Mid Lake

Oneida County, Wisconsin

Comprehensive Management Plan

March 2013

Sponsored by:

Mid Lake Protection & Rehabilitation District

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Onterra LLC
Lake Management Planning

Mid Lake

Oneida County, Wisconsin

Comprehensive Management Plan

March 2013

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1.0 INTRODUCTION

Mid Lake, Oneida County, is 223-acre spring lake with a maximum depth of 12 feet and mean depth of approximately 6 feet. The Lake Tomahawk Thoroughfare is a natural water body that connects Lake Tomahawk to Lake Minocqua. Mid Lake's short outlet leads to the thoroughfare connecting it to the Minocqua Chain of Lakes to the north and Tomahawk Lake to the south. Many people visit the Minocqua Chain of Lakes and use its waters for recreational activities making it a large asset to local communities and to the state. Much of the Minocqua Chain of Lakes is within the Northern Highland Legion State Forest including all of Mid Lake. Located just south of Mid Lake on the chain is Indian Mounds Campground, a state-managed facility complete with boat launch facilities, handicap access, and 2 public beaches.

Mid Lake's shallow depth and dense aquatic vegetation population are major concerns of the Mid Lake Protection and Rehabilitation District (MLPRD) and are intensified when water levels are low due to natural causes or through manipulations by the Wisconsin Valley Improvement Corporation who owns the Minocqua Dam. Currently harvesting activities are used to increase recreational opportunities and remove excessive amounts of plant material which have been attributed to low winter dissolved oxygen levels.

The non-native aquatic plant, curly-leaf pondweed, (*Potamogeton crispus*) is also a concern of the MLPRD. Chemical control methods have been applied in the past, with results being rated positive, at least anecdotally. With compounding issues, the MLRPD understands the importance of understanding the Mid Lake ecosystem as a whole to ensure current management actions are properly coordinated and all management alternatives are fully understood. The MLPRD also understands the importance of educating stakeholders on the ecology and management of the lake so realistic management goals can be achieved

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 July 26, 2008, a project kick-off meeting was held at the Woodruff Town Hall to introduce the project to the general public. The meeting was announced through a mailing and personal contact by MLPRD board members. The approximately 18 attendees were welcomed by Clair Jowett and were informed about the events that led to the initiation of the project. Mr. Jowett's opening remarks were followed by a presentation given by Eddie Heath that started with an educational component regarding general lake ecology and ending with a detailed description of the project including opportunities for stakeholders to be involved. Mr. Heath's presentation was followed by a question and answer session.

Stakeholder Survey

In late summer of 2008, the Mid Lake Planning Committee developed an anonymous stakeholder survey with assistance from Onterra staff. This survey was reviewed and approved by a WDNR sociologist. During September 2008, a six-page, 23-question survey was mailed to riparian property owners in the Mid Lake watershed. When the surveys were returned, those results were entered into a spreadsheet by members of the Mid 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 October 14, 2009, Eddie Heath of Onterra met with the Mid Lake Planning Committee for nearly four hours. The primary focus of this meeting was the delivery of the study results and conclusions to the committee and discussion of management options and actions for the lake. Kevin Gauthier, WDNR Lake Coordinator for the Northern region of Wisconsin, was also in attendance.

Following Mr. Heath's results and conclusions presentation that lasted approximately 1 ½ hours, the group spent the next 2 ½ hours discussing the condition of the lake, the need for continued vegetation and water quality monitoring, the changes members of the Planning Committee have seen on the lake over the past two or more decades, and the results of the stakeholder survey. Much of the last half of that session, Mr. Heath led the group through the many alternatives available for managing the curly-leaf pondweed on Mid Lake, including an experimental procedure in which harvesting would be used to combat the infestation. This is discussed more in depth in the Implementation Plan.

Planning Committee Meeting II

On October 26, 2009, Eddie Heath met with seven members of the Mid Lake Planning Committee once again to finalize goals for the Lake Management Plan. The meeting lasted approximately 3 ½ hours. During this time, actions were developed which would allow the Mid Lake Planning Committee to work towards the previously discussed goals for the lake.

Project Wrap-up Meeting

Scheduled to occur during summer 2010.

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 on Mid Lake (data contained in Appendix C) are compared to other lakes in the region and state. 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 Mid 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. Oneida 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 averages and historic data from Mid Lake are displayed in Figures 3.1-2 - 3.1-4. Please note that the data in these graphs represent values collected from the deepest location in Arbutus 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 Mid Lake were collected at a depth of 3 feet.

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

The data presented in Figures 3.1-2 – 3.1-4 represents samples collected during the growing season (March 31-November 1) and during the summer (May 31-September 1). These values may differ due to seasonal fluctuations in nutrients or physical water events such as lake mixing and stratification (discussed further below); therefore, they are separated and analyzed differently.

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 Mid 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 district 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.

> 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.

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.

Volunteers from the Mid Lake Protection & Rehabilitation District collected many of the water quality samples utilized in this study. These samples were collected as a part of the Citizen Lake Monitoring Network, which on Mid Lake, does not include dissolved oxygen and temperature collection; therefore, profiles are only available for the sample dates completed by Onterra staff; including the spring and fall turnover samples, and the winter sample.

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.

Mid Lake Water Quality Analysis

Mid Lake Long-term Trends

Unfortunately, a limited amount of water quality data exists for Mid Lake, making an examination of long-term trends impossible. Some historical (1979) water quality data is available, and recent Citizen Lake Monitoring Network (CLMN) efforts have resulted in consistent data within the past few years. However it is unreasonable to attempt to draw conclusions on changes in water quality when significant gaps exist in the dataset. Natural annual fluctuations in water quality can and do occur in Wisconsin lakes, so without consistent yearly data it is impossible to tell if perceived changes in water quality are due to environmental circumstances or the influence of human. Despite this limitation, sufficient recent data exists to evaluate the current water quality status of Mid Lake.

Annual summer averages for total phosphorus have ranged from 31 to 40 μg/L between 2007 and 2009 (Figure 3.1-2). These values fall into a WQI category of *Fair*. Summer averages in past years have fallen into the WQI categories of *Good* and *Fair*. The most recent averages are higher than those found in similar Wisconsin natural lakes, as well as those lakes found only in the Northeast region.

Unlike the phosphorus data, the chlorophyll-*a* data displays much more variability. Annual summer averages have ranged from 7 to 22 μg/L between 2007 and 2009, and were found to be much lower (a single August sample of 2.8 μg/L) in 2003 (Figure 3.1-3). The 2007 and 2009 values rank in the WQI *Good* category while 2008 averages rank as *Poor*. A weighted average over all years of collected data is lower than the average for other Wisconsin natural lakes, and is only slightly higher than lakes in the Northeast region.

It is important to note that the presence of the invasive plant curly-leaf pondweed has been documented to influence nutrient concentrations in lakes. Specifically, a mid-summer die-off of this plant can increase the phosphorus and chlorophyll-*a* concentrations within a short period of time. The die-off, and resulting plant decomposition, releases nutrients into the water column where existing algae may feed intensively and grow in numbers. When the biomass of curly-leaf pondweed increases within a lake over time, the potential for a larger nutrient release exists. The biomass of curly-leaf pondweed is still relatively small in Mid Lake, compared to the size of the lake, and may not be sufficient to cause a nutrient "spike". Additionally, the data collected on Mid Lake cannot be used to determine if this phenomenon occurs or not.

The Secchi depth clarity in Mid Lake, along with phosphorus and chlorophyll-*a* concentrations, has fluctuated over the small dataset and has done so especially within the past 3 years. Average summer clarities have ranged from a WQI category of *Poor* to *Good*, and a weighted average of these years ranks as *Good*, falling below averages seen in similar lakes statewide and regionally (Figure 3.1-4). Secchi disk depth is highly correlated with the amount of algae in the water column; as algae become more abundant the clarity of the water decreases; therefore, it is not surprising to see that the highest summer phosphorus average, highest chlorophyll-*a* average, and lowest measured Secchi disk average all coincide within the same year (2008).

