Mid Lake

(of the Minocqua Chain of Lakes)

Oneida County, Wisconsin

Comprehensive Management Plan

October 2022

Sponsored by:

Mid Lake Protection and Management District

WDNR Surface Water Grant Program

ACEI-147-14

Onterra, LLC
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Onterra, LLC
Lake Management Planning

Mid Lake

Oneida County, Wisconsin

Comprehensive Management Plan

October 2022

Created by: Eddie Heath, Brenton Butterfield, Tim Hoyman, Todd Hanke, Heather Lutzow, Josephine Barlament

Onterra, LLC
De Pere, WI

Funded by: Mid Lake Protection and Management District
Wisconsin Dept. of Natural Resources
(ACEI-147-14)

Acknowledgements

This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

Mid Lake Planning Committee

Robert Grant	Kelly Hugget McCann
Ed Bruner	Chris McCann
Andy Bullock	Barb Coulter-Smith

TABLE OF CONTENTS

FIGURES

TABLES

PHOTOGRAPHS

MAPS

APPENDICES

A. Public Participation Materials
B. 2019 Riparian & MLPMD Member Stakeholder Survey Response Charts & Comments
C. Water Quality Data Summary
D. Point-Intercept Aquatic Macrophyte Survey Data
E. WDNR Fisheries Materials
- 2009 Comprehensive Fisheries Survey of Minocqua Chain
- 2015 Fisheries Information Sheet
- 2019 Minocqua Chain Project Trifold Brochure

F. Comment Response Document for the Official First Draft

1.0 INTRODUCTION

At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in 2017. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 224.9 acres. Mid Lake, Oneida County, is a shallow lowland drainage lake with a maximum depth of 12 feet and a mean depth of 6 feet located off the Thoroughfare between Lake Tomahawk and Lake Minocqua (Figure 1.0-1). This eutrophic lake has a relatively small watershed when compared to the size of the lake. Thirty-five native plant species were found in Mid Lake in 2019, of which fern-leaf pondweed is the most common plant. Five exotic plant species are known to exist in Mid Lake.

Field Survey Notes

Great scenic beauty on the Mid Lake. The system supports high amounts of aquatic plants which are actively managed through mechanical harvesting.

Photograph 1.0-1 Mid Lake, Oneida County

Lake at a Glance - Mid Lake

Morphology	
Acreage	225
Maximum Depth (ft)	12
Mean Depth (ft)	6
Shoreline Complexity	3.1
Vegetation	
Number of Native Species (2019)	35
Exotic Plant Species	Eurasian watermilfoil, curly-leaf pondweed, purple loosestrife, pale-yellow iris, flowering rush
Simpson's Diversity	0.77
Average Conservatism	6.3
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	9.0
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	3:1

Figure 1.0-1. Mid Lake, Oneida County, Wisconsin.

Mid Lake is part of the Minocqua Chain, just off the Thoroughfare between Minocqua Lake and Tomahawk Lake (Figure 1.0-1). Prior to European settlement, Mid Lake was called Nawaii Lake. In the Ojibwa language, this means "middle."

Mid Lake is managed by the Mid Lake Protection and Management District (MLPMD), an organization that votes on expenditures and can levy taxes to fund activities. The purpose of the MLPMD is to preserve and protect Mid Lake and its surroundings, and to enhance the water quality, fishery, boating safety, and aesthetic values of Mid Lake as a public recreational facility for today and for future generations. The MLPMD has been managing nuisance levels of aquatic plants on Mid Lake for over 30 years to maintain navigation in specific areas of the lake with their mechanical harvester. In recent years, the MLPMD has also focused on monitoring for aquatic invasive species (AIS).

Minocqua and Kawaguesaga Lakes are managed by the Minocqua Kawaguesaga Protective Association (minocquakawaga.org). Tomahawk Lake, Little Tomahawk, Mud, Inkwell Lakes, Paddle Pond, and the Thoroughfare are managed by the Tomahawk Lake Association (tomahawklake.org). Both of these organizations have volunteer membership.

MLPMD completed a *Comprehensive Lake Management Plan* in March 2013 (LPL-1202-08, LPL-11203-08). The MLPMD implemented the management goals and actions within that plan, including aquatic invasive species (AIS) management and monitoring through several additional WDNR grant-funded projects (AEPP-270-11, AEPP-390-13, ACEI-147-14). While these grants were obtained with the intent to initiate a multi-year herbicide control strategy targeting invasive curly-leaf pondweed, the population was found to have declined naturally to levels that did not warrant treatment. The MLPMD worked with the WDNR to modify their mechanical harvesting strategy to include areas of curly-leaf pondweed.

In an effort to reassess the ecological condition of Mid Lake and update management goals and actions as necessary, the MLPMD utilized remaining funds from one of the AIS management grants (ACEI-147-14) to complete an *Updated Comprehensive Lake Management Plan*, of which this document is the final deliverable. The primary focus of this update was to reassess the lake's aquatic plant community, both native and non-native, water quality, shoreland condition, stakeholder perceptions, and to update management and monitoring goals. The Summary and Conclusions Section (4.0) provide a succinct overview of the health of Mid Lake (Click Here).

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, and the completion of a stakeholder survey.

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

Planning Committee Meeting I

On October 7, 2020, Eddie Heath of Onterra met virtually with the MLPMD Planning Committee for nearly 4 hours. Scott Van Egeren, local WDNR lakes biologist, was also in attendance. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. Study components including AIS survey results, aquatic plant inventories, water quality analysis, watershed modeling, and shoreland assessment results were presented and discussed.

Planning Committee Meeting II

On January 21, 2021, Eddie Heath of Onterra met virtually with the MLPMD Planning Committee for over 2 hours. The focus of this meeting was to develop management goals and associated management actions to serve as the Implementation Plan Section (5.0).

Management Plan Review and Adoption Process

Based upon the discussion from previous planning meetings, a draft Implementation Plan Section (5.0) was created by Onterra and sent to the planning committee for review. On February 8, 2021, an early draft of the Implementation Plan was provided to the MLPMD Planning Committee and MLPMD Board of Directors for review. Comments were aggregated by the MLPMD Planning Committee Chair and provided to Onterra. These comments were addressed to result in the Official First Draft.

On June 25, 2021, the Official First Draft of the MLPMD's Comprehensive Management Plan for Mid Lake was supplied to WDNR (lakes and fisheries programs), Oneida County, Great Lakes Indian Fish and Wildlife Commission, and Lac du Flambeau Tribe to solicit comments. At that time the Official First Draft was posted to the MLPMD's website for public review, with outreach efforts requesting riparians to provide comments. The posting remained active until it was replaced with the finalized version. No comments were received from the general public nor from entities other than the WDNR.

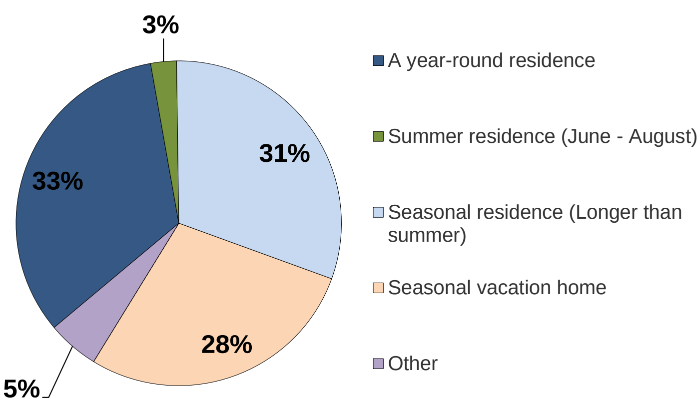
Written review of the draft plan was received on July 28, 2021 from WDNR fisheries (Zach Woiak, John Kubisiak) and on February 17, 2022 from Scott Van Egeren (WDNR lakes coordinator). The WDNR comments and how they are addressed in the final plan are contained in Appendix F. The WDNR indicated that all comments were adequately addressed and deliverables were met on October 13, 2022 - the date used for finalizing this Plan.

