Some riparians may state, “there were never this many lily pads within this bay” – and they may be correct. However, it does not necessarily suggest that something is wrong or needs to be done to ‘fix’ the situation, especially if riparians are not being adversely affected. Removing large areas of native vegetation may seem to have obvious benefits to stakeholders, but this disturbance can be very hard on a lake and make it vulnerable to threats such as exotic species infestation. By prioritizing these actions to only occur when absolutely necessary will be important to the long-term health of Muskellunge Lake.

Sedimentation or ‘silt’ build-up is also a common concern of stakeholders brought forth from the stakeholder survey (Appendix B, Question #14 and #15). It is interesting that both sedimentation and the abundance of native aquatic plants were discussed within the 1998 report authored by Rand Atkinson of Aquatic Resources, Inc. This shows that these are not novel issues facing the management of Muskellunge Lake and educating district members will likely be needed as turn-over of property owners occurs.

Another similarity with the 1998 report is that user conflicts continue to be concerns of stakeholders (Appendix B, Question #14 and #15). Current state law requires a slow-no-wake zone for personal watercraft (jet skiis) within 200 feet of the shoreline. A slow-no-wake bill (2009 Wisconsin Act 31) has recently passed and has taken effect on February 24, 2010 that established a slow-no-wake zone within 100 feet of the shoreline for all watercraft. These regulations are displayed on Map 6. Essentially, motor boats are able to operate at high-speed rates through the ‘narrows,’ whereas PWC cannot. While voluntary compliance and/or enforcement of these rules may not occur, it is important to note that these laws were enacted for personal safety reasons as well as to reduce the impacts of these activities on the lake, which can negatively affect near-shore ecosystems. Boating close to the shoreline can cause shoreline erosion, stir up lake bottom sediments causing turbidity and sedimentation, and release nutrients such as phosphorus which can contribute to algal growth. In addition, boating in these areas can be harmful to fish habitat as propellers uproot emergent plant populations.

Based on studies conducted by the WDNR, there is little evidence to support that privately stocked walleye have survived within the lake. Dave Seibel, WDNR fisheries biologist, has shared and presented information to the district relating to the negative repercussions of stocking walleye in Muskellunge Lake. In an attempt to increase the size structure of the bluegill population within Muskellunge Lake, a strategy was put into effect that would build bass abundance and size structure where the bass can effectively predate on bluegill. Because walleye are not an efficient predators of bluegill, any increase in walleye populations will negatively impact bass populations and undermine the management strategies put forth. A continued dialogue between the district and the WDNR will be needed to guide the fisheries goals of Muskellunge Lake.

Overall, the results and conclusions drawn from the many studies completed on Muskellunge Lake during this project indicate that the lake is in excellent health. With that in mind, the Implementation Plan contained within the next section, is primarily aimed at protecting this unique resource.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Muskellunge Lake Protection & Rehabilitation District Planning Committee and ecologist/planners from Onterra. It represents the path the MLPRD will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of Muskellunge Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Increase Muskellunge Lake Protection & Rehabilitation District's Capacity to Communicate with Lake Stakeholders

Management Action: Support an Education Committee to promote clean boating, water quality, public safety, and quality of life on Muskellunge Lake

Timeframe: Begin summer 2009

Facilitator: Board of Directors to form Education Committee

Description: In addition to the public boat landing, many private properties are used for boat launching. As a result boats are not inspected and many water users are not aware of AIS issues, boating regulations and the general impacts of their activities on the lakes and the enjoyment of others. Education represents a good tool to address issues that impact water quality such as lake shore development, lawn fertilization and other issues such as air quality, noise and boating safety. An Education Committee will be created to promote lake protection and the quality of life through a variety of educational efforts.

Regularly published newsletters allow for exceptional communication within a lake group. This level of communication is important within a management group because it builds a sense of community while facilitating the spread of important district news, educational topics, and even social happenings. It also provides a medium for the recruitment and recognition of volunteers. Perhaps most importantly, the dispersal of a well written newsletter can be used as a tool to increase awareness of many aspects of lake ecology and management among district members. By doing this, meetings can often be conducted more efficiently and misunderstandings based upon misinformation can be avoided. Educational pieces within the district newsletter may contain monitoring results, district management history, as well as other educational topics listed below.

In addition to creating regularly published district newsletter, these may include educational materials, awareness events and demonstrations for lake users as well as activities which solicit local and state government support.

Example Educational Topics:

Specific topics brought forth in other management actions

Boating safety
Catch and release fishing
Noise, air, and light pollution
Shoreland restoration and protection
Septic system maintenance

Action Steps:

1. Recruit volunteers to form Education Committee.
2. Investigate if WDNR small-scale Lake Planning Grant would be appropriate to cover initial setup costs.
3. The MLPRD Board will identify a base level of annual support for educational activities to be undertaken by the Education Committee.