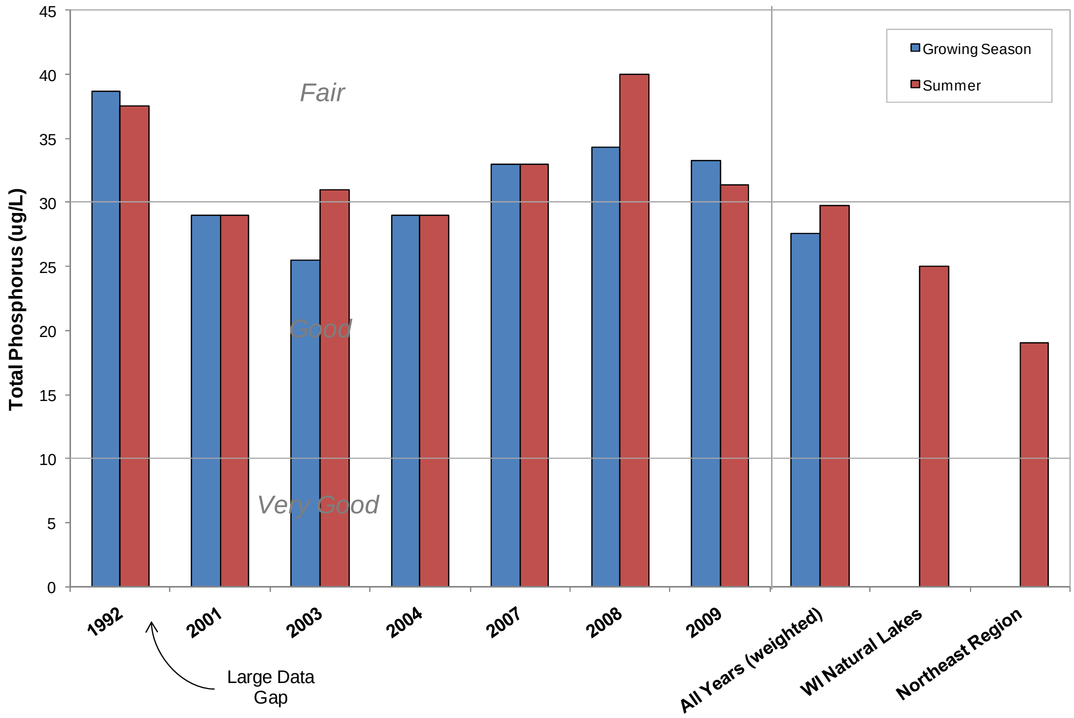

Figure 3.1-2. Mid Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

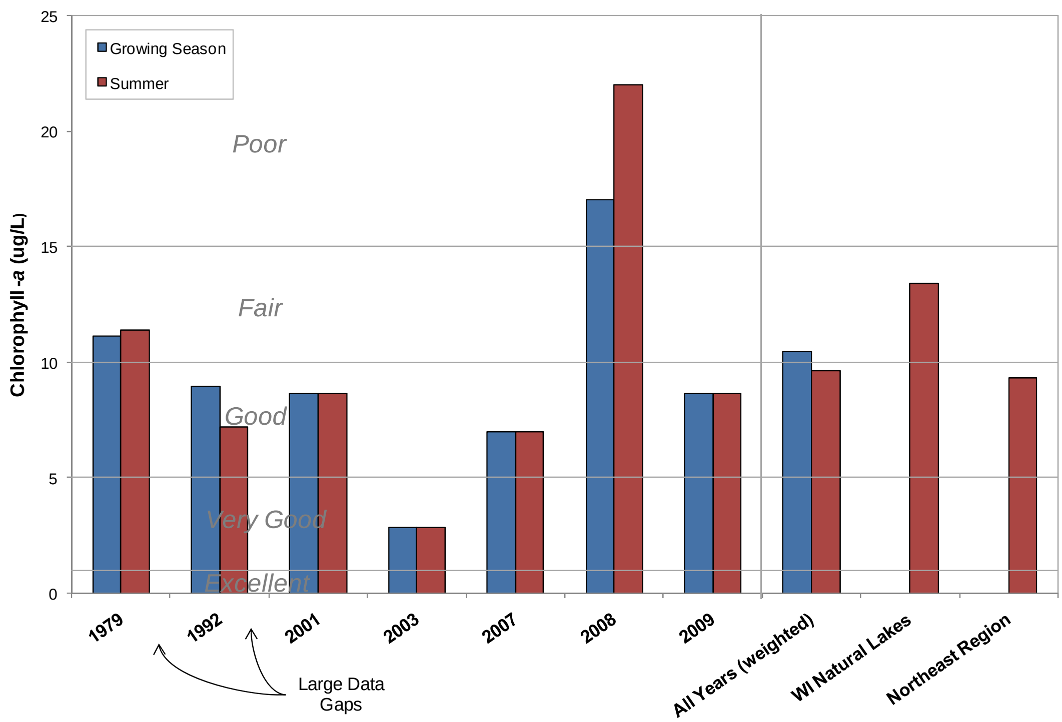

Figure 3.1-3. Mid Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

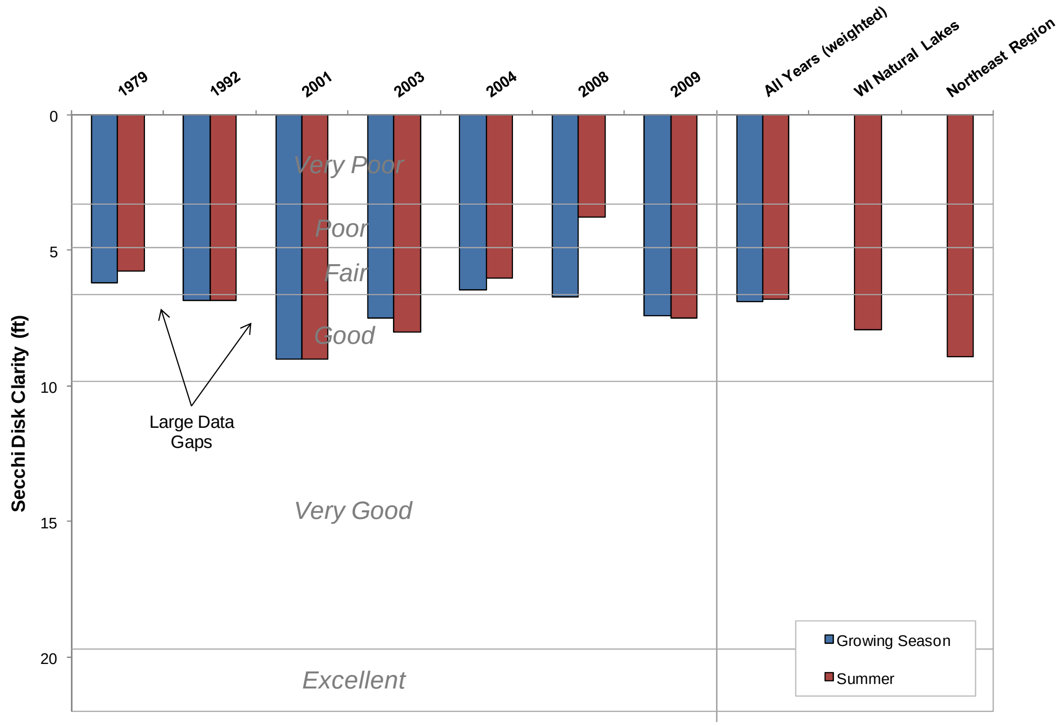

Figure 3.1-4. Mid Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

Limiting Plant Nutrient of Mid Lake

Using midsummer nitrogen and phosphorus concentrations from Mid Lake during 2003, a nitrogen:phosphorus ratio of 19:1 was calculated. This finding indicates that Mid 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.

Mid Lake Trophic State

Figure 3.1-5 contain the WTSI values for Mid Lake. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from mid-eutrophic to upper 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 Mid Lake is in a mid eutrophic state. Considering the high macrophytic biomass within the trophic state determination indicates that Mid Lake is definitely a productive (eutrophic) system.

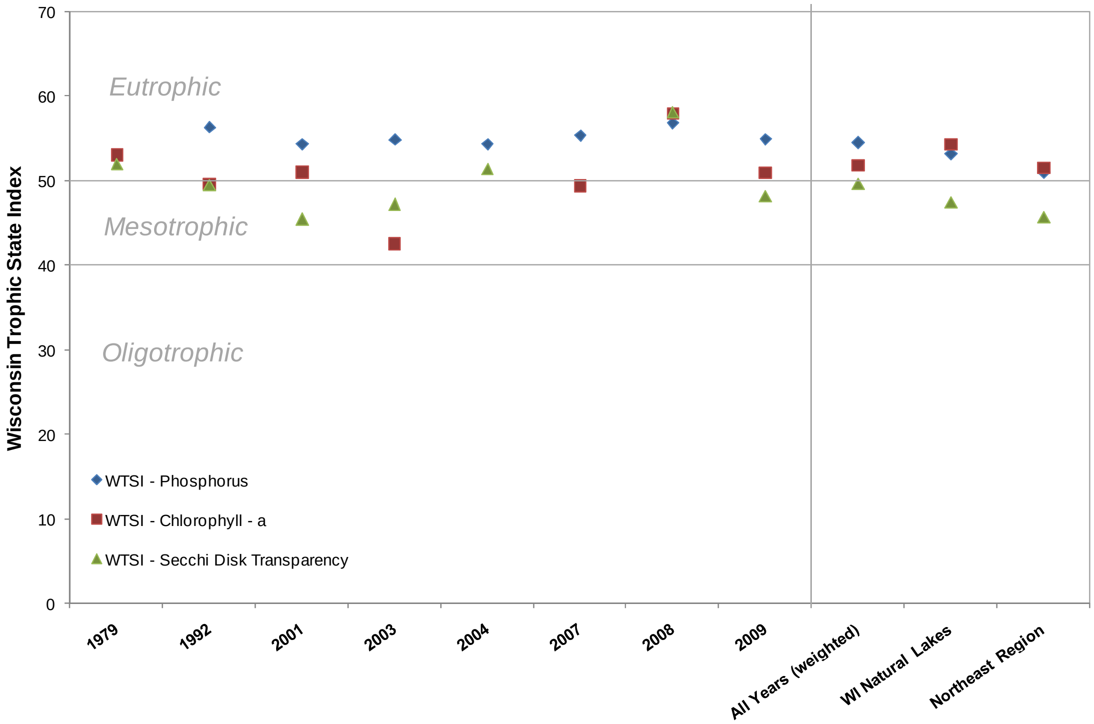

Figure 3.1-5. Mid Lake, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

Dissolved Oxygen and Temperature in Mid Lake

Dissolved oxygen and temperature information was collected by Onterra staff in late winter of 2008 and 2009. Roger Smith of the Mid Lake CLMN collected temperature data during spring and summer of these two years as well. Graphs of the most recent (2009) data are displayed in Figure 3.1-6.

Mid Lake was found to mix well in the spring, and remain mixed throughout the summer months. This is not uncommon in lakes that are moderately shallow. Energy from the wind is sufficient to mix the lake from top to bottom, which results in keeping the entire water column at nearly the same temperature. In late winter of 2009, dissolved oxygen levels were found to be very high (<10 mg/L) just under the ice; however, the concentrations plummeted quickly to 3 mg/L at 3 feet of depth. At 5 feet, the oxygen fell below 1.0 mg/L. Generally, it is believed that oxygen levels of at least 3.0 mg/L are required to sustain most aquatic life found in northern Wisconsin lakes. However, WDNR fisheries biologists believe that sport-fish species can tolerate oxygen levels as low as 1.0 mg/L for a period of 3-4 weeks. While the drop in oxygen is substantial, the upper portion of the water column holds more than enough oxygen and likely serves as a refuge for fish in the late winter.

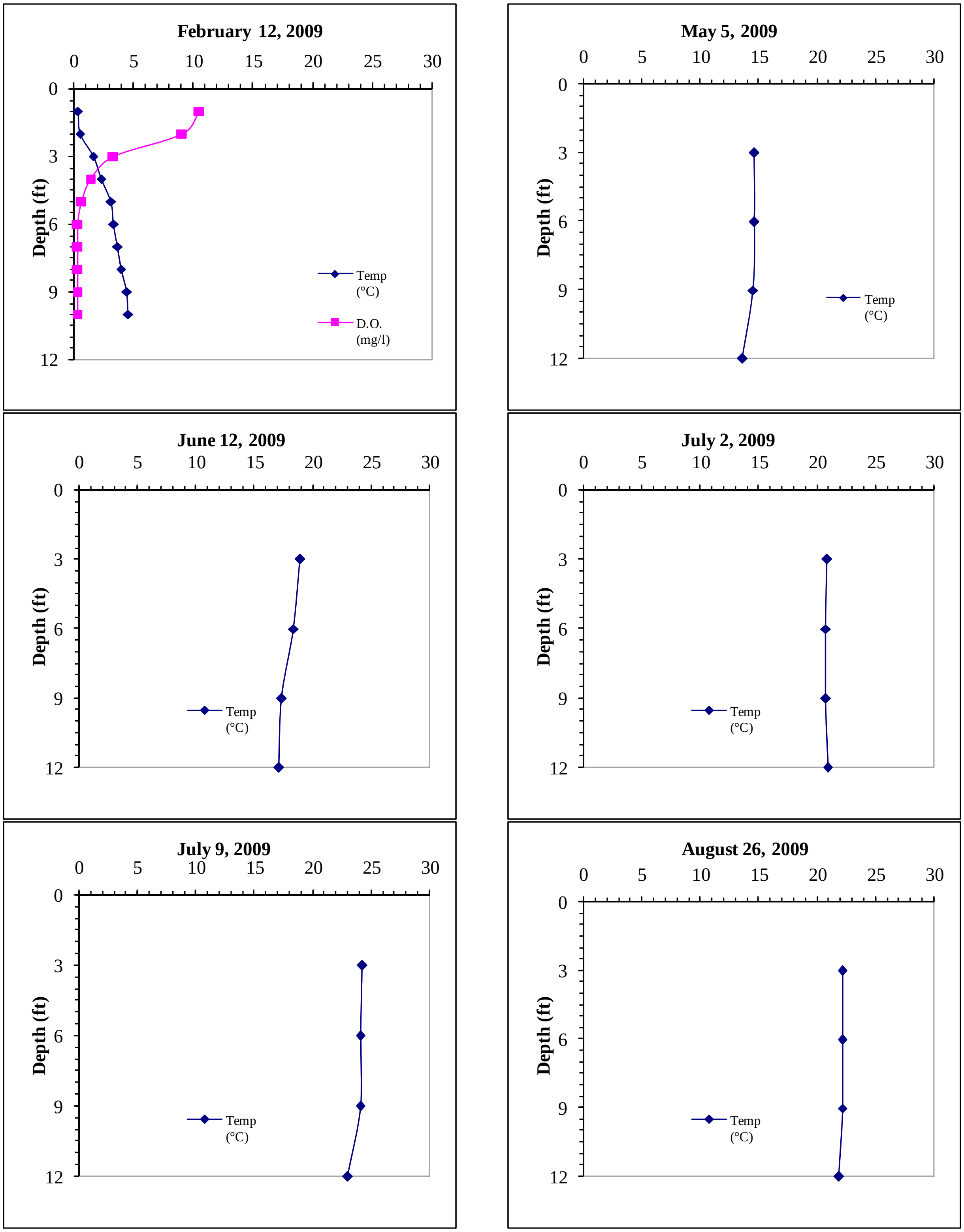

Figure 3.1-6. Mid Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Mid Lake

Alkalinity and calcium were not measured in the lake as a part of this project, however these water quality parameters were measured several years ago. In 2003 alkalinity was measured at 39.0 mg/L as $CaCO_3$ indicating that the lake has a higher buffering capacity against acid rain. During the same time, the lake's pH was measured at 8.9 or slightly alkaline. The pH value is normal for a lake such as Mid Lake and is at the high end of the optimal range for zebra mussels. Calcium analysis from a sample collected during 2003 returned a value of 10 mg/L, which is at the very low end for 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 10-15:1 or higher, 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.