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to riparian property owners around Mid Lake. The survey was designed by Onterra staff and the MLPMD planning committee and reviewed by a WDNR social scientist. During August 2019, the seven-page, 32-question survey was posted online through Survey Monkey for property owners to answer electronically. If requested, a hard copy was sent to the property owner with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a third-party for analysis. Forty-five percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. The data were analyzed and summarized 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 and a general summary is discussed below.

Based upon the results of the stakeholder survey, much was learned about the people who use and care for Mid Lake. Thirty-three percent of stakeholder respondents live on the lake year-round, while 31% use their property as a seasonal residence, 28% use it as a seasonal vacation home, and 3% use it as a summer residence. Forty-nine percent of stakeholders have owned their property for over 15 years, and 41% have owned their property for over 25 years (Appendix B, Question #4).

Question 2: How is your property on Mid Lake utilized?



Question 3: How many days each year is your property used by you or others?

Category (# of days)	Responses	
0 to 100	17	44%
101 to 200	11	28%
201 to 300	3	8%
301 to 365	8	21%

Figure 2.0-1. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Relaxing/entertaining was the highest ranked activities when riparians were asked why the own property on Mid Lake (Figure 2.0-2). Riparian respondents also ranked *motor boating* and *open water fishing* as reasons they choose to be a Mid Lake riparian.

Question 15: Please rank up to three activities that are important reasons for owning or renting your property on Mid Lake.

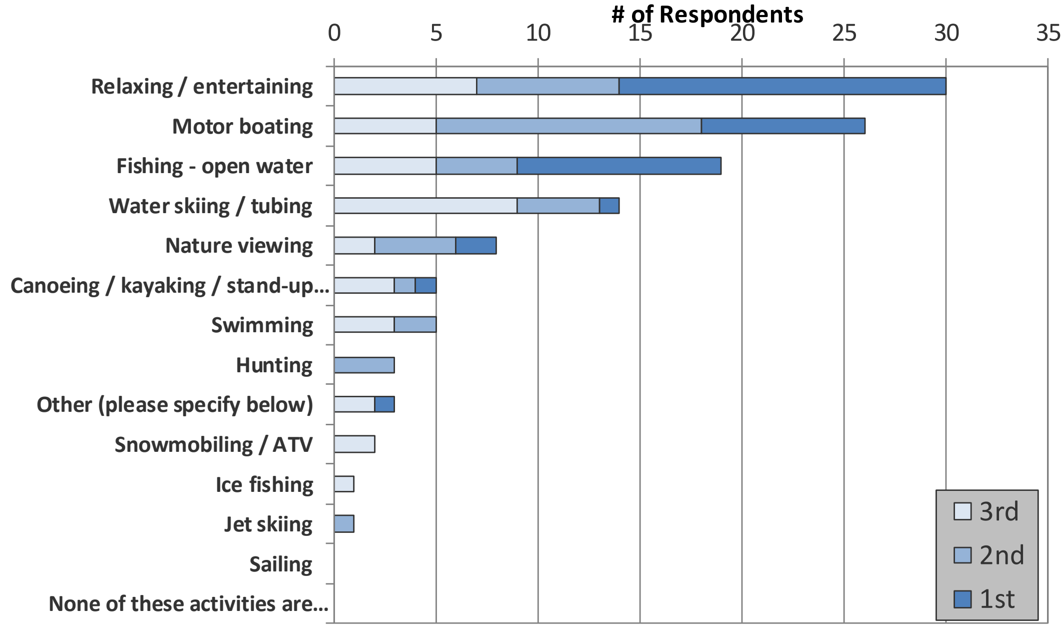


Figure 2.0-2. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Almost 80% of survey respondents indicated that they use a motor boat with greater than 25 hp motor on Mid Lake, 59% use a pontoon, and 51% use a canoe/kayak/or stand-up paddleboard (Figure 2.0-3). Jet skis were also a popular option.

Question 12: What types of watercraft do you currently use on Mid Lake?

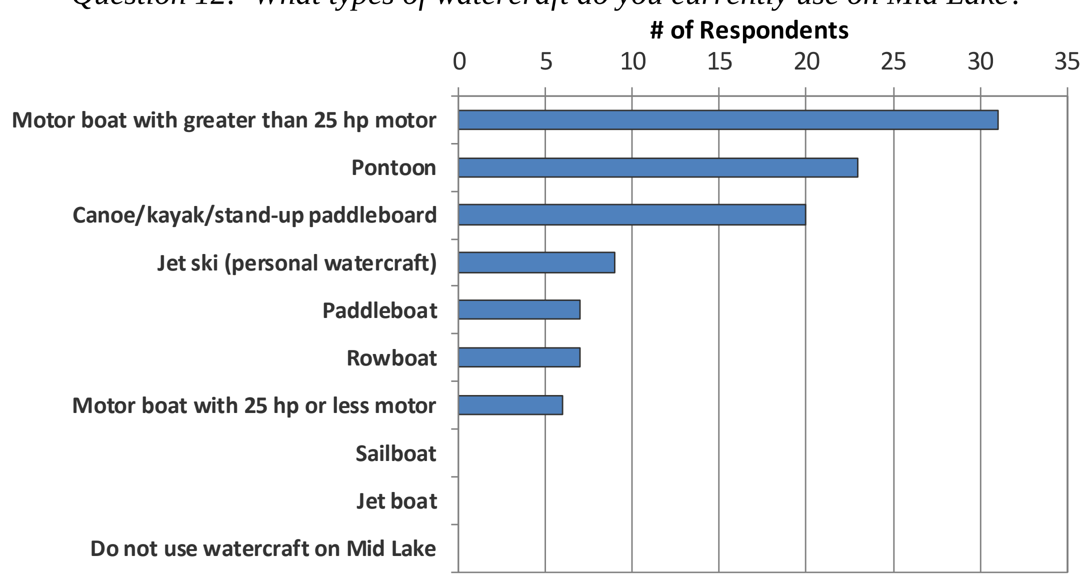


Figure 2.0-3. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

On a relatively small lake such as Mid Lake, especially with its abundance of aquatic vegetation, the importance of responsible boating activities is increased. The need for responsible boating increases even more during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen in Question 15, several of the top recreational activities on the lake involve boat use (Figure 2.0-2). Unsafe watercraft practices ranked 4th in the list of Mid Lake stakeholders' top concerns, and excessive watercraft traffic ranked ninth (Question #23, Appendix B).

A concern of stakeholders noted throughout the stakeholder survey (see Question 23 and survey comments – Appendix B) was excessive aquatic plant growth. These topics are touched upon in the Aquatic Plants Section (3.5), Summary & Conclusions (4.0) as well as within the Implementation Plan Section (5.0).

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect to these particular topics.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

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, 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 analyses 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 productivity 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 analyses 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.

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 lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Mid Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the 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 quadrants (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).

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.

> 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.

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 clearer understanding of the lake's trophic state while facilitating clearer long-term tracking. Carlson (1977) presented a trophic state index that gained great acceptance among lake managers.

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 epilimnion 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, fish kills 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 processes that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Internal Nutrient Loading

In lakes that support stratification, whether throughout the summer or periodically between mixing events, 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 turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can *pump* phosphorus from the sediments into the water column throughout the growing season. In lakes that only mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algal blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add smaller loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algal 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 determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of the phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. days or weeks 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.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR 2017) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Mid Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, and hydrology. An equation developed by Lathrop and Lillie (1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

> **Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.
>
> **Drainage Lakes** have surface water inflow and/or outflow in the form of rivers and/or streams.
>
> > Headwater drainage lakes have a watershed of less than 4 square miles.
> >
> > Lowland drainage lakes have a watershed of greater than 4 square miles.