Management Goal 2: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Timeframe: Continuation of current effort.

Facilitator: Mark Dochnahl and Greg Guthrie

Description: Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. The lack of this type of historical information hampered the water quality analysis during this project. Early discovery of negative trends may lead to the reason as of why the trend is developing. Volunteers from the MPPRD have collected Secchi disk clarities and water chemistry samples during the past through the WDNR Citizen Lake Monitoring Program, but not in recent years. A set of volunteers would be solicited from the MLPRD to collect water quality samples on the lake, including dissolved oxygen using the probe owned by the district. The volunteer monitoring of the water quality is a large commitment and new volunteers may be needed in the future as the volunteer's level of commitment changes. It is the responsibility of the Planning Committee to coordinate new volunteers as needed. Note: as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

Please see description above.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to Muskellunge Lake.

Timeframe: Begin 2009

Facilitator: Education Committee

Description: As the watershed section discusses, the Muskellunge Lake watershed is in good condition; however, watershed inputs still need to be focused upon, especially in terms of the lake's shoreland properties. These sources include faulty septic systems, shoreland areas that are maintained in an unnatural manner, impervious surfaces.

On April 14th, 2009, Governor Doyle signed the "Clean Lakes" bill (enacted as 2009 Wisconsin Act 9) which prohibits the use of lawn fertilizers containing phosphorus. Phosphorus containing fertilizers were identified as a major contributor to decreasing water quality conditions in lakes, fueling plant growth. This law will go into effect in April 2010. While this law also bans the display and sale of phosphorus containing fertilizers, educating lake stakeholders about the regulations and their purpose is important to ensure compliance.

To reduce these negative impacts, the MLPRD will initiate an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include newsletter articles and guest speakers at district meetings.

Topics of educational items may include benefits of good septic system maintenance, methods and benefits of shoreland restoration, including reduction in impervious surfaces, and the options available regarding conservation easements and land trusts.

Action Steps:

1. Recruit facilitator.
2. Facilitator gathers appropriate information from WDNR, UW-Extension, Lincoln County, and other sources.
3. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for district meetings.

Management Action: Complete Shoreland Condition Assessment as a part of next management plan update

Timeframe: Begin 2009

Facilitator: Board of Directors

Description: As the discussed above, unnatural shorelands can negatively impact the health of a lake, both by decreasing water quality conditions as well as removing valuable habitat for fish and other aquatic species that reside within the lake. Understanding the shoreland conditions around Muskellunge Lake will serve as an educational tool for lake stakeholders as well as identify areas that would be suitable for restoration. Shoreland restorations would include both in-lake and shoreline habitat enhancements. In-lake enhancements would include the introduction of course woody habitat, a fisheries habitat component lacking around the shores of Muskellunge Lake. Shoreline enhancements would include leaving 35-foot no-mow zones or by planting native herbaceous, shrub, and tree species as appropriate for Lincoln County. Ecologically high-value areas delineated during the survey would also be selected for protection, possibly through conservation easements or land trusts (www.northwoodslandtrust.org). Useful information for shoreland enhancements may be found through numerous resources, including:

- Wisconsin Lakes website: (www.wisconsinlakes.org/shorelands)
- UW-Extention Shoreland Restoration: http://www.uwex.edu/ces/shoreland/Why1/whyres.htm)
- WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)

Projects that include shoreline condition assessment and restoration activities will be better qualified to receive state funding in the future. These activities could be completed as an amendment to this management plan and would be appropriate for funding through the WDNR small-scale Lake Planning Grant program.

Action Steps: See description above.

Management Goal 3: Maintain Riparian Access to Muskellunge Lake

Management Action: Support reasonable and responsible actions by shoreland property owners to gain navigational access to open water areas of Muskellunge Lake

Timeframe: Begin 2009

Facilitator: District Board of Directors

Description: Only 12% of stakeholder survey respondents stated that they did not feel aquatic plant control was needed on Muskellunge Lake (Appendix B, Question #17). Nuisance levels of aquatic plants were also stated to be the single greatest factor negatively impacting Muskellunge Lake (Appendix B, Question #14 & 15). The plant species of concern on the lake are largely emergent species such as pickerelweed and floating-leaf species such as water lilies and watershield.