Mid Lake's watershed contains approximately 1,356 acres of land. The majority of this land is forested (72%). Mid Lake's surface (17%) is the second most dominant type of cover, while wetlands and pasture/grassland comprise a smaller portion of the watershed (Figure 3.2-1). The watershed to lake area ratio is fairly small, at 6:1. This small ratio indicates that land cover located within this watershed plays a significant role in the lake's water quality. Input of the watershed land cover data within WiLMS produced a loading estimate of 161 lbs of phosphorus annually (Figure 3.2-2 and Appendix D), which is relatively low for a watershed of this size. It is interesting to note that although the largest land use type (forests) in the watershed produce the largest percentage of phosphorus to Mid Lake, atmospheric fallout produces a substantial portion of the phosphorus load (37%) to the lake despite only constituting 17% of the watershed.

Based upon average precipitation and evaporation rates for Oneida County and Mid Lake's volume (1,430 acre-feet), WiLMS modeling calculated a flushing rate of about 88% of its volume per year. This means that Mid Lake's water is exchanged about every 416 days (water residence time). The fairly long residence time may allow for some accumulation of sediments and phosphorus in the waterbody with only a portion of the annual load being flushed into the Tomahawk Thoroughfare and eventually into Tomahawk Lake. This factor likely contributes to Mid Lake's somewhat higher than average phosphorus concentrations, which would normally be slightly lower given the amount of forested land that drains to the lake.

Another factor contributing to Mid Lake's phosphorus content may be the history of this lake. Mid Lake was likely an emergent/shallow wetland in years past. With the addition of the dam, water collected in this lake and turned a naturally productive wetland into a productive lake. Because the majority of the watershed is forested, we can conclude that nutrients are largely recycled within the lake, taken in and then released from the abundant plants that characterize this system. With this in mind, the lake will be impacted most by disturbances that occur within the immediate watershed (shoreland) of the lake, as opposed to elsewhere in the watershed.

The lake's surrounding forests consist of private properties and also the American Legion Forest, which is publicly owned. This forested land is essentially protected from development perpetually while the privately owned land, 45% of all forested land in the watershed, is not. Although it is unlikely to occur, development of this land would increase the phosphorus loading to Mid Lake. WiLMS was utilized to run several scenarios in which development took place on the privately owned forested land of the watershed (436 acres). The scale of development would however play is a significant role in any additional phosphorus loading. If medium density urban development (1 house per quarter acre) occurs in place of the privately forested lands, the phosphorus load would nearly double, reaching 319 lbs annually (Figure 3.2-3). If rural development (1 house per acre or greater) was to take the place of forested land, the phosphorus load would only increase by 2.7% (161 to 165 lbs).

The scenario modeling may not be probable in that development of this nature does not typically take place in many areas of northern Wisconsin. Nevertheless the benefit of scenario modeling is to better understand how the lake and watershed are connected, and where the real threat to the health of Mid Lake lies. If rural development occurs to a large portion of the watershed, the lake is still well protected from impacts normally associated with this activity. As mentioned above, it is vital that conservation efforts to the Mid Lake watershed are focused upon the area that is most critical to the ecosystem – along its shoreline.

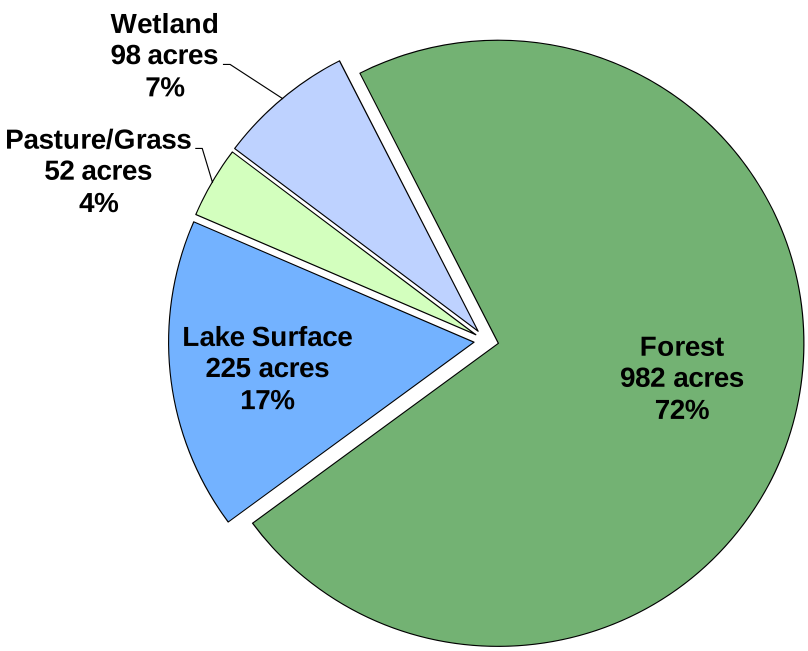

Figure 3.2-1. Mid Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998).

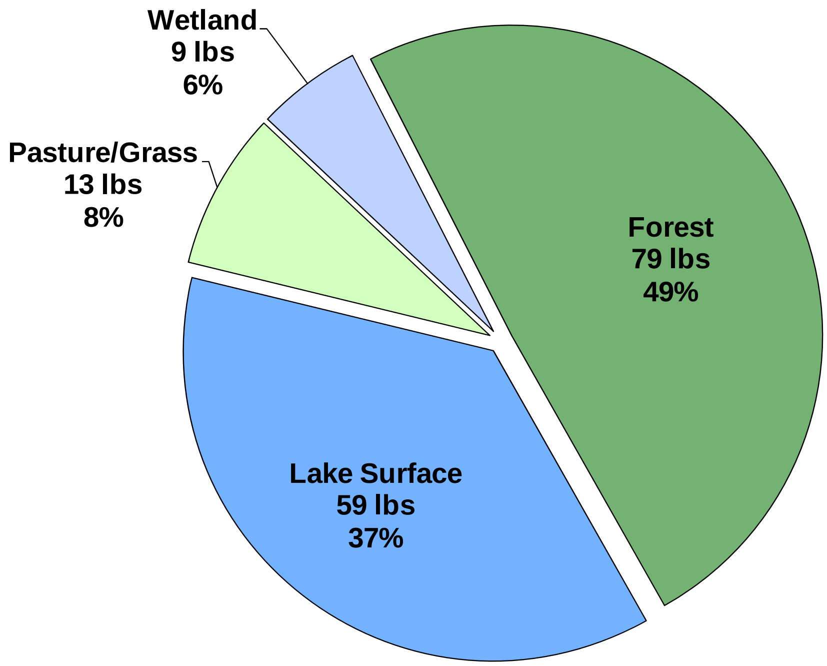

Figure 3.2-2. Mid Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

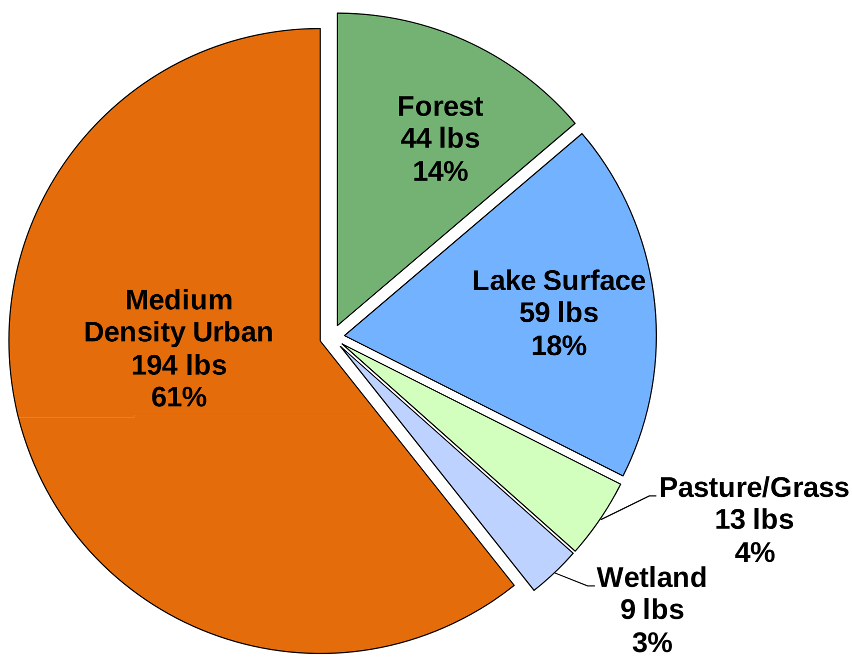

Figure 3.2-3. Mid Lake watershed phosphorus loading in pounds under an alternative scenario. Load is based upon conversion of 45 percent of current forested land into medium density urban land use. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

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 Mid 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 Mid 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).

Photograph 3.3-1. Example of a biolog restoration site.

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. Please note that a WDNR permit may be needed for installation of a bottom 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 effects 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.

<u>Fluridone</u> (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 where dilution can be controlled. Required length of contact time makes this chemical inapplicable for use in flowages and impoundments. Irrigation restrictions apply.

<u>Diquat</u> (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.

<u>Endothall</u> (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.

<u>2,4-D</u> (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.

<u>Triclopyr</u> (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.

<u>Glyphosate</u> (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, systemic 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.

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, such as 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 Mid 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 Mid 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.

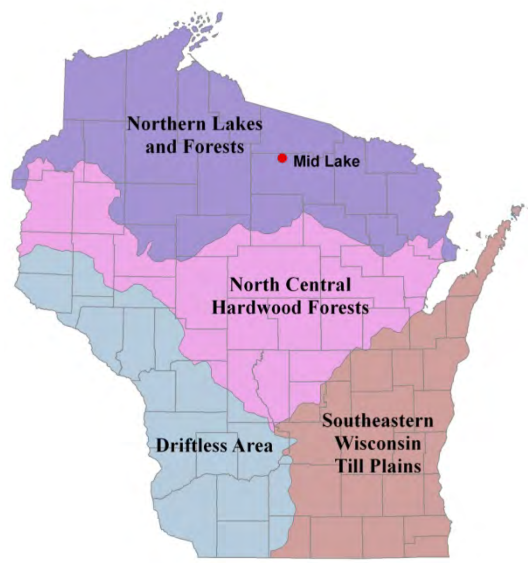

Figure 3.3-1. Location of Mid Lake within the ecoregions of Wisconsin. After Nichols 1999.

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.

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 Mid 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.

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.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900s 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 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

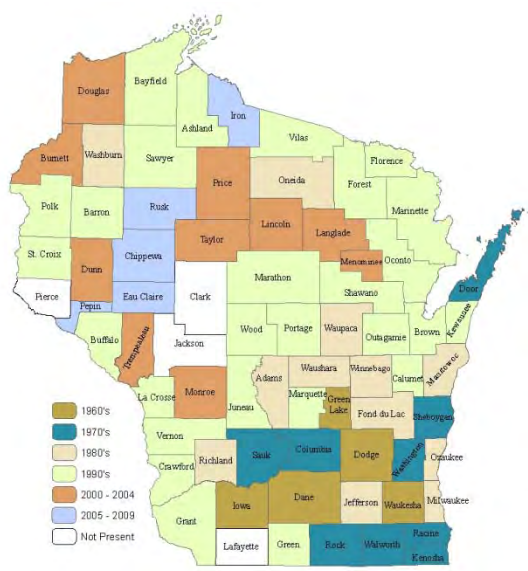

Figure 3.3-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2009 mapped by Onterra.