It is important to note that under natural conditions, Mid Lake would be a headwater drainage lake; however, with being connected to Kawaguesaga Lake which has a dam, the water level in Mid Lake is "artificially elevated" which allows water to flow both in or out of the lake. The entire Minocqua Chain of Lakes, including Mid Lake, is classified as a lowland drainage system. Because of its shallow depth and polymictic nature, Mid Lake is classified as a shallow lowland drainage lake (category 4 in Figure 3.1-1).

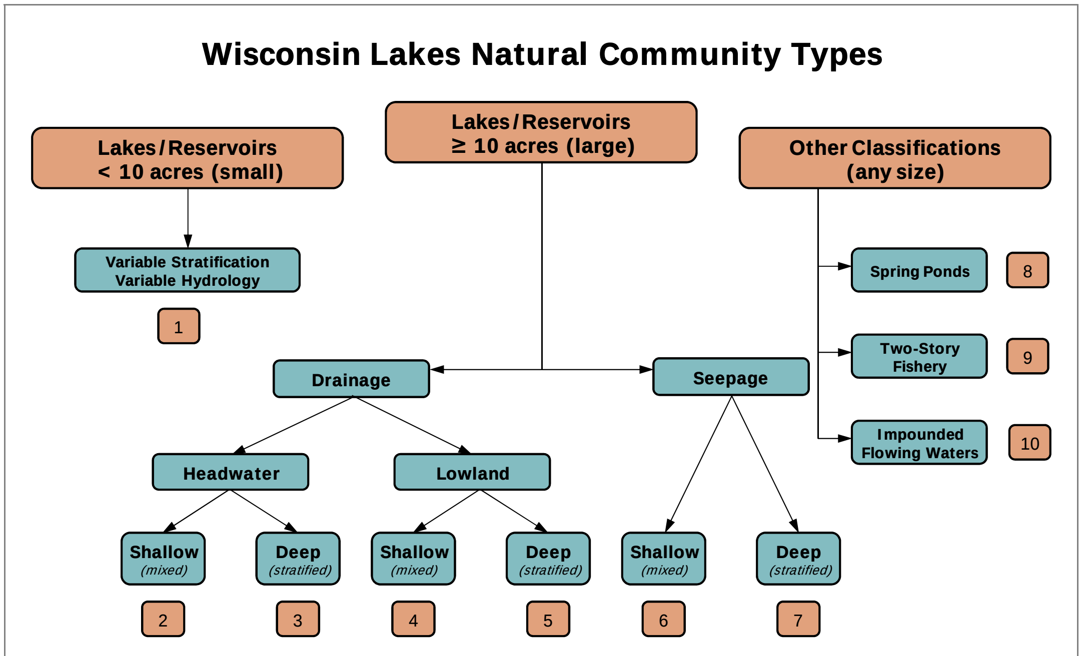


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

Garrison, et. al (2008) developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for six of the lake classifications. Though they did not sample sufficient lakes to create median values for each classification within each of the state's ecoregions, they were able to create median values based on all of the lakes sampled within each ecoregion (Figure 3.1-2). 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. Mid Lake is within the Northern Lakes and Forests ecoregion.

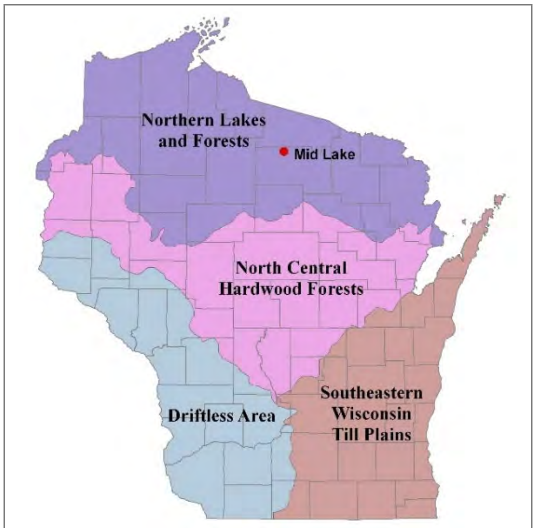


Figure 3.1-2. Location of Mid Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2018 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions, phosphorus concentrations that are known to produce nuisance algal blooms, and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Mid Lake is displayed in Figures 3.1-4 - 3.1-7. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). 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.

Mid Lake Water Levels

The Wisconsin River Reservoir system consists of 21 Wisconsin Valley Improvement Company (WVIC) water storage reservoirs used to maintain a nearly uniform flow of water as practicable in the Wisconsin River by storing surplus water in reservoirs for discharge when water supply is low to improve the usefulness of the rivers of the rivers for hydropower, flood control, and public use (Figure 3.1-3). Of these 21 reservoirs, 16 are natural-lake reservoirs and 5 are man-made reservoirs constructed between 1911 and 1937. The man-made reservoirs account for 73% of WVIC's usable water storage.

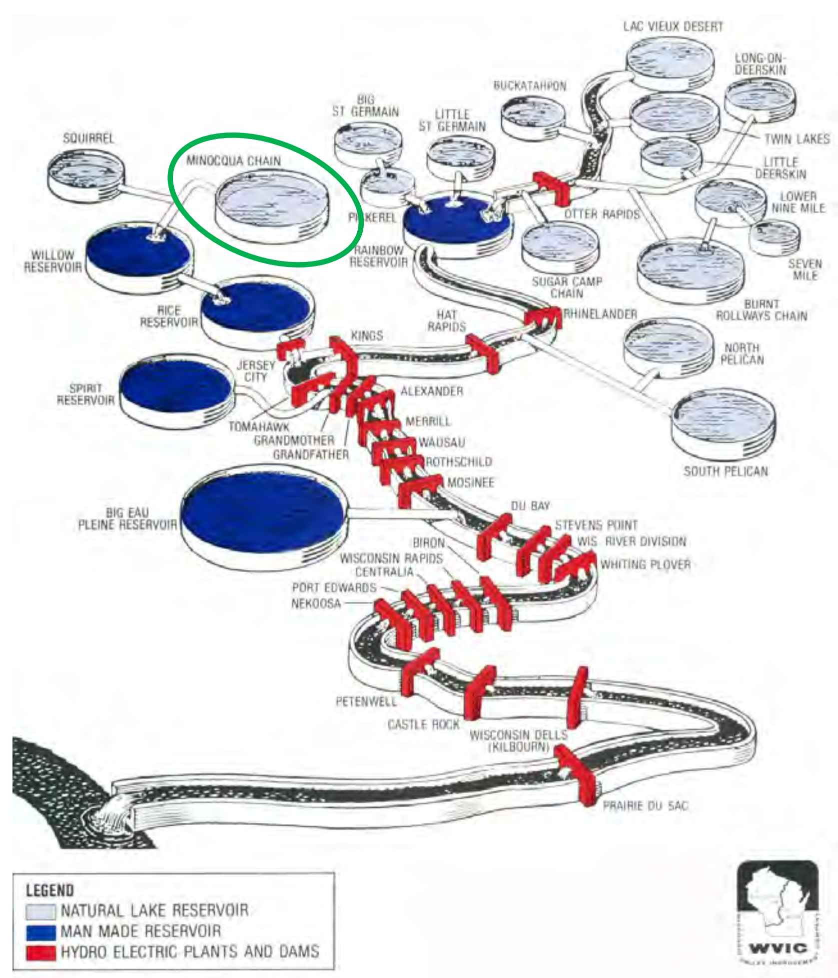


Figure 3.1-3. WVIC reservoir system. The Minocqua Chain reservoir is outlined in green. Adapted from WVIC website.

Mid Lake is part of the Minocqua Chain of Lakes which is one of the 16 natural lake reservoirs. The Minocqua Dam was built in 1917 to create the Minocqua reservoir, operates under Federal Energy Regulatory Commission (FERC) Order 2113P, and owned by the WVIC. Although the Minocqua Dam does not generate power, by providing consistent flow in the Wisconsin River WVIC estimates this increases power generation of 25 downstream hydroelectric dams by about 14 percent annually (FERC Order 2113P).