The MLPRD supports reasonable and environmentally sound actions to facilitate access to open water areas of Muskellunge Lake by shoreland property owners. These actions would target nuisance levels of native aquatic plants in order to restore watercraft access to open water areas of the lake. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area required to permit the access. These actions do not include areas that can be controlled through manual removal such as swimming areas and areas around piers and boatlifts. Individual property owners are solely responsible for the financial burden of the control and for documenting the need for nuisance control as described in Aquatic Plant Management Strategy Northern Region WDNR (Summer 2007). This guidance document clearly states that no individual permits will be issued. If documentation of impairment exists, this plan must be amended to specifically delineate the areas requiring control and a permit must be obtained by the district.

Five possibilities exist to maintain access to open water from the impacted riparian properties.

1. Riparian manually remove 30-foot (length of shore) by 150-foot (out from shore) area without a permit, but all manually removed plants must be taken to

shore and the area must include any docks, piers, or swimming areas on the property (Map 5).

2. Contract to have the plants removed manually, possibly by an aquatic plant nursery or landscaping company, without a permit in the area listed above.

Only applicable when the above possibilities do not feasibly yield lake access

3. Obtain a permit and contract to have the plant manually removed in the form of an access lane.
4. Contract to have the plants cut and removed through mechanical harvesting.

Only applicable when the above possibilities do not feasibly yield lake access

5. Contract licensed applicator to use contact herbicides on target plants.

At this time it is unknown if a contractor exists that is able to manually remove the plants in feasible manner that would create navigation lanes to open water from the shoreland properties. Local landscaping companies may fill this niche as more lakes seek this service. It is also unknown if mechanical harvesting is possible in these area due to shallow water and type of plants that would be targeted. However, both of these techniques would be preferable over chemical treatments; therefore, those options will be exhausted before herbicide applications are used.

Regardless of the technique used, their impact on the native plant community will be minimized by removing only as much native habitat as necessary in order gain access to open water. No more than a 30-foot wide navigation lane will be cleared in any area and the shortest route possible will be used.

If aquatic plants continue to be at nuisance levels and the first four possibilities listed above have been documented to be infeasible, the use of herbicides will only be considered by the WDNR if all adjacent property owners contain natural buffer areas along their shorelands. Excessive plant growth is associated with increased nutrient levels. Best management practices for shoreland properties to reduce their nutrient loads are to have buffer areas of native plant species at least 35 feet wide along their shorelines. These improvements would provide important shoreline habitat improvement to mitigate the losses of the floating-leaf habitat that would be removed by the control action.

Before control of native aquatic plant species occur on the lake, a defined plan of management would need to be developed to serve as an amendment to the current lake management plan.

Action Steps:

1. Individual property owners document impairment, either on their own or by hiring a professional as described in the Aquatic Plant Management Strategy Northern Region WDNR
2. The property owner provides the materials to the WDNR and the district for review.
3. The district requests a site visit by the WDNR to verify impairment.

4. The district updates the current management plan to further define the management objective and associated actions (mechanical harvesting or herbicide application) needed to augment the impairment.
5. District obtains a permit to implement management action after WDNR verifies impairment and approves the update to the management plan.
6. If chemical herbicides are necessary, contact the Lincoln County Conservation Department to discuss necessary steps to begin shoreland restorations on applicable properties.

Management Action: Perform a feasibility study of dredging near the public boat landing
Timeframe: Initiate as needed
Facilitator: District Board of Directors
Description: Second only to excessive aquatic plant growth as indicated by the stakeholder survey sent to all district members, sedimentation/silt build up is a major factor believed to be negatively impacting Muskellunge Lake (Appendix B, Question #14 and #15). Sedimentation is a natural process that occurs as a lake ages. Sedimentation rates can increase when near shore areas of the lake are in an unnatural state (manicured lawns and impervious surfaces). Although studies were not completed to specifically address that state of Muskellunge Lake's shoreline, its condition would likely not be the sole cause of the level of sedimentation that is perceived on the system. Muskellunge Lake supports a large biomass of aquatic plants. It is likely the decomposition of these plants that contributes to the increase in organic sediments found within the lake.

While individual riparian concerns about sediment build up exist, the MLPRD is most concerned about the lake's single public access site. This boat landing was built in a shallow bay off of the lake's central basin (Map 1). It is suspected that settling of organic materials that become suspended as boats move within this bay and participate in high speed boating within the adjacent basin is occurring. Launching of boats using this landing can be difficult, especially pontoon boats and other deep-hulled watercraft.

An investigation of dredging costs was initiated by Mark Dochnahl in 2006, at which time he was the president of the MLPRD. At that time, a cost estimate for sediment removal was approximately $30,000 per year, likely requiring multiple years (up to 5 years) worth of dredging due to sediment 'sloughing.'

At this time, the MLPRD does not intend on initiating dredging in this area, but the steps required to complete this project are addressed in the event that the costs of this activity decrease and/or more funds (public and private) become available to the group.