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. On June 19, 2008, a survey was completed on Mid Lake that focused upon curly-leaf pondweed. Numerous occurrences of this exotic plant were mapped during the survey (Map 5), with the largest area being located along the lake's western shore. Curly-leaf pondweed was considered to be the dominant plant within this entire area, with some larger areas of surface matting. Some smaller areas of curly-leaf pondweed were also mapped along the eastern and southeastern shorelines.

The median value is such 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.

The point intercept survey was conducted on Mid Lake on July 14, 2008 by Onterra ecologists. Additional surveys were completed by Onterra on Mid Lake to create the aquatic plant community maps (Map 3) during August 2008.

During the point-intercept and aquatic plant mapping surveys, 40 species of plants were located in Mid Lake (Table 3.3-1), three are considered non-native species: curly-leaf pondweed, purple loosestrife, and pale yellow iris. All three of these species are discussed in depth in a separate section below.

The invasive Eurasian water milfoil was not located in Mid Lake, but one native milfoil species, northern water milfoil (*Myriophyllum sibiricum*) was found. This species 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. Eurasian water milfoil is known to occur in nearby Tomahawk and Minocqua Lakes which have a direct connection to Mid Lake from the Thoroughfare that connects these lakes. Northern water milfoil does not exist in great abundance in Mid Lake, so it would be worth giving milfoil plants observed in new areas a second look as they could possibly be Eurasian water milfoil.

Mid Lake has a high number of aquatic plant species, and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influences its diversity. The diversity index for Mid Lake's plant community of 0.87 shows that the lake has a relatively even distribution (relative frequency) of plant species throughout the lake (Figure 3.3-3). Coontail, flat-stem pondweed, slender naiad, and fern pondweed were the most abundant species within the lake. As stated within the water quality section, Mid Lake is a productive, eutrophic system, and the abundance of these species is indicative of these conditions. With a mean depth of six feet, Mid Lake is a shallow lake, and over 98% of the point-intercept locations were within the depth range of aquatic plant growth (14 feet).

Table 3.3-1. Aquatic plant species located in Mid Lake during 2008 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)
Emergent	*Calla palustris**	Water arum	9
	*Dulichium arundinaceum**	Three-way sedge	9
	*Iris pseudacorus**	Pale yellow iris	Exotic
	*Juncus effusus**	Soft rush	4
	*Lythrum salicaria**	Purple loosestrife	Exotic
	*Pontederia cordata**	Pickerelweed	9
	*Sagittaria latifolia**	Common arrowhead	3
	*Schoenoplectus acutus**	Hardstem bulrush	5
	*Schoenoplectus tabernaemontani**	Softstem bulrush	4
	*Scutellaria galericulata**	Marsh skullcap	5
	*Typha latifolia**	Broad-leaved cattail	1
FL	*Brasenia schreberi*	Watershield	7
	Nuphar variegata	Spatterdock	6
	Nymphaea odorata	White water lily	6
	*Polygonum amphibium**	Water smartweed	5
FL/E	*Sparganium angustifolium**	Narrow-leaf bur-reed	9
	*Sparganium emersum**	Short-stemmed bur-reed	8
Submergent	*Ceratophyllum demersum*	Coontail	3
	*Chara sp.**	Muskgrasses	7
	Elodea canadensis	Common waterweed	3
	Heteranthera dubia	Water stargrass	6
	*Isoetes echinospora**	Spiny-spored quilwort	8
	*Megalodonta beckii**	Water marigold	8
	Myriophyllum sibiricum	Northern water milfoil	7
	Najas flexilis	Slender naiad	6
	Potamogeton amplifolius	Large-leaf pondweed	7
	Potamogeton crispus	Curly-leaf pondweed	Exotic
	*Potamogeton friesii**	Fries' pondweed	8
	Potamogeton illinoensis	Illinois pondweed	6
	Potamogeton illinoensis x gramineus	Illinois pondweed x Variable pondweed hybrid	NA
	Potamogeton praelongus	White-stem pondweed	8
	Potamogeton pusillus	Small pondweed	7
	Potamogeton richardsonii	Clasping-leaf pondweed	5
	Potamogeton robbinsii	Fern pondweed	8
	*Potamogeton strictifolius**	Stiff pondweed	8
	Potamogeton zosteriformis	Flat-stem pondweed	6
	Ranunculus aquatilis	White water-crowfoot	8
	Utricularia vulgaris	Common bladderwort	7
	Vallisneria americana	Wild celery	6
S/E	*Eleocharis acicularis**	Needle spikerush	5
	*Sagittaria cristata**	Crested arrowhead	9
FF	*Lemna minor*	Lesser duckweed	5
	Lemna trisulca	Forked duckweed	6
	*Spirodela polyrhiza**	Greater duckweed	5

FL = Floating Leaf
FL/E = Floating Leaf and Emergent
S/E = Submergent and Emergent
FF = Free Floating
* = Incidental

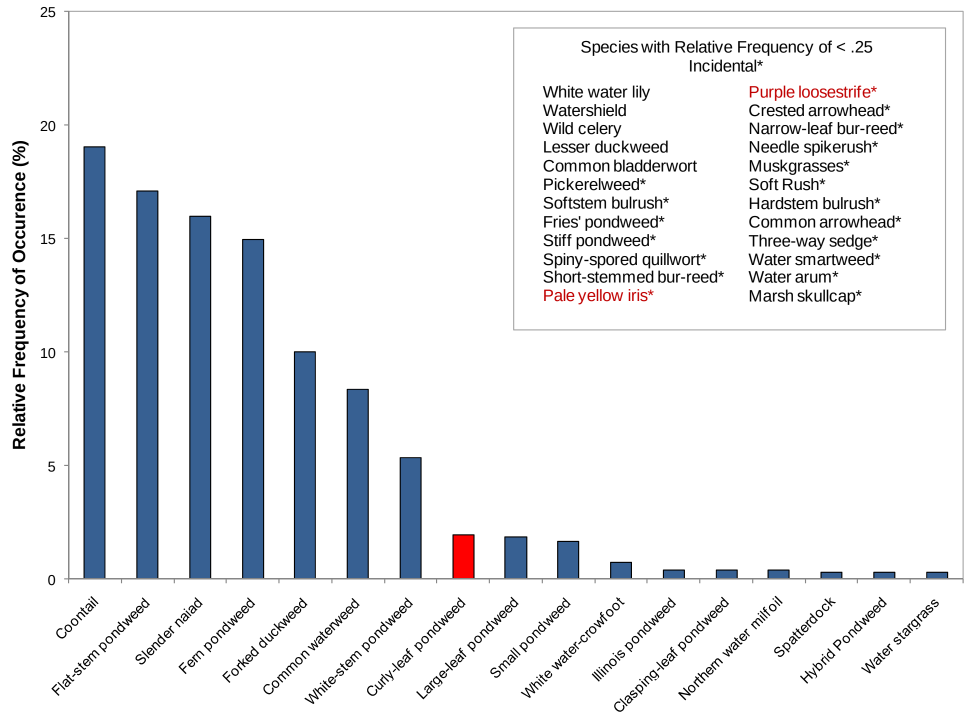

Figure 3.3-3 Mid Lake aquatic plant occurrence analysis. Created using data from July 2008 surveys. Exotic species indicated with red. Hybrid pondweed is Illinois pondweed x Variable pondweed.

During the surveys, excessive plant growth (native plants matting on the surface) was observed, particularly on the northern section of the lake. The high amount of nutrients within the water column, organic substrate, and shallow water probably all contribute to high amounts of plant biomass observed. Results from the stakeholder survey indicate that excessive aquatic plant growth is the primary concern facing the lake (Appendix B, Question 14), and 100% of respondents state that aquatic plant growth impacts their enjoyment on Mid Lake (Appendix B, Question 16). Over 94% believe that aquatic plant control is needed on Mid Lake (Appendix B, Question 17), and only 2 residents indicated that they were not at least moderately supportive of mechanical harvesting occurring on the lake (Appendix B, Question 18).

Data collected from the aquatic plant surveys indicate that the number of native plants in Mid Lake is higher than the state median and the Northern Lakes Ecoregion median (Figure 3.3-4). However, the average conservatism value (6.3) is slightly above the state median but slightly below the Northern Lakes Ecoregion media, demonstrating that while many species occur in the lake, many are indicative of a disturbed system. Combining the lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a high value of 39.8 (equation shown below); again, above the median values of the state and ecoregion (Figure 3.3-4).

FQI = Average Coefficient of Conservatism (6.3) * √ Number of Native Species (40)
FQI = 39.8

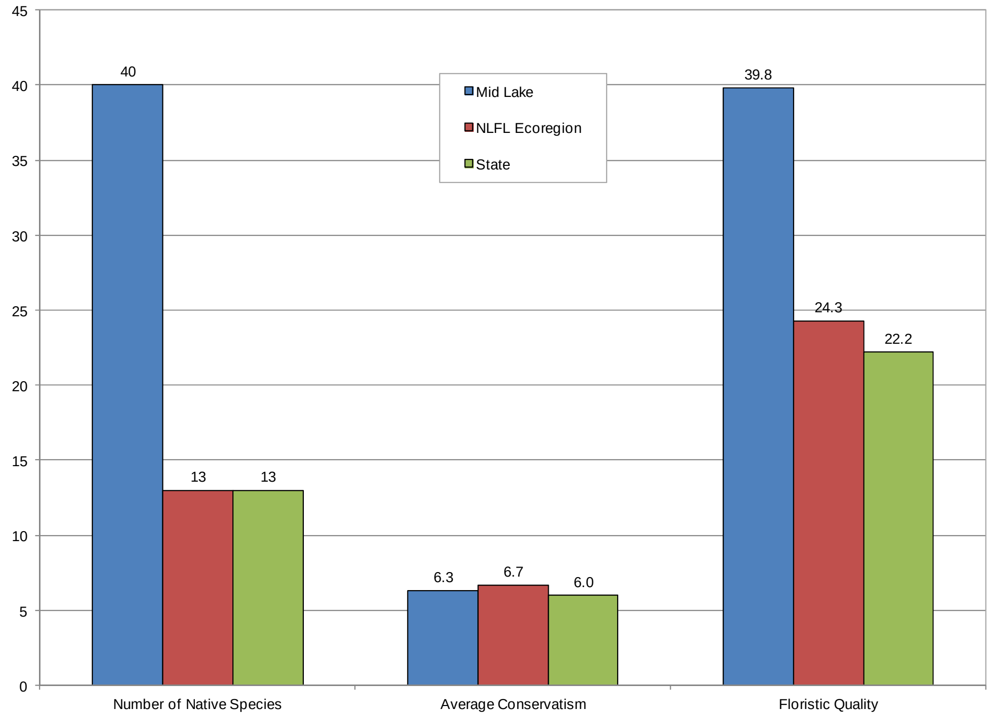

Figure 3.3-4. Mid Lake Floristic Quality Assessment. Created using data from July and August 2008 surveys. Analysis following Nichols (1999). Note that NLFL = Northern Lakes and Forest lakes after Nichols 1999.

This quality is also indicated by the high incidence of emergent and floating-leaf plant communities, particularly along the western and northern shorelines. The 2008 community map indicates that approximately 9.5 acres (4.2%) of the 225-acre lake contains these types of plant communities (Table 3.3-2, Map 3). Fifteen native floating-leaf and emergent species were located on Mid Lake, providing valuable fish and wildlife habitat important to the ecosystem of the lake.

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

Plant Community	Acres
Emergent	0.2
Floating-leaf	0.8
Mixed Floating-leaf and Emergent	8.5
Total	9.5

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 Mid 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.