Hydroelectric power projects are licensed by the Federal Energy Regulatory Commission (FERC). As part of the FERC operation license, the minimum and maximum water levels are set for each waterbody. Natural lake reservoir water levels are maintained within a relatively narrow range in comparison to the five man-made reservoirs which exhibit changes of water levels that could span 10-20 feet in a single year.

The Minocqua reservoir is a natural lake reservoir. The 2113P FERC operating order grants an operational range of 1,584.05 – 1,585.05 feet during the summer (June 1 to September 30) and 1,582.72 – 1,585.05 feet during the winter (October 1 to May 31). Water elevation data is shown in the Aquatic Plant Section (3.4) as it relates to the timing of aquatic plant species.

Mid Lake Water Quality Analysis

Mid Lake Long-term Trends

Water quality data was collected from Mid Lake on four occasions in 2019/2020. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Near-surface total phosphorus data are available for Mid Lake for the years 2003, and 2007-2019 (Figure 3.1-4). The mean summer total phosphorus concentration is 28.4 µg/L, placing the lake in the *excellent* category for Wisconsin's shallow lowland drainage lakes. Mid Lake's average summer total phosphorus concentration is lower than other shallow lowland drainage lakes in Wisconsin (median 33 µg/L) but higher than other lakes within the North Lakes and Forests (NLF) Ecoregion (median 21 µg/L). Although summer phosphorus concentrations range from 21.1 to 40.0 µg/L they were always in either the *excellent* or *good* categories and they were well in the excellent category in 2019. There is no trend either up or down during the period of record.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available in Mid Lake for the same time period as phosphorus, 2003 and 2007-2019 (Figure 3.1-5). The mean summer chlorophyll-*a* concentration is 8.6 µg/L, placing the lake in the *excellent* category, for shallow lowland drainage lakes in Wisconsin. Mid Lake's mean summer chlorophyll-*a* concentration is lower than the median concentration for Wisconsin's shallow lowland drainage lakes (9.4 µg/L) but higher than the median concentration for lakes within the NLF ecoregion (5.6 µg/L). As with phosphorus, chlorophyll-*a* concentrations have fluctuated between good and excellent categories, but in 2019 it was well in the excellent category.

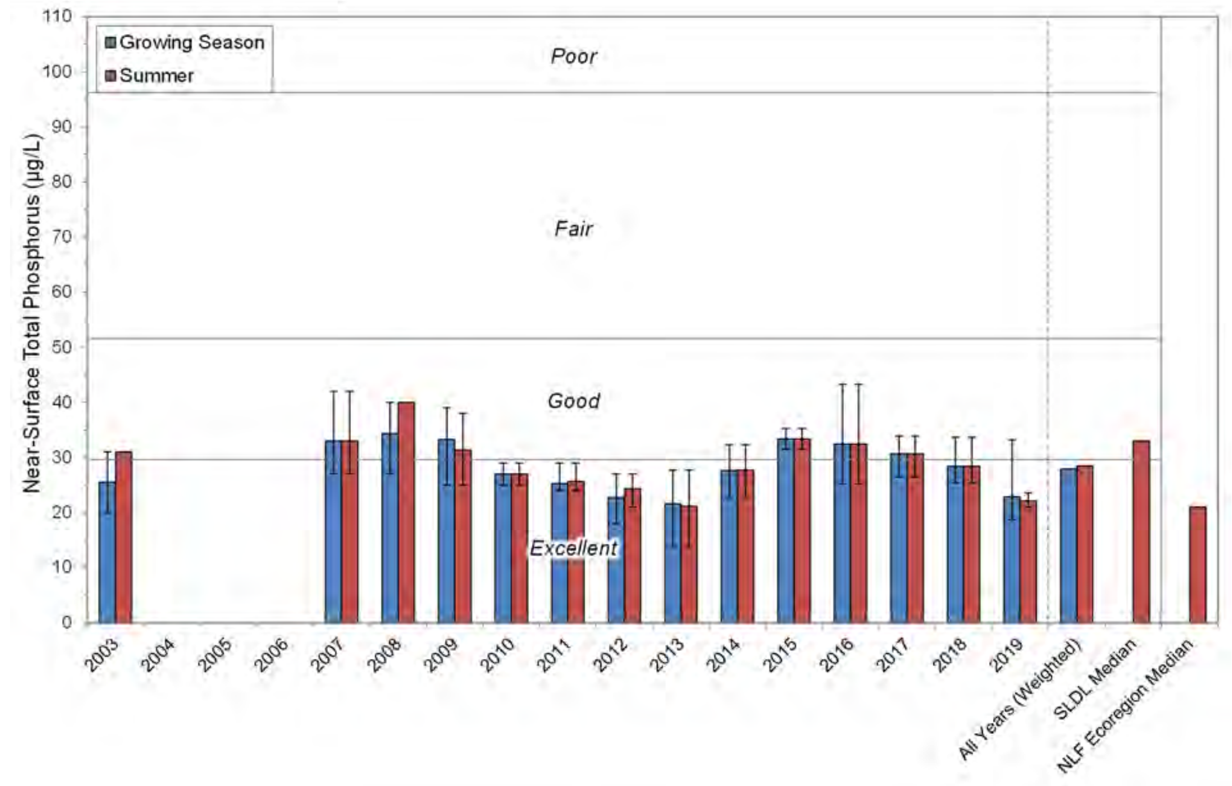


Figure 3.1-4. Mid Lake, statewide shallow lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

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 (CLP) increases within a lake over time, the potential for a larger nutrient release exists.

As will be discussed in the vegetation section, the amount of CLP in Mid Lake varies from year to year. The acreage of CLP in Mid Lake was plotted against summer average total phosphorus and chlorophyll concentrations to see if years with higher CLP acreage were correlated with years with higher phosphorus and chlorophyll concentrations. As illustrated in Figure 3.1-6, years with higher CLP did not necessarily correlate to years with higher chlorophyll concentrations in August. At present, it does not appear that the CLP population in Mid Lake has a significant impact on the lake's water quality.

It is more likely much of the released phosphorus is absorbed by the algae that grows attached to the extensive submerged aquatic vegetation that remains in the lake. This type of algae is not measured in the chlorophyll-*a* samples that are collected in the near surface of the lake. The higher than normal algal levels in August of some years (2008, 2013) are likely the result of a combination of factors including CLP levels, phosphorus entering the lake from the watershed and the channel from the Tomahawk River, as well as food web interactions, specifically the amount of zooplankton which consume algae.