Completing a dredging project is not only costly to implement, but the extensive permitting process is extremely taxing. Muskellunge Lake is designated as being an Area of Special Natural Resource Interest (ASNRI) and therefore is required to obtain a permit for all forms of dredging, including manual dredging. This designation is likely because Muskellunge Lake is known to contain populations of endangered, threatened, special concern species, or unique ecological communities identified by the Natural Heritage Inventory. As a part of the permitting process, the MLPRD may also be required to conduct an analysis of the sediments to be extracted if upon pre-application screening the department determines there is a reason to believe some level of contamination may exist. If contaminants are not perceived to exist within the system, the department may waive the sediment sampling requirements under NR 347.06 (3)(a) Adm. Code.

More information regarding dredging in lakes and the permits that are or are not required may be found at the WDNR's waterway and wetland permits: dredging website - http://dnr.wi.gov/topic/Waterways/construction/dredging.html

Action Steps:

1. Retain engineer/consultant to create a comprehensive dredging plan to amend current management plan.
2. Follow State of Wisconsin Dredging Review Process (Adopted from WDNR Publication WT-778, 2003 – see Appendix G).
   a. Applicant Submits Preliminary Application
   b. WDNR determines sediment sampling requirements
   c. Applicant submits Sampling and Analysis Plan
   d. Applicant submits Chapter 30 dredging permit application
   e. Applicant conducts sampling and submits results
   f. WDNR determines what permits and approvals are necessary including Wisconsin Environmental Policy Act (WEPA) requirement
   g. Applicant submits all necessary approval applications
   h. WDNR issues decisions on all permit and approval applications
   i. Applicant notifies WDNR and begins dredging
3. Engineer/consultant access need for repeat dredging.

Management Goal 4: Prevent Introduction and Establishment of Aquatic Invasive Species within Muskellunge Lake

Management Action: Initiate Clean Boats Clean Waters watercraft inspections at Muskellunge Lake public access

Timeframe: In progress

Facilitator: Board of Directors to form Invasive Species Committee

Description: Muskellunge Lake is believed to be free of aquatic invasive species. Initiating a program of watercraft inspections based upon the WDNR Clean Boats Clean Waters program will help to reduce the chance that exotic species, such as Eurasian water milfoil, zebra mussels, and curly-leaf pondweed would be introduced to the lake. Muskellunge Lake is not considered a primary fishing destination in Lincoln County, largely because it is a relatively small lake amongst larger systems (Rice Reservoir, Lake Mohawksin) and has difficult public access. Because of these factors, it is not visited on a frequent basis by lake users that do not have property on the lake. An inspection program aimed at the most busy weekends of the year would be targeted for watercraft inspections by volunteers from Muskellunge Lake.

Action Steps:

1. Members of district attend Clean Boats Clean Waters training
2. Training of additional volunteers completed by those trained.
3. Begin inspections during high-risk weekends
4. Report results to WDNR and MLPRD.
5. Promote enlistment and training of new of volunteers to keep program fresh.

Management Action: Initiate volunteer-based monitoring of aquatic invasive species.
Timeframe: Start 2009
Facilitator: Invasive Species Committee
Description: In lakes without Eurasian water milfoil, early detection of pioneer colonies commonly leads to successful control and in cases of very small infestations, possibly even eradication. Using trained volunteers is a feasible method to monitor for the occurrence of these unwanted species. The keys to success are proper training and persistence by the lake group.

Action Steps:

1. Volunteers from MLPRD attend training session conducted by WDNR/UW-Extension.
2. Trained volunteers recruit and train additional district members.
3. Complete lake surveys following protocols.
4. Report results to WDNR and MLPRD.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Muskellunge Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

	Spring		**June**		**July**		**August**		**Fall**		**Winter**	
Parameter	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Dissolved Phosphorus	●	●			●	●					●	●
Chlorophyll a	●		●		●		●		●			
Total Kjeldahl Nitrogen	●	●	●		●	●	●		●		●	●
Nitrate-Nitrite Nitrogen	●	●	●		●	●	●		●		●	●
Ammonia Nitrogen	●	●	●		●	●	●		●		●	●
Laboratory Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Total Suspended Solids	●	●	●		●	●	●		●	●	●	●
Calcium	●											

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was be completed using a Hydrolab DataSonde 5.

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Muskellunge Lake during a 6/30/08 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Muskellunge Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in "Appendix C" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin, (April, 2005) was used to complete this study on 7/16/08 and 7/17/08. A point spacing of 40 meters was used resulting in approximately 394 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Muskellunge Lake (emergent and floating-leaved vegetation) were mapped on 8/5/08 using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

Watershed Analysis

The watershed analysis began with an accurate delineation of Muskellunge Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

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