Exotic Plants in Mid Lake

As described above, three invasive plant species were located within Mid Lake during this project's studies: curly-leaf pondweed, purple loosestrife, and pale yellow iris. Purple loosestrife and pale yellow iris were found in scattered locations along the shoreline of Mid Lake (Map 6). Both are wetland, emergent perennials native to Europe and were brought over to North America as ornamental garden plants. They have escaped from their garden landscapes and into wetland habitats where they out-compete our native plants for space and resources. Detailed discussion regarding the control of purple loosestrife will be discussed in the implementation plan.

Curly-leaf pondweed was first documented in Mid Lake during 2005, and is of particular concern when found growing in any lake, but even more when the lake in question uses mechanical harvesting to control nuisance native plant levels as this practice can potentially accelerate the exotic's spread. Curly-leaf pondweed produces turions in mid to late June before the plants themselves die back, and harvesting areas of curly-leaf pondweed during this period can potentially scatter these turions to other areas of the lake creating new colonies. As described in the Implementation Plan, harvesting areas of curly-leaf pondweed in May began in 2009 in an attempt to remove the plants before they began producing turions. It is the goal of this strategy to prevent future turion production and reduce the current turion base. A more detailed discussion of this curly-leaf pondweed control plan can be found in the Implementation Plan.

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) and the Great Lakes Indian Fish & Wildlife Commission (GLIFWC 2010). For some fisheries components, data was available not for Mid Lake, but was for other connecting lakes (Kawaguesaga, Minocqua and Tomahawk). For this section, Mid Lake and the three connecting waterbodies will be collectively referred to as the Minocqua Chain.

Table 3.4-1. Non-gamefish present in the Minocqua Chain (Becker, 1983).

Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name
Banded Darter	*Etheostoma zonale*	Ciscoes & Whitefishes	*Coregonus* & *Prosopium* spp.	Johnny Darter	*Etheostoma nigrum*
Blackchin Shiner	*Notropis heterodon*	Common Shiner	*Luxilus cornutus*	Logperch	*Percina caprodes*
Blacknose Shiner	*Notropis heterolepis*	Creek Chub	*Semotilus atromaculatus*	Mimic Shiner	*Notropis volucellus*
Bluntnose Minnow	*Pimephales promelas*	Fathead Minnow	*Pimephales promelas*	Mottled Sculpin	*Cottus bairdi*
Brassy Minnow	*Hybognathus hankinsoni*	Golden Shiner	*Notemigonus crysoleucas*	Ninespine Stickleback	*Pungitius pungitius*
Brook Stickleback	*Culaea inconstans*	Grass Pickerel	*Esox americanus vermiculatus*	Northern Redbelly Dace	*Phoxinus eos*
Burbot	*Lota lota*	Hornyhead Chub	*Nocomis biguttatus*	Pearl Dace	*Margariscus margarita*
Central Mudminnow	*Umbra limi*	Iowa Darter	*Etheostoma exile*	White Sucker	*Catastomus commersoni*

Table 3.4-2. Gamefish present in the Minocqua Chain with corresponding biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near Chara or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other inverts
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 205 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 pikes, 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 (ter. and aq.)
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1cm-1m deep	Crustaceans, insect larvae, and other inverts
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)
Walleye	*Sander vitreus*	18	Mid April – Early May	Rocky, wave-washed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
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 vegetation	Small fish, aquatic invertebrates

Mid Lake Fishing Activity

Based on data collected from the stakeholder survey fishing was the third highest ranked important or enjoyable activity on Mid Lake (Appendix B, Question #9). The majority of survey respondents stated that the quality of fishing on Mid Lake is "fair" (54%) and has remained this way since their property was purchased (64%) (Appendix B, Question #6 and #7). Survey respondents did however express concern over the loss of fish habitat (Appendix B, Questions #14 and #15).

Tables 3.4-1 and 3.4-2 (above) show the popular game fish and non-game fish that are present in the Minocqua Chain. As previously stated, residents of Mid Lake are fairly concerned over loss of fish habitat, which may be a result of excessive plant growth (both native and non-native). 100% of the responding stakeholders stated that aquatic plant growth sometimes or always impacts their enjoyment of Mid Lake (Appendix B, Question #16). Furthermore, 94% believe aquatic plant control is needed (6% were unsure) on the lake (Appendix B, Question #17). With all actions that are taken to address plant growth in Mid Lake, it will be important to understand the potential impacts they 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 plant management, as this could eliminate nursery areas for the emerged fry of these species. Muskellunge is another species that may be impacted by early season actions as water temperatures and spawning locations often overlap. The current Implementation Plan for the management of aquatic plant growth calls for mechanical harvesting of plants (native and non-native) in select areas of Mid Lake. The plan specifies that harvesting is to begin after June 1st in areas with only native plant growth, which would allow the vast majority of fish species to complete their spawning season. To control curly-leaf pondweed, harvesting is scheduled to occur earlier in the year, in strictly defined areas. An open water conservation area along the northern shoreline of Mid Lake consisting of approximately 13 acres is off-limits to mechanical harvesting. Please see the Implementation Plan for more details on this aquatic plant control strategy.

Figure 3.4-1. Location of Mid Lake within the Native American Ceded Territory (GLIFWC 2009). This map was digitized by Onterra; therefore it is a representation and not legally binding.

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 10). Mid 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. Studies suggest that up to 35% of a lake's walleye population and 20% of a muskellunge population can be removed annually without adverse affects. Each year, a "Safe Harvest" level is set at 35% of the walleye population and 20% of the muskellunge population. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. In late winter, the six Wisconsin Chippewa Bands declare their intent to harvest a tribal quota. The tribal quota is a portion of the safe harvest. Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal quota and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. In 2010, Chippewa bands declared approximately 40% of the walleye safe harvest on Minocqua, Tomahawk and Little Tomahawk Lakes, resulting in 3-walleye daily bag limits and 77% of the safe harvest on Mid and Kawaguesaga Lakes, resulting in 2-walleye daily bag limits. Mid Lake was not speared and the bag limit was revised to 5 fish prior to Memorial weekend.

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. 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.

Estimated safe harvests for both muskellunge and walleye are displayed in Table 3.4-3 for the lakes on the Minocqua Chain for 2009 and 2010. Although Mid Lake has been declared as a spear harvest lake, it has historically never seen a harvest. However spearing does occur on the other connected lakes of the chain. Walleye open water spear harvest records for these lakes are provided in Table 3.4-4. One common misconception is that the spear harvest targets the large spawning females. Table 3.4-4 and Figure 3.4-2 clearly show that the opposite is true with only 8.4% (551 out of 6,567) of all harvested and sexed walleyes since 1998 comprising of female fish on the Minocqua Chain . 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. This regulation limits the harvest of the larger, spawning female walleye.

Table 3.4-3. Estimated safe harvests for muskellunge and walleye for the Minocqua Chain in 2009 and 2010. The table summarizes safe harvest estimates (not actual harvests) calculated for Kawaguesaga, Mid, Minocqua and Tomahawk Lakes. (GLIFWC annual reports for Kawaguesaga, Krueger 1998-2007).

Lake	2009 Muskellunge Safe Harvest	2010 Muskellunge Safe Harvest	2009 Walleye Safe Harvest	2010 Walleye Safe Harvest
Kawaguesaga	16	16	256	279
Mid	8	8	12	9
Minocqua	25	25	504	339
Tomahawk	42	43	365	529
Total	*91*	*92*	*1,137*	*1,156*

Table 3.4-4. Spear harvest data of walleye for the Minocqua Chain. The table summarizes spearing efforts that have taken place on Kawaguesaga, Minocqua and Tomahawk Lakes combined. (GLIFWC annual reports for the Kawaguesaga, Minocqua and Tomahawk Lakes, Krueger 1998-2007).

Year	Tribal Quota	Tribal Harvest	% Quota	% Male*	% Female*	% Unknown*
1998	1,142	1,127	98.7	81.3	4.1	14.5
1999	894	894	100.0	74.2	13.9	12.0
2000	766	767	100.1	80.0	9.7	10.3
2001	691	653	94.5	76.3	9.9	13.8
2002	654	640	97.9	85.6	6.2	8.2
2003	864	860	99.5	78.0	11.2	10.7
2004	808	808	100.0	84.4	11.4	4.2
2005	1,164	1,155	99.2	65.6	6.5	27.9
2006	756	756	100.0	68.9	4.5	26.6
2007	629	635	101.0	70.2	6.0	23.8

**Based on Total Sexed*

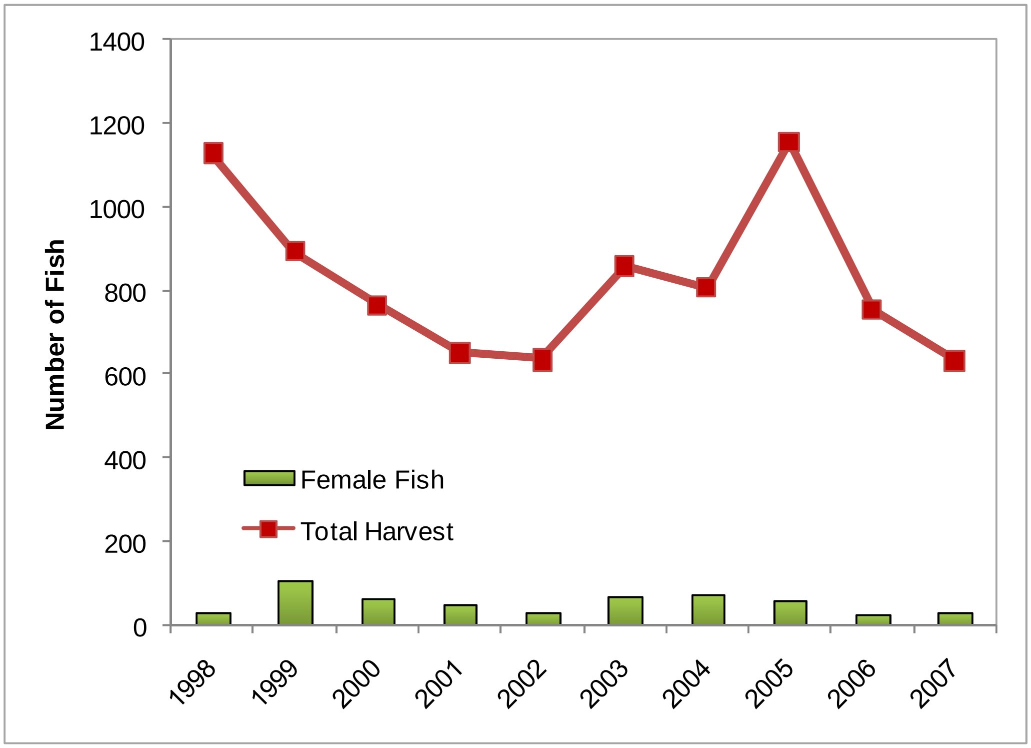

Figure 3.4-2. Minocqua Chain walleye spear harvest data. Annual total walleye harvest and female walleye harvest are displayed since 1998 from GLIFWC annual reports for Kawaguesaga, Minocqua and Tomahawk Lakes (Krueger 1998-2007).

Table 3.4-5. Spear harvest data of muskellunge for the Minocqua Chain. The table summarizes spearing efforts that have taken place on Kawaguesaga, Minocqua and Tomahawk Lakes combined. (WDNR Northern Region, 1989-1997 & 2008 and GLIFWC annual reports for Kawaguesaga, Minocqua and Tomahawk Lakes, Krueger 1998-2007).