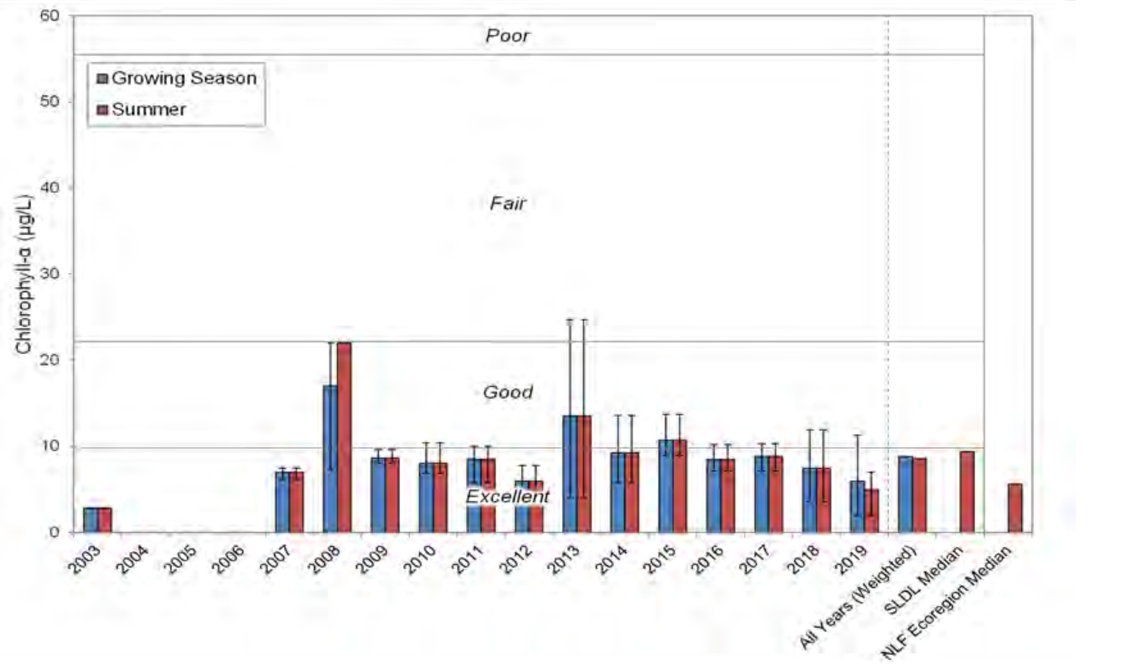


Figure 3.1-5. Mid Lake, statewide shallow lowland drainage lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

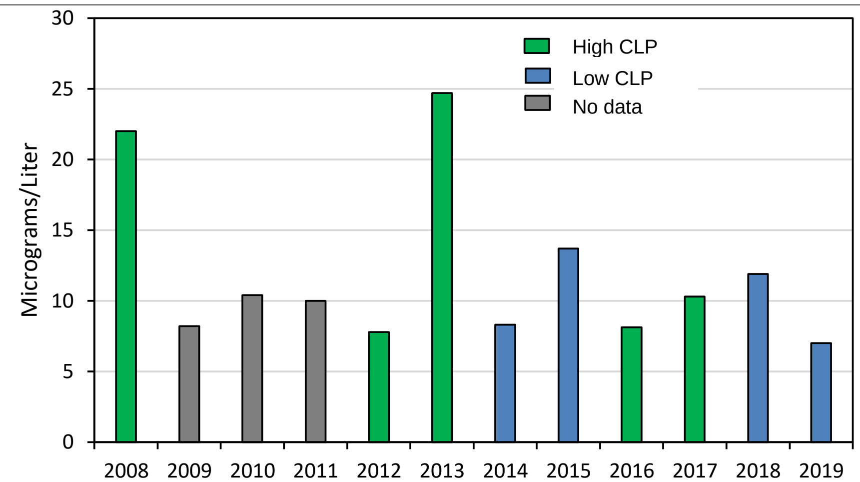


Figure 3.1-6. August chlorophyll-a concentrations in relation to the amount of curly-leaf pondweed (CLP) that was present in the same year. There is no CLP data available for the years 2009-11).

Secchi disk transparency data, a measure of water clarity, are available in Mid Lake for the years 2001, 2003-2004, and 2008-2019 (Figure 3.1-7). Mean summer Secchi disk depth has ranged from 3.8 feet in 2008 to 9.0 feet in 2001, with an overall weighted mean of 7.1 feet. This value places the lake in the *excellent* category for Wisconsin's shallow lowland drainage lakes and is the same categories for phosphorus and chlorophyll-*a*. This value is deeper than the median values for other shallow lowland drainage lakes (5.6 feet) but less than other lakes within the NLF ecoregion (8.9 feet).

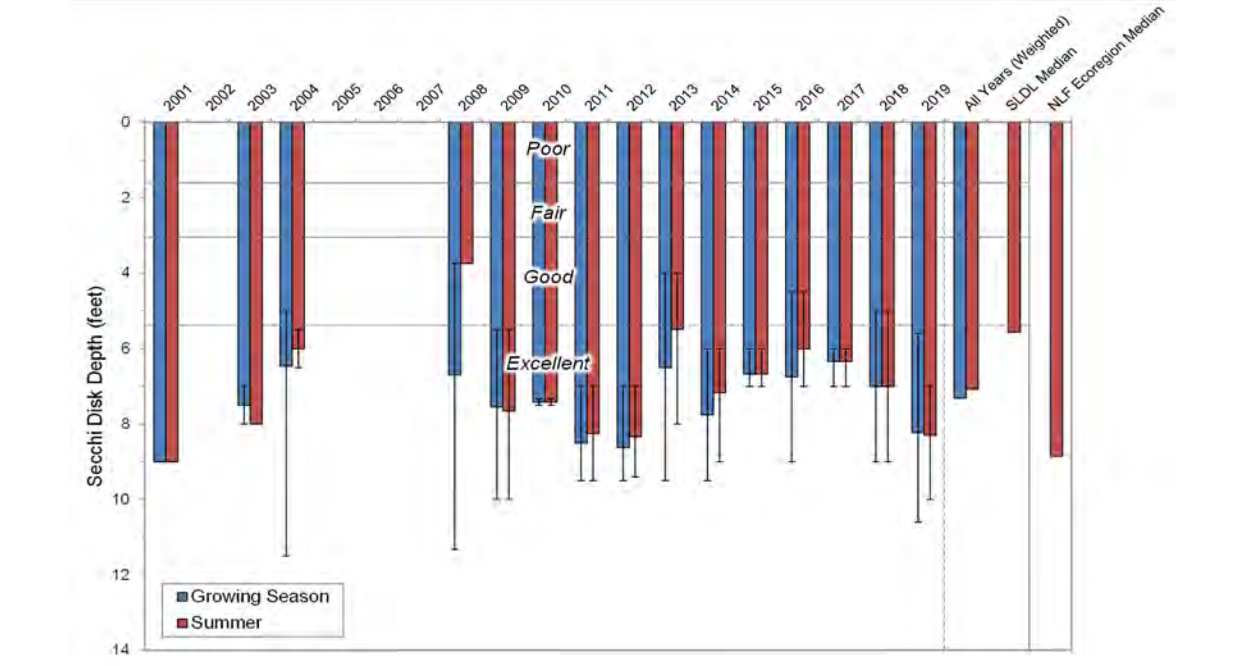


Figure 3.1-7. Mid Lake, statewide shallow lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Mid Lake

Using midsummer nitrogen and phosphorus concentrations from Mid Lake, a nitrogen:phosphorus ratio of 20:1 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 3.1-8 contain the TSI values for Mid Lake. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus. 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* TSI values, it can be concluded that Mid Lake is on the border between mesotrophic and eutrophic states.