Year	Tribal Quota	Tribal Harvest	% Quota
1998	39	14	35.9
1999	39	16	41.0
2000	38	22	57.9
2001	39	11	28.2
2002	38	17	44.7
2003	38	18	47.4
2004	37	17	45.9
2005	43	14	32.6
2006	40	25	62.5
2007	42	20	47.6

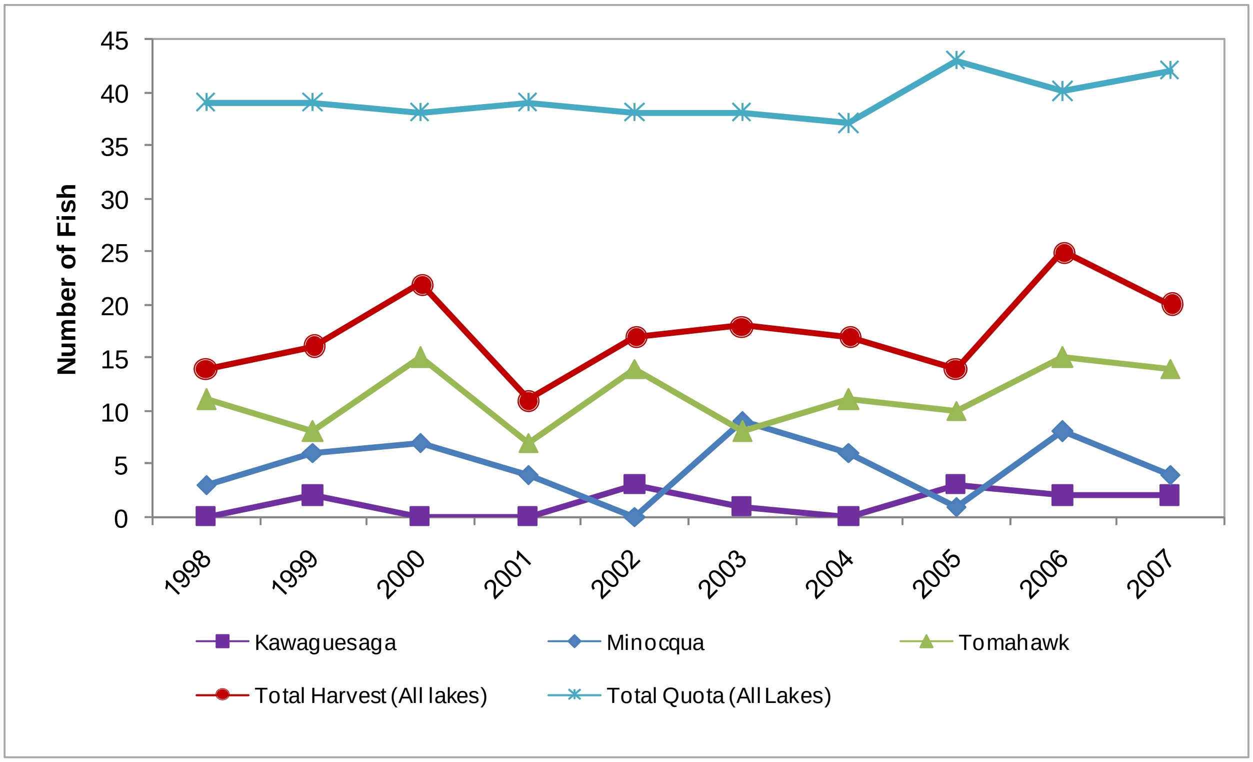

Figure 3.4-3. Minocqua Chain muskellunge spear harvest data. Annual total open water muskellunge harvest is displayed since 1998 from GLIFWC annual reports for Kawaguesaga, Minocqua and Tomahawk Lakes, as well as the Minocqua Chain (all lakes combined). The total tribal declared quota for the Minocqua Chain is also displayed. (Krueger 1998-2007).

Table 3.4-5 (above) displays the Native American open water muskellunge spear harvest since 1998. Tribal muskellunge spearing declarations are based upon a safe harvest estimate, as is with walleye. Tribal declarations are typically below 60% of this estimate, which results in no change in angler regulations. Since this time, approximately 17 muskellunge per year have been harvested during the open water fishery. In most years, the majority of this harvest is taken from the largest lake of the Minocqua Chain, Tomahawk Lake (Figure 3.4-3). Only twice in the past 10 years (2000 & 2006) has the total harvest of muskellunge exceeded 50% of the declared quota for the Minocqua Chain (Figure 3.4-3).

As stated above, Mid Lake is located within ceded territory and special fisheries regulations for walleye and muskellunge may occur if the lake receives tribal declaration. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which would explain the more restrictive bag or length limits for the lake. There are currently no special regulations on Mid Lake, allowing for 5 walleye to be harvested per day and 1 muskellunge greater than 34 inches to be harvested per day.

Mid Lake Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fish in a waterbody that were raised in nearby permitted hatcheries. Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Fish can be stocked as fry, fingerlings or even as adults.

The WDNR has stocked both walleye and muskellunge in Mid Lake, though not in recent history. Nearby lakes in the Minocqua Chain have been stocked as well. Table 3.4-6 displays historic stocking that has taken place in Mid Lake, while additional stocking data of Kawaguesaga, Minocqua and Tomahawk Lakes can be viewed in Appendix F (WDNR 2010).

Table 3.4-6. Fish stocking data from Mid Lake available from the WDNR from 1972 to present. Data from WDNR 2010. Please see Appendix F for stocking efforts in Kawaguesaga, Minocqua and Tomahawk Lakes.

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Muskellunge	Fingerling	467	13
1974	Muskellunge	Fingerling	717	8
1977	Muskellunge	Fingerling	600	9
1979	Muskellunge	Fingerling	433	8.67
1983	Muskellunge	Fingerling	400	10
1984	Muskellunge	Fingerling	350	12
1986	Muskellunge	Fingerling	400	10.33
1988	Muskellunge	Fingerling	526	10
1990	Muskellunge	Fingerling	400	10
1992	Muskellunge	Fry	44,500	1
1997	Muskellunge	Fry	25,000	0.5
1975	Walleye	Fry	1,000,000	N/A
1976	Walleye	Fingerling	10,000	3

Fish Population Estimates

To gain information on the abundance of gamefish species in a lake, managers will often conduct studies to formulate a population estimate. A common method of assessing the fish population is through a mark-recapture study. Although variations of the technique exist, the basic mark-recapture process involves capturing fish on one occasion, marking the individual fish with a unique identifier (harmlessly clipping a fin is a common technique), and releasing the fish back into the lake. The researcher will return to sample the fish population again, noting fish that are recaptured with the unique identifier as well as fish captured for the first time. Following a mathematical analysis, a reliable estimate of the population is able to be made. Table 3.4-7 displays WDNR walleye population estimates for lakes in the Minocqua Chain. Please note that the Tomahawk Lake data is provided from two different sources.

Table 3.4-7. Walleye population estimates for lakes in the Minocqua Chain. (WDNR 2010 and GLIFWC 2010).

Waterbody	Year	Source	Population Estimate	Number / Acre
Kawaguesaga Lake	1992	WDNR	2,973	4.4
	1998	WDNR	3,495	5.2
	2009	WDNR	2,274	3.4
Mid Lake	1992	WDNR	191	0.9
Minocqua Lake	1992	WDNR	7,638	5.6
	1998	WDNR	6,276	4.6
	2009	WDNR	2,764	2.0
Tomahawk Lake	1992	WDNR	8,437	2.5
	1998	WDNR	8,508	2.5
	2000	GLIFWC	5,086	1.4
	2002	GLIFWC	8,671	2.4
	2004	GLIFWC	7,845	2.2
	2009	WDNR	4,321	1.3

In 2003, WDNR biologists conducted a baseline fisheries survey on Mid Lake. Fourteen species were captured between an August and October sampling event. Bluegill were the most abundant species caught, and young-of-the-year largemouth bass were also relatively abundant in the lake. The survey highlights are displayed in Appendix G in the form of an information sheet drafted by John Kubisiak of the WDNR.

YOY Walleye surveys in the Minocqua Chain of Lakes

GLIFWC, in cooperation with the United States Fish and Wildlife Service (USFWS) and WDNR, has monitored age 0 (young of the year) and age 1 (yearling) walleyes to assess the level of recruitment that is occurring. Sampling is done in the fall of each year using an electofishing boat, which samples the shoreline during the night hours when young walleyes move to the littoral zone to feed. Figure 3.4-4 summarizes boomshocking efforts on Kawaguesaga, Minocqua and Tomahawk Lakes (GLIFWC 2010). The decreasing abundance of YOY depicted by the GLIFWC surveys is comparable to survey information collected by the WDNR (see Appendix H, Figure 2). In a report published in March 2010, fisheries biologist John Kubisiak noted that despite good spawning habitat and natural recruitment, YOY walleye in Tomahawk Lake, the largest of the Minocqua Chain of Lakes, are heavily impacted by the presence of cisco. Cisco are known to prey upon YOY walleye and compete with walleye fry. However, they are also an important forage fish for adult walleye and muskellunge. Because cisco inhibit the natural reproduction of walleye in Tomahawk Lake, WDNR fish biologists recommend supplemental stocking of walleye here. For additional fisheries information collected by WDNR biologists on the Minocqua Chain, see Appendix H.

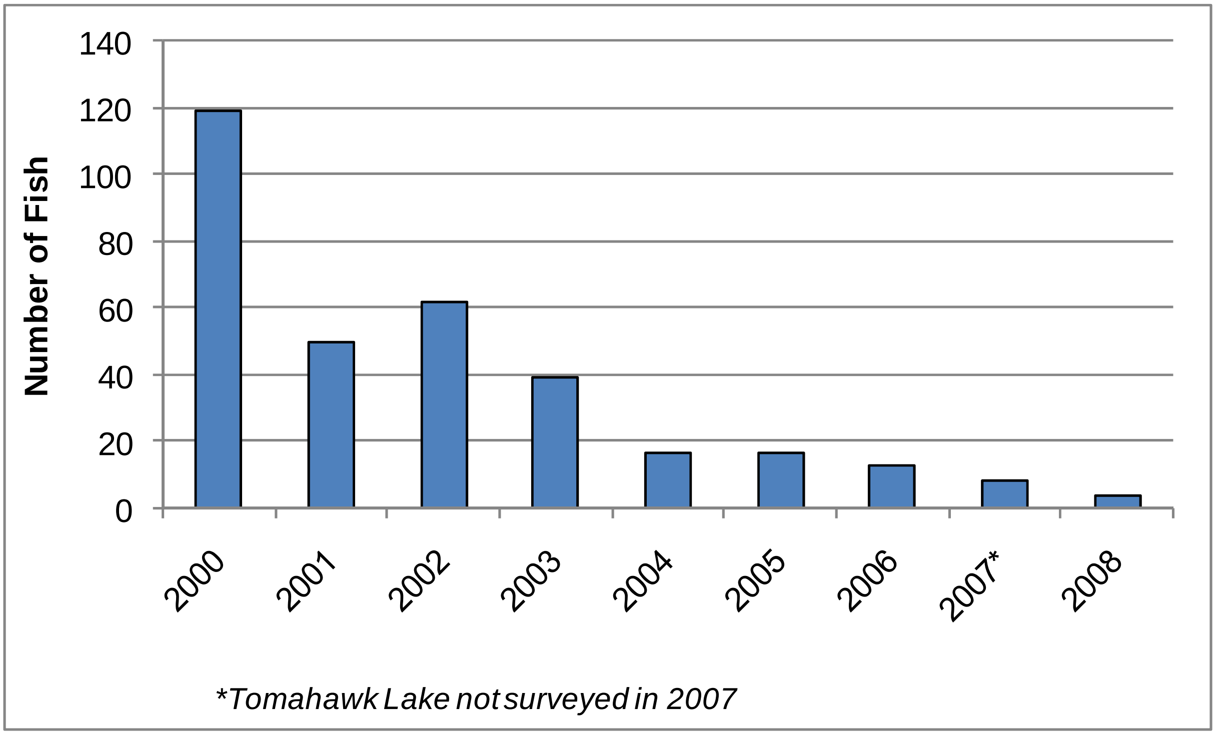

Figure 3.4-4. Walleye YOY boomshocking surveys of the Minocqua Chain of Lakes. Annual surveys target age 0 and age 1 walleyes, and were conducted on Kawaguesaga, Minocqua and Tomahawk Lakes (GLIFWC 2010).

Mid Lake Substrate Type

According to the point-intercept survey conducted by Onterra in 2008, the vast majority of the substrate sampled in the littoral zone on Mid Lake was muck (99.6%). 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. 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 the eggs 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.

Because of the high abundance of aquatic vegetation and mucky sediments, the fishery of Mid Lake is likely always going to consist of panfish, bass, and northern pike. John Kubisiak, has stated that winter decomposition of aquatic plants has historically produced relatively small fish kills all the way back to the 1960s. An aeration system may be of some benefit to the system, though Mr. Kubisiak believes the costs likely outweigh the potential benefits achieved from such a system. These events largely affect smaller size classes of less tolerant fish species, and larger gamefish are usually affected to a much smaller degree. In fact, smaller winterkills may help the fishery because as the overall biomass decreases it may allow for an increase in individual growth rates.

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 Mid Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on curly-leaf pondweed.
3) Collect sociological information from Mid Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

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

Forty native aquatic plant species were found during the summer 2008 survey - an outstanding level of species richness when compare to other lakes within the state and to lakes within the Northern Lakes and Forests ecoregion. With an average conservatism value of 6.3, the plant community of Mid Lake is comprised of species that can tolerate disturbance and not those found in more pristine environments. Some likely forms of disturbance on the system include maintenance of unnatural water levels, high recreational use, aquatic invasive species, and mechanical harvesting.

The establishment of a large and diverse population of native plant species likely has made it difficult for Eurasian water milfoil to take residence in Mid Lake. Large established populations of this exotic species are present in the other lakes of the Minocqua Chain and have ongoing large-scale (and costly) management actions occurring on them to reduce their populations. Mid Lake has the ability to support a large amount of aquatic plants. If Eurasian water milfoil becomes established in Mid Lake, the nuisance plant problems that the district currently deals with will seem quite small in comparison.

As discussed in many of the sections above, nuisance levels of native aquatic plants within Mid Lake ultimately spurred the MLPRD (Mid Lake Protection & Rehabilitation District) to initiate this planning effort. The WDNR requires that lakes conducting large-scale manipulations, like mechanical harvesting, update their management plan to the latest standards every 5-7 years. As addressed in the aquatic plant section, Mid Lake is a highly productive system that supports a large biomass of aquatic plants. The MLPRD has been controlling nuisance levels of aquatic plants on Mid Lake for over 30 years. Mechanical harvesting began during the early 1980's, but before that the plants were controlled using herbicide applications. The district purchased a mechanical harvester approximately 15 years ago with financial aid from the WDNR and the Town of Woodruff.

The MLPRD has developed a harvesting plan that utilizes common-use navigation channels to provide riparians with access to deeper parts of the lake and to the Thoroughfare the leads to the other lakes of the chain. Valuable emergent and floating-leaf plant communities are not harvested, as well as a large open water conservation area along the northern part of Mid Lake.

One common objection to mechanical harvesting is this technique's tendency to spread aquatic invasive species around a lake. At this time, Mid Lake only contains one submergent aquatic invasive species: curly-leaf pondweed. Although its presence was known since approximately 2005 this species has rapidly spread around much of the western part of the lake – especially near the harvester off-load location (Map 5). A past and current condition of the MLPRD's *native* harvesting permit is to not harvest within areas that contain aquatic invasive species. Please note that the nuisance native aquatic plant harvesting permit is different than the curly-leaf pondweed experimental control program, which is described within Management Goal 3 of the Implementation Plan.

Although it is likely that the harvester has accelerated the spread of this species within Mid Lake, it is now being utilized as a tool to reduce curly-leaf pondweed's occurrence within the lake. A properly timed, early-season harvest of curly-leaf pondweed has been established in which this plant is harvested prior to producing its asexual reproductive structures (turions). Functioning largely as an annual plant, it will take numerous years before the turion bank has been exhausted from Mid Lake. The MLPRD understand that in order to continue this experimental approach, continued monitoring would be a condition of the harvesting permit. After harvesting activities occurred in 2009, plant surveys located curly-leaf pondweed in additional parts of the Mid Lake. Map 7 shows the 2010 early-season harvesting plan in which these locations area also targeted for control.

Because the lake contains a large biomass of aquatic plants, very low oxygen levels have been documented during the winter. The decomposition of plant material over the winter depletes the oxygen within the lake. These anoxic conditions have the ability to cause minor fishkills, as observed in 2009 when dead fish washed up on the shores after ice-out. WDNR fisheries biologist, John Kubisiak, noted that partial fishkills have been documented on Mid Lake since the 1960s. He is not concerned about this phenomenon, as many large gamefish likely detect the low oxygen levels and migrate to other parts of the chain. Aeration systems can be used to alleviate this problem, but the cost of these systems and the dangers associated with open water on the lake during the winter may outweigh the benefits.

With the limited amount of historic data, no long term trend analysis could be conducted. Phosphorus concentrations hover around 30 µg/L, on the edge of being considered *Good* or *Fair* based on Lillie & Mason's Apparent Water Quality Index. Macrophytic plant growth dominates the lake's plant community, allowing the lake to maintain its water clarity and remain in a 'clear state'. In the past, when algal biomass dominated the plant community, water clarity was much worse and the lake was considered to be in a 'turbid state'.

In 2008, professional surveys found large amounts of curly-leaf pondweed within Mid Lake. That summer, chlorophyll-*a* averaged over 20 µg/L, more than twice the levels observed in any other year. Water clarity values also dropped to below 4 feet, approximately 2 feet less than the average of all years with available data. In lakes with dense curly-leaf pondweed occurrence, the water quality of the lake can be affected following the die-off of this species in late June/early July. It is possible that the senescence of this plant increased phosphorus levels in the system, keeping Mid Lake in a semi-turbid state for the remainder of the season. However, it must be noted that this analysis is made with very limited data and in actuality, the increase in phosphorus and chlorophyll-*a* may just be the result of fluctuations brought on by other environmental circumstances.

Mid Lake has a relatively small watershed draining to it. Another positive of the Mid Lake watershed is that the majority (72%) is comprised of forest, the best land cover type for the health of the lake. But because Mid Lake was likely an emergent/shallow wetland in years past, the addition of the dam likely turned a naturally productive wetland into a moderately productive lake. A major source of the nutrients that support the plant and algae growth of Mid Lake are likely from internal nutrient dynamics from decaying plants and nutrient rich sediments within the lake. Watershed improvement efforts should be aimed at reducing the impacts of the properties along the immediate shoreline. The MLPRD plans on conducting a shoreline assessment at the time of their next updated management planning effort to evaluate and prioritize areas for restoration and conservation.

Overall, Mid Lake is good condition. At this time, the most pressing issues facing the lake consist of reducing the curly-leaf pondweed population, ensuring that Eurasian water milfoil does not establish within the lake, and reducing the near-shore impacts of riparian properties. The fact that Mid Lake is located in the middle of a large chain of lakes is going to be one of the largest management difficulties. Particular to aquatic invasive species control, its position within the chain will continually expose the lake to these species. A partnership and line of communication between the connected waterbodies needs to be established to ensure that management strategies dovetail and the health of the entire waterbody is considered.

5.0 IMPLEMENTATION PLAN

The intent of this project was to complete a comprehensive management plan for Mid Lake. As described in the proceeding sections, a great deal of study and analysis were completed involving many aspects of the Mid Lake ecosystem. This section stands as the actual "plan" portion of this document as it outlines the steps the Mid Lake Protection and Rehabilitation District will follow in order to manage Mid Lake, its watershed, and the district itself.

The implementation plan is broken into individual Management Goals. Each management goal has one or more management actions that if completed, will lead to the specific management goal in being met. Each management action contains a timeframe for which the action will be taken, a facilitator that will initiate or carry out the action, a description of the action, and if applicable, a list of prospective funding sources and specific actions steps.

Management Goal 1: Maintain Current Water Quality Conditions

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

Timeframe: Continuation of current effort.

Facilitator: Roger Smith

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. Early discovery of negative trends may lead to the reason as of why the trend is developing. Volunteers from the MLPRD have collected Secchi disk clarities and water chemistry samples during the past through the WDNR Citizen Lake Monitoring Program. A set of volunteers would be solicited from the MLPRD to collect water quality samples on the lake. 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.

Winter dissolved oxygen levels were shown to be quite low on Mid Lake. If increasing concerns about these levels exist within the MLPRD, the district should purchase a dissolved oxygen probe. This would allow this parameter to be monitored in conjunction with the regularly scheduled CLMN water sample collection.

Action Steps:

Please see description above

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

Timeframe: Begin 2010

Facilitator: Education Committee

Description: As the watershed section discusses, the Mid 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 starting in April 2010. Phosphorus containing fertilizers were identified as a major contributor to decreasing water quality conditions in lakes, fueling plant growth. 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 association 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, Oneida County, and other sources.
3. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for association meetings.

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

Timeframe: Next Management Plan Update

Facilitator: Board of Directors

Description: As 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 Mid 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 debris, a fisheries habitat component lacking around the shores of Mid Lake. Shoreline enhancements would include leaving 30-foot no-mow zones or by planting native herbaceous, shrub, and tree species as appropriate for Oneida County.

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 2: Maintain Navigation in Open Water and Near-shore Areas on Mid Lake

Management Action: Use district-owned mechanical harvester to maintain reasonable navigation on Mid Lake.

Timeframe: Ongoing

Facilitator: Mid Lake P & R District Board of Directors

Description: The purpose of the harvesting is to allow navigability in certain areas of the lake that contain dense, nuisance levels of native aquatic plants. Map 4 shows the mechanical harvesting plan that was developed in conjunction with Onterra ecologists, WDNR staff, and district members. A single 60-foot common use lane follows the shoreline where riparian properties exist and connects to a 100-foot lane beginning at the mouth of Mid Lake at the connection to the thoroughfare and extends to deeper water where plants do not hinder navigation.

The harvesting activities normally start in early June and continue throughout the summer until early September. The district understands the importance of Mid Lake as a muskellunge spawning refuge for the connecting waterbodies (Tomahawk, Minocqua, and Kawaguesaga Lakes) and therefore does not start harvesting until after the spawning season (approximately after June 1st). An approximately 13 acre open water conservation area in the northern part of the lake was also established where no harvesting activities will occur. Harvesting activities are also not to occur in the approximately 9.4 acres of emergent and floating-leaf plant communities that occur near the lake's margins.

The Mid Lake District has purchased a GPS unit capable of supporting base maps created by Onterra. Essentially, a background map of the harvesting areas will be loaded on the GPS unit allowing the harvester operator to know exactly where they are in relation to the permitted harvest lanes. This technology was utilized starting in 2009. A track log continually displaying the actual harvester path is recorded on the GPS and can be provided to the WDNR if requested. These data may also be useful in understanding areas where increased frequency of harvesting is needed each year.

The abundance of largely non-rooted plants such as coontail and common waterweed within the system produce large floating mats of these species in many areas of the lake. In the past, the WDNR has allowed the district to pick up these *floaters* using the mechanical harvester in its shallowest setting (approximately 6 inches below the water). This type of activity would not occur within the open water conservation area nor areas where emergent and floating-leaf plant communities occur.

Mechanical harvesting activities have the ability to spread aquatic invasive species throughout a lake. Harvesting activities will not occur if Eurasian water milfoil or curly-leaf pondweed is found within the harvest areas.

Action Steps:

1. District applies for a multiyear harvesting permit (3 year).
2. District obtains written permission to utilize state-owned lands for harvester off-loading and parking during that timeframe.
3. District harvests in areas shown on Map 4 while following the plan listed above and restrictions indicated on WDNR permit.
4. Harvest summary report is provided to the WDNR annually after each harvesting season.