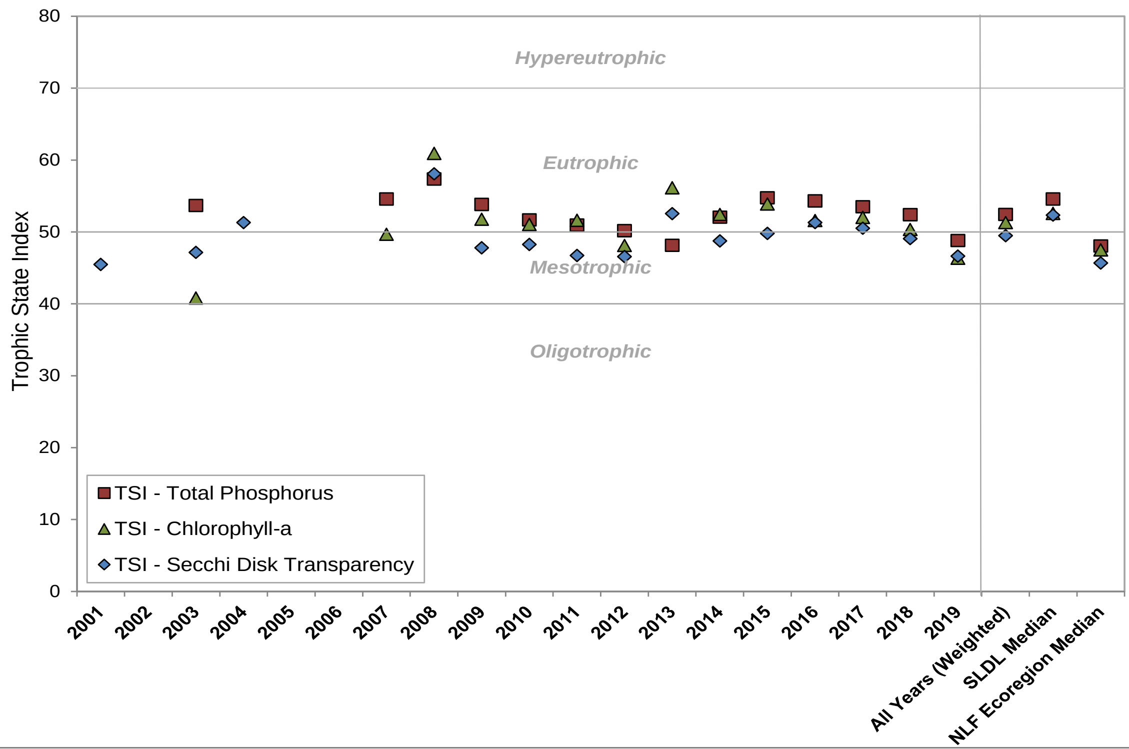


Figure 3.1-8. Mid Lake, statewide shallow lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

The Role of Aquatic Plants in Mid Lake's Water Quality

Shallow lakes are considered to exist in one of two general stable states: a turbid (low water clarity) state dominated by phytoplankton (free-floating algae) and containing little submersed aquatic vegetation, or a clear state dominated by vascular aquatic vegetation (macrophytes) and lower phytoplankton abundance (Sondergaard et al. 2007). When in the clear state, aquatic vegetation reduces the suspension of bottom sediments, utilizes nutrients that would otherwise be available to phytoplankton, and provide refuge for zooplankton which eat phytoplankton. The aquatic plant community plays a vital role in maintaining this clear-water state. Once a lake transitions from a clear to turbid state, it is near-impossible to return it to a clear state.

A number of factors which can lead to the loss of aquatic vegetation often cause shallow lakes to transition from the clear to turbid state. Excessive nutrient loading, particularly when total phosphorus concentrations approach 100 µg/L, can lead to increased phytoplankton abundance, reductions in water clarity, and a reduction in aquatic plant habitat. As aquatic vegetation declines, bottom sediments become more susceptible to wind-induced sediments resuspension and water clarity declines further. The stabilization of water levels in shallow lakes can also lead to declines in aquatic vegetation as many species require natural, annual fluctuations for their persistence and reproduction.

Mid Lake's shallow nature in combination with nutrient-rich sediments creates ideal conditions for excessive aquatic plant growth. The current total phosphorus concentrations in Mid Lake are too low to for concern into *flipping* into to a turbid state through relatively minor reductions of aquatic plants from mechanical harvesting. However, these plants are essential for maintaining Mid Lake's current water clarity.

Dissolved Oxygen and Temperature in Mid Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Mid Lake by Onterra staff. Graphs of those data are displayed in Figure 3.1-9 for all sampling events.

Mid Lake is a polymictic lake meaning that it mixes frequently throughout the ice free season. This frequent mixing means that the bottom waters nearly always contained sufficient oxygen for fish. In February of 2020, oxygen levels were less than 3 mg/L throughout the water column. This means the lake is susceptible to winter fish kills. Because the lake is connected to the Tomahawk River, many fish likely will leave the lake is they become stressed from low oxygen. However, in some years fish kills of panfish have occurred. The low winter oxygen levels are exacerbated in this relatively shallow lake by the intentional lowering of water levels at the downstream Minocqua Dam during the winter. This likely results in lower lake levels in Mid Lake which means there is less water volume which reduces the ability of the lake to maintain adequate oxygen levels to prevent fish kills.

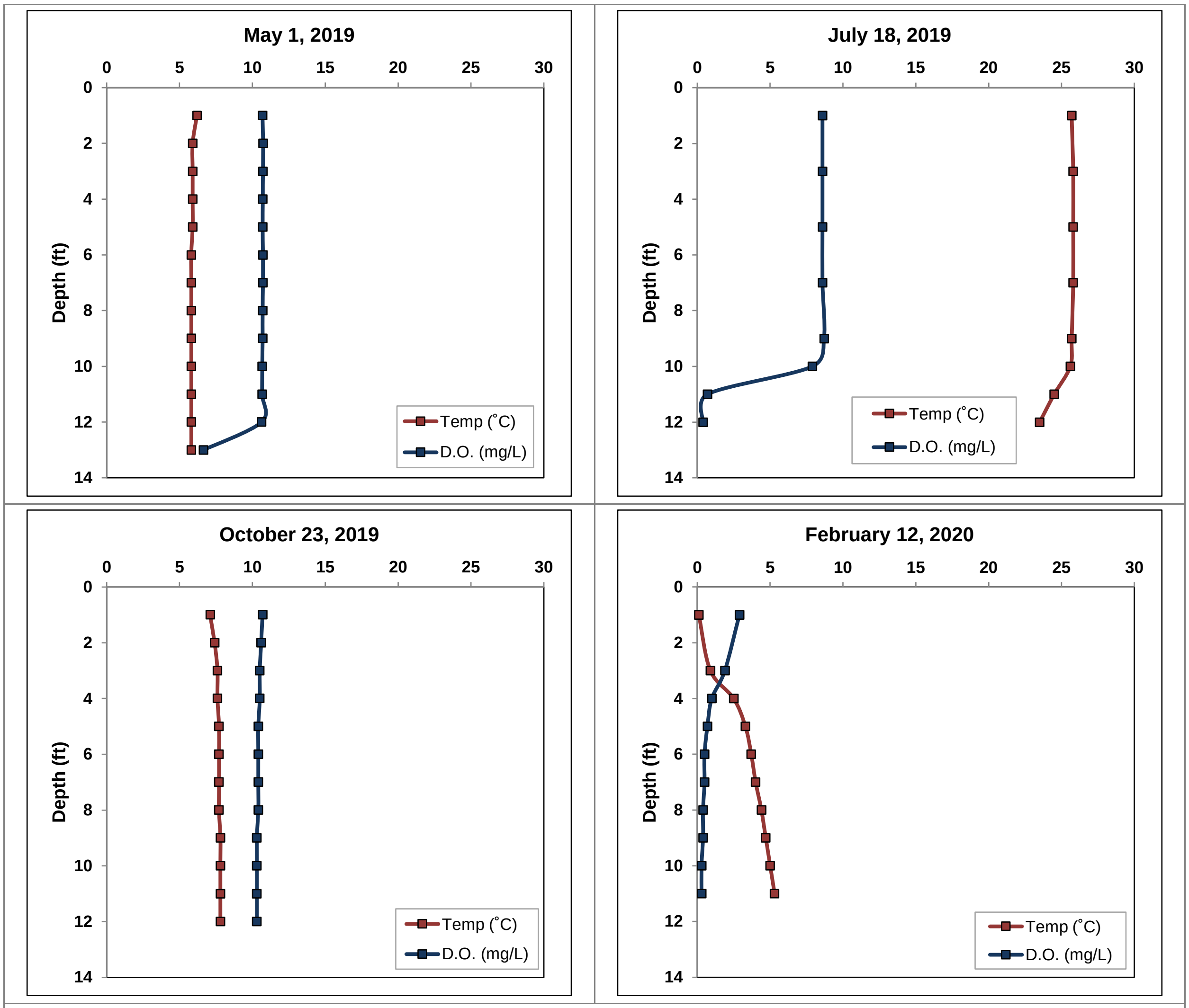


Figure 3.1-9. Mid Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Mid Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Mid Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium. Values were much lower in April compared with the July samples. The low values in April reflect concentrations during snowmelt when chemicals are diluted. The concentrations reported below, except calcium, reflect concentrations during July. It is expected these concentrations were change from year to year depending upon precipitation and its impact on flows in the rivers.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-) and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw 1985). Mid Lake's surface water pH was measured at 9.0 during July 2019 (Figure 3.1-10). This value is slightly higher than the normal range for Wisconsin lakes. The pH samples are collected during the daytime when plants and algae are photosynthesizing. When rates of photosynthesis are high, plants remove carbon dioxide from the water which increases the pH. In the summer, pH usually increases during the day and then goes down overnight. The pH in May was 7.5 at a time when aquatic plant growth is much lower than in mid-summer.