Management Goal 3: Control Aquatic Invasive Species within Mid Lake

Management Action: Control curly-leaf pondweed infestation on Mid Lake.
Timeframe: Initiated in 2009
Facilitator: Planning Committee with professional help as needed
Description: Curly-leaf pondweed was first located in Mid Lake in 1979. A single herbicide treatment occurred in 2005, successfully controlling a single year's growth of curly-leaf pondweed. Although the advice of the herbicide applicator was to retreat the area again in 2006 and likely for 3-4 years, future surveys by the district's consultant at that time failed to locate curly-leaf pondweed; therefore no additional treatments occurred.

Traditionally, curly-leaf pondweed control consists of numerous annual herbicide treatments conducted in May of each year. This will kill each year's plants before they are able to produce reproductive turions (asexual seed-like structures). After multiple years of treatment, the turion base becomes exhausted and the curly-leaf pondweed infestation becomes significantly less. Normally a control strategy such as this includes 3-5 years of treatments of the same area.

Surveys competed in June 2008 showed that curly-leaf pondweed has spread to many areas of the lake since 2005, especially just south of Grundy Point where the harvester off-loading site is located. In 2008, the district was advised to hold off on harvesting the densest areas to minimize the accelerated spread of curly-leaf pondweed to new areas. The harvesting of curly-leaf pondweed was also prohibited by the district's harvesting permit.

Over the winter of 2008-09, with cooperation from the WDNR, a control strategy was developed to reduce curly-leaf pondweed occurrences within the lake. Utilizing the district's mechanical harvester, an early-season harvesting strategy aimed at cutting curly-leaf pondweed before turion production occurs and continuing until the middle of July, when this plant begins to die back, was implemented (Map 5). The WDNR extended additional grant funds to the district under their existing Lake Planning Grants to help cover the costs of monitoring this experimental approach to curly-leaf pondweed management in 2009.

The objective of this management action is not to eradicate curly-leaf pondweed from Mid Lake, as that would be impossible. The objective is to bring curly-leaf pondweed down to more easily controlled levels. In other words, the goal is to reduce the amount of curly-leaf pondweed in Mid Lake to levels that may be suitable for smaller harvest areas to keep the exotic under control. To complete this objective efficiently, a cyclic series of steps is used to plan and implement this control strategy. Even though the district will be seeking a multi-year harvesting permit, annual revisions to this plan will need to be approved by the WDNR in the manner outlined below. The series includes:

1. A lake-wide assessment of curly-leaf pondweed completed while the plant is at peak biomass (late June).
2. Creation of early-season harvesting areas for the following spring based upon the peak biomass survey results are submitted to the WDNR in the form of a conditional harvesting permit.
3. Verification and refinement of early-season harvest areas immediately before harvesting occurs. Quantitative monitoring would occur at this time as well (see explanation below).
4. Updated harvest areas submitted to the WDNR to serve as the final harvesting permit.
5. Completion of harvesting activities.

Once Step 5 is completed, the process would begin again that same summer with the completion of a peak biomass survey. The survey results would then be used to create the next spring's treatment strategy.

Obviously, monitoring is a key aspect of the cycle, both to create the treatment areas and monitor the action's effectiveness. The monitoring would also facilitate the "tuning" or refinement of the control strategy as the control project proceeds. It must be remembered, that this portion of the management plan (control plan) would be intended to span approximately 3-6 years before it would need to be updated to account for changes within the ecosystem. The ability to tune the control strategies is important because it allows for the best results to be achieved within the plan's life span.

In addition to refining each year's early-season harvest areas, a quantitative sub-sampling of select proposed early-season harvest areas would be completed during the spring survey. Monitoring would occur during early spring following a protocol currently being developed by the WDNR, and in general, would use guidance supplied in <u>Aquatic Plant Management In Wisconsin</u> (2007) and <u>Pre and Post AIS Chemical Herbicide Treatment Monitoring (Draft)</u> (April 2008). In general, control areas would be quantitatively monitored before and after treatments through the use of a modified point-intercept based survey. At each point, we would complete one rake tow and if curly-leaf pondweed is located, estimate its abundance on the rake using a scale of 1-3. Depth and substrate would also be noted for each point. These data would then be used for comparisons with similar data collected after the treatment.

Quantitative sampling would be conducted the spring just previous to the treatment (pretreatment) and the spring following the treatment (post treatment).

Because of the early senescence of this species, a post treatment survey a few weeks following the treatment would not differentiate if a reduction in occurrence can be attributed to the herbicide application or the natural die-off of this species.

Project Funding Assistance

The above plan was implemented in 2009 and funded by amending the Lake Planning Grants already awarded to the district. Costs associated with the post treatment monitoring of the 2009 control plan (spring 2010) were not included within the above mentioned grant amendment.

Funds from the Wisconsin Department of Natural Resources Aquatic Invasive Grant Program will be sought to partially fund this control program and other elements of this management plan. Specifically, funds would be applied for under the Established Population Control Project classification and/or the Education, Planning, and Prevention classification.

Action Steps:

1. Retain qualified professional assistance to develop a specific project design utilizing the cyclic series of steps discussed above.
2. Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3. Initiate control plan.
4. Revisit control plan in 3-6 years.
5. Update management plan to reflect changes in control needs and those of the lake ecosystem.

<u>Management Action:</u> Initiate *modified* Clean Boats Clean Waters watercraft inspections at Mid Lake public access

Category: Prevention & Education

Timeframe: In progress

Facilitator: Planning Committee

Description: At this time, Eurasian water milfoil has not been located from Mid Lake. However, control strategies exist on the other lakes of the chain to combat established populations of this species. Initiating a modified program of watercraft inspections based upon the WDNR Clean Boats Clean Waters program will help to reduce the chance that Eurasian water milfoil and other aquatic invasive species would be introduced to the lake; and help to ensure that aquatic invasive species present in Mid Lake do not get spread to other nearby lakes.

While Mid Lake does have a single boat landing (Grundy Point), this access point is rarely used, especially by those that do not own property on the lake. The majority of the access to Mid Lake is from the thoroughfare that connects Lake Tomahawk to Kawaguesaga and Minocqua Lakes. With many access locations on the chain, members of the MLPRD should focus on monitoring the boat landing located on the thoroughfare. It is also likely that existing Clean Boats Clean Waters programs initiated by the chain's other lake groups do not encompass this landing.

Since the majority of access to Mid Lake is from the Thoroughfare, placing informative signage at this juncture may raise awareness about aquatic invasive species. In addition to alerting transient boaters entering Mid Lake to make sure they are not transporting aquatic invasive species (especially plant species), the signage would also be displayed for those boaters leaving Mid Lake informing them that they are exiting a curly-leaf pondweed infested waterbody and should not transport this species to other areas of the chain. Currently slow-no-wake signs exist at this location, but communication with WDNR personnel in regards to placing signage at this location would need to occur before the action is initiated.

Action Steps:

1. Members of association attend Clean Boats Clean Waters training session.
2. Training of additional volunteers completed by those trained during the summer of 2010.
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: Coordinate annual volunteer monitoring of Aquatic Invasive Species
Timeframe: Ongoing
Facilitator: Planning 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. Volunteers would monitor the entire area of the lake in which plants grow (littoral zone) annually to locate occurrences of Eurasian water milfoil as well as other non-native plant species. Using an "adopt-a-shoreline" approach, volunteers would be responsible for surveying specified areas of their lake.

Action Steps:

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

Management Action: Reduce occurrence of purple loosestrife on Mid Lake shorelands
Timeframe: Summer 2010
Facilitator: Planning Committee
Description: Purple loosestrife can be found in numerous locations along the wetland margins of Mid Lake (Map 6) and other parts of the Thoroughfare. Accessibility to these areas is very difficult, reducing the applicability of hand removal or chemical control methods to be utilized.

The use of biological control measures is most suited for these areas, due to accessibility and the quantity of purple loosestrife in these areas. According to the GLIFWC interactive mapping website (maps.glifwc.org), biological control measures were imitated by the WDNR on select locations of the chain in 1999. The status of these *Gallerucella spp.* populations is unknown at this time.

With the help of UW Extension, colonies would be selected for biological control methods. Following the selection process, *Gallerucella sp*. beetles would be collected using aspirators from established populations in the area. This method would also be coordinated by the UW Extension. Beetles would then be released directly onto the target colony.

Action Steps: See description above.

Management Goal 4: Raise Awareness of Blue-green Algae on Mid Lake

Management Action: Educational initiative aimed at raising awareness of blue-green algae blooms on Mid Lake

Timeframe: Summer 2010

Facilitator: Planning Committee

Description: Like 'true' algae, cyanobacteria or blue-green algae are able to convert sunlight into energy through the process of photosynthesis. Many species of blue-green algae can naturally be found in Wisconsin waters, some of which can produce toxins potentially dangerous to people and animals. Exposure to these toxins occurs can be from ingestion of water, skin contact, and by inhaling aerosolized water droplets.

The largest risk of exposure consists of swallowing water containing the toxins, usually during water-sporting activities. Symptoms include nausea, vomiting, diarrhea and in severe cases, liver failure or paralysis. Skin contact with algae can produced blistering of the exposed skin. Allergy-like symptoms including coughing, watery eyes, and nose/throat irritation are most commonly associated when wind and motor boat activity cause the toxins to become aerosolized.

Because dogs and other domestic animals actively drink water from lakes, these symptoms can be much more developed and can lead to death in some instances. If you suspect an illness, either from a human or an animal, the case should be reported to the Wisconsin Department of Health Services (http://dhs.wi.gov/eh/bluegreenalgae/). Please note that this resource solely collects information for tracking blue-green algae outbreaks within the state. Individuals or animals experiencing severe symptoms should consult the appropriate medical attention immediately.

Pictures of algae were sent to James Kreitlow, WDNR algae specialist, by a Mid Lake riparian. Mr. Kreitlow confirmed that blue-green algae were present in the pictures, but could not indicate what types (genera) were present and whether toxin production was an issue. Blue-green algae samples can be collected with a specialized plankton net and shipped to the Wisconsin State Laboratory of

Hygiene for toxin analysis. The cost of the analysis is approximately $350-400 a sample.

At this time, the MLPRD are not aware of incidents of blue-green related illnesses of people or animals from Mid Lake. The MLPRD will include educational information about blue-green algae and the potential risks related to their toxins within materials distributed to district members. If blue-green algae blooms are observed on Mid Lake in the future, the MLPRD may decide to have samples collected. Even if toxic blue-green algae are confirmed, there are no control measures that can be taken to remove the algae. Simply limiting exposure during an algae bloom and waiting for the bloom to dissipate is all that can be done. In this instance, the MLPRD would distribute information to district members informing them to limit their use of the lake during the bloom.

Like algae, blue-green algae blooms are associated with increased nutrient levels. Following the management actions listed within Management Goal 1, this will act to reduce blue-green algae blooms on Mid Lake over time. Additional information relating to blue-green algae can be found on the WDNR's website (http://dnr.wi.gov/lakes/bluegreenalgae/).

Action Steps: See description above.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Mid Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network protocols and occurred once in spring and winter and three times during the summer. All samples that required laboratory analysis were processed through the Wisconsin State Laboratory of Hygiene (SLOH). The parameters measured, sample collection timing, and designated collector are contained in table below. Secchi disk transparency was also included during each visit.

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

**Winter samples collected by consultant*

The diamond shape indicates samples collected as a part of the Citizen Lake Monitoring Network and the circle indicates samples collected under the proposed project funding. The winter samples were collected by Onterra. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle.

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were Mid Lake on June 19, 2008 during field visits, 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. Colonies were mapped utilizing a Trimble GPS with sub-meter accuracy.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Mid 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, 2008) was used to complete this study on July 14 and 15, 2008. A point spacing of 55 meters was used resulting in approximately 293 points.

Community Mapping

On August 6, 2008, the aquatic vegetation community types within Mid Lake (emergent and floating-leaved vegetation) were mapped 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 Mid 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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