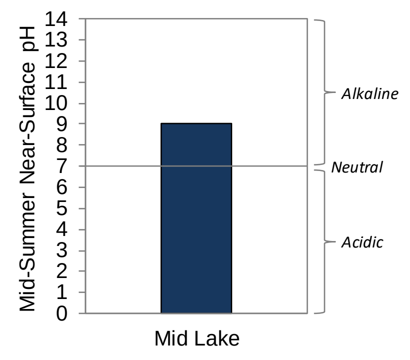


Figure 3.1-10. Mid Lake mid-summer near-surface pH value.

A lake's baseline pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The average alkalinity concentration in Mid Lake during 2019 was measured at 44.3 (mg/L as $CaCO_3$) (Figure 3.1-11)

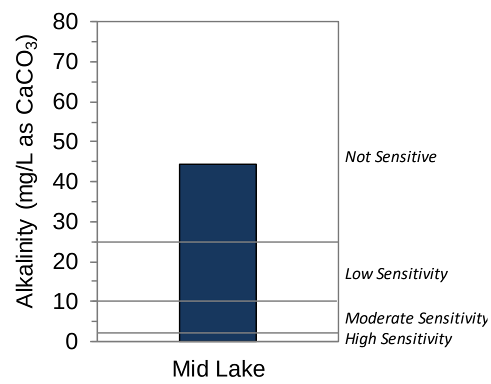


Figure 3.1-11. Mid Lake summer total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Mid Lake during May 2019. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Mid Lake's pH of 9.0 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Mid Lake was found to be 14.8 mg/L, which means the lake has a low susceptibility for zebra mussels (Figure 3.1-12).

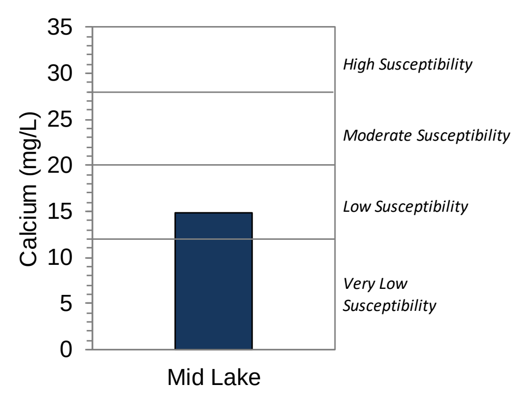


Figure 3.1-12. Mid Lake summer calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

A measure of water clarity once all of the suspended material (i.e. algae and sediments) have been removed, is termed *true color*, and indicates the level of dissolved organic material within water. The highly colored water reduces water clarity as well as light penetration into the water column which can restrict algal growth. Water color in Mid Lake in 2019 averaged 10 units which means the water was *clear* (Figure 3.1-13). While data was not collected in other areas of the Minocqua Chain, its water has been reported to have higher amounts of tannins and it is more tea-colored.

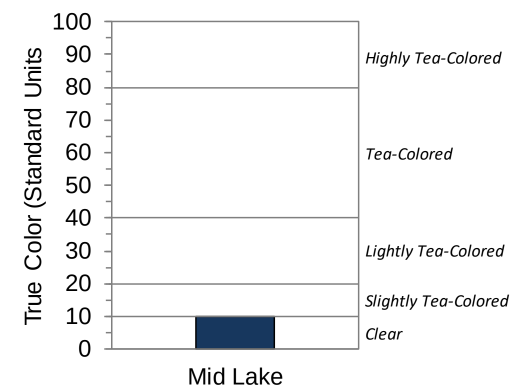


Figure 3.1-13. Mid Lake true color value. Samples collected from the near-surface.

Blue-Green Algae Blooms

Blue-green algae blooms have been periodically noted on Mid Lake. Understanding algae dynamics in lakes is complicated because so many factors control growth rates of algae, such as light availability, nutrient levels, water temperatures, zooplankton populations, and interactions between algal species themselves. The complexity is compounded in systems like Mid Lake.

Like 'true' algae, cyanobacteria or blue-green algae are able to convert sunlight into energy through the process of photosynthesis (Photograph 3.1-1). Many species of blue-green algae can naturally be found in Wisconsin waters, some of which can produce toxins potentially

Photograph 3.1-1. Blue-green algae bloom. Phillips Chain of Lakes, Price County. Photo credit: Onterra August 2013.

dangerous to people and animals. Exposure to these toxins occurs can be from ingestion of water, skin contact, and by inhaling aerosolized water droplets. It is unknown if the blue-green algae blooms noted in the past on Mid Lake produced toxins.

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.

Stakeholder Survey Responses to Mid Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.1-14 and 3.1-15 display the perceptions of Mid Lake stakeholder survey respondents to questions regarding water quality and how it has changed over their years visiting Mid Lake. Most respondents believe the water quality of Mid Lake to be *good*, and possibly improved over time.

Question 16: How would you describe the overall current water quality of Mid Lake?

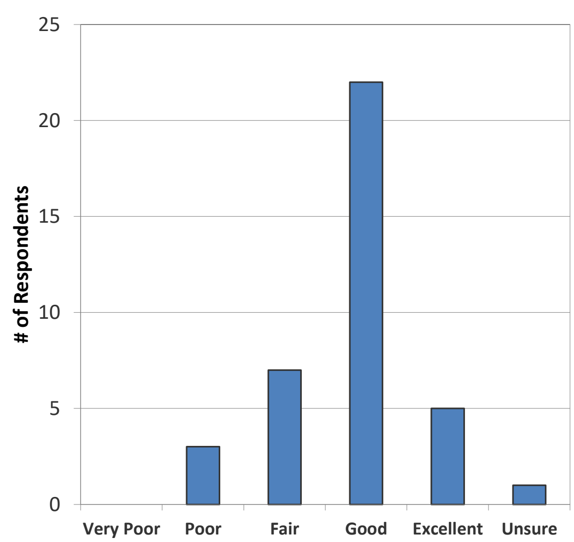


Figure 3.1-14. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 17: How has the overall water quality changed in Mid Lake since you first visited it?

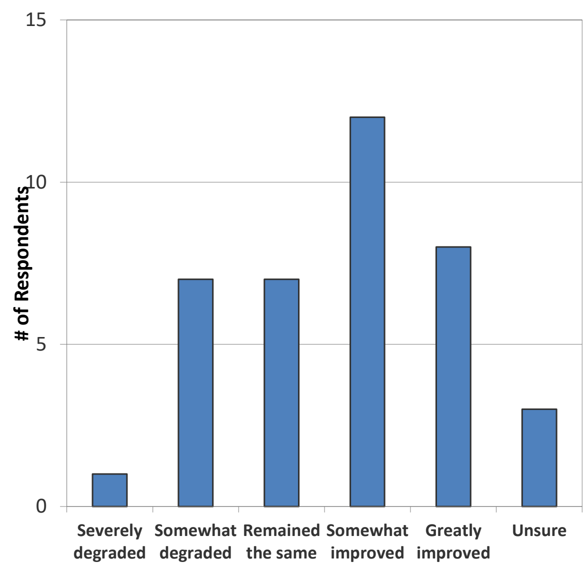


Figure 3.1-15. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

The majority of respondents indicated aquatic plant growth was what they thought of when describing water quality. Aquatic plant growth can affect and be affected by water quality, but is not a water quality metric. Water clarity was the second most common attribute respondents indicated factored into their description of water quality. Although fluctuations are noted on Mid Lake, water clarity is *excellent*.

Question 18: Considering how you answered the questions above, what do you think of when describing water quality?

Answer Options	Response Percent	Response Count
Water clarity	78.4%	29
Aquatic plant growth	81.1%	30
Water color	21.6%	8
Algae blooms	46.0%	17
Smell	27.0%	10
Water level	29.7%	11
Fish kills	21.6%	8
Other	5.4%	2
	answered question	**37**
	skipped question	**3**

Figure 3.1-16. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.2 Watershed Assessment

Watershed Modeling

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. For these reasons, it is important to maintain as much natural land cover (forests, wetlands, etc.) as possible within a lake's watershed to minimize the amount runoff (nutrients, sediment, etc.) from entering the lake.

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 (a residence time of years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time and lead to a problem such as internal nutrient loading. 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 effect 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 are 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 Watershed Assessment – WiLMs Model

Mid Lake's watershed is 808 acres in size. Compared to Mid Lake's surface area of 225 acres, this makes for a very small watershed to lake area ratio of 4:1. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Mid Lake's residence time is about 2 years or that the water within the lake is completely replaced 0.42 times per year. Of the 808-acre direct watershed, 37% is forested, 28% is the lake surface itself, 25% is wetlands, 8% is pasture/grass, 2% is rural residential, and urban – medium density makes up less than 1% of the total watershed (Figure 3.2-1).

Using the land cover types and their acreages within Mid Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Mid Lake from its watershed. In addition, data obtained from a stakeholder survey sent to Mid Lake riparian property owners in 2019 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems.

Of the estimated 131 pounds of phosphorus delivered to the lake annually, 60 pounds (46%) is deposited on the lake surface from precipitation, 24 pounds (19%) is derived from forest, 18 pounds (13%) is from wetlands, 18 pounds (13%) from grass, 9 pounds (7%) is from septic systems, and 2 pounds (2%) is from rural residential land (Figure 3.2-2).

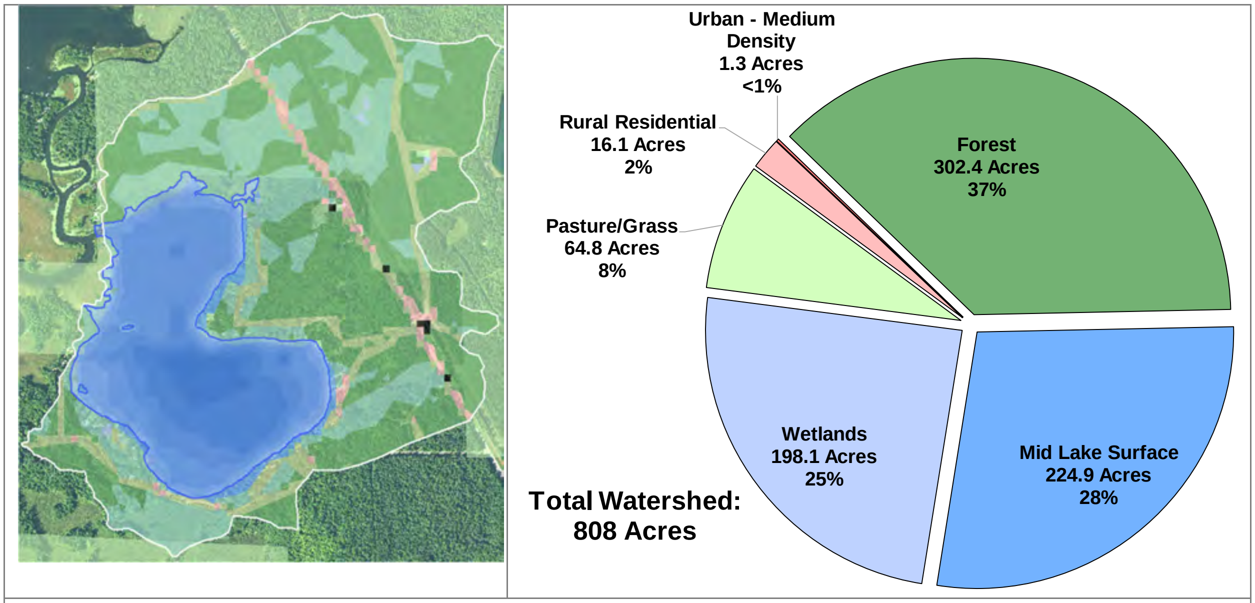


Figure 3.2-1. Mid Lake watershed boundary (white line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2016).

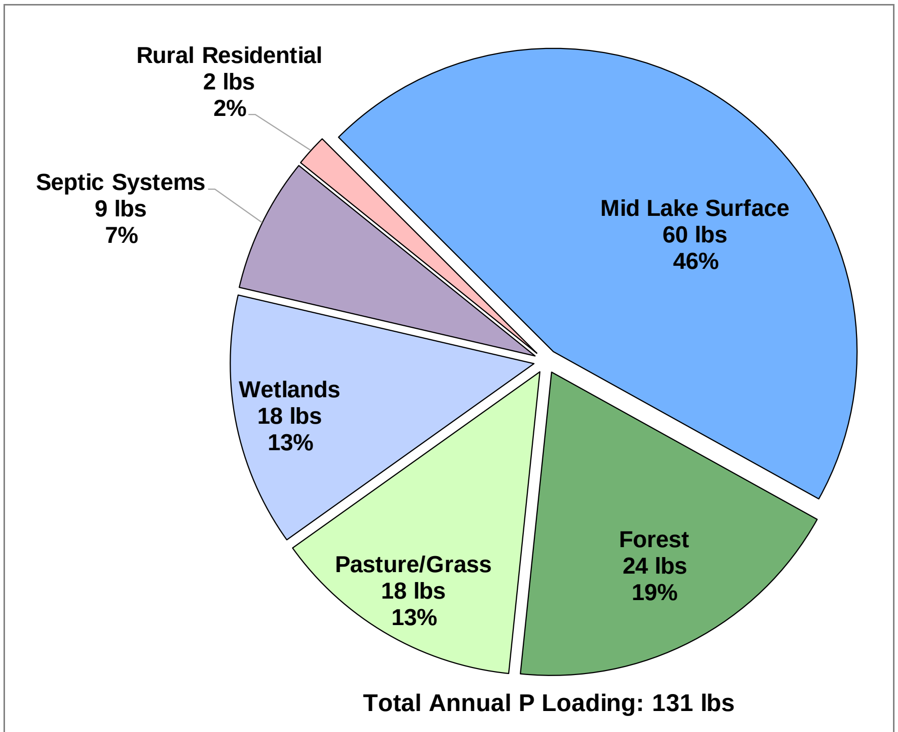


Figure 3.2-2. Mid Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 24 µg/L, which is lower than the measured growing season average total phosphorus concentration of 28 µg/L. Mid Lake is connected to the Tomahawk River by a short channel. It is likely that when the river level is elevated some water enters Mid Lake. This source would provide additional phosphorus to the lake which is not accounted for in the WiLMS modelling. Curly-leaf pondweed may bring another source of phosphorus to the lake. Modeling for curly-leaf pondweed coverage, however, was not included because in Mid Lake curly-leaf pondweed populations are variable from year to year dependent upon snow cover. Years with higher curly-leaf pondweed result in worse water clarity later in the summer which may indicate internal loading after the curly-leaf populations die-off.

Mid Lake Watershed Assessment – TMDL Model

Section 303(d) of the Clean Water Act (CWA) requires states to determine which waterbodies are impaired and orchestrate a plan to reach the goal of restoring all identified impaired waters to meet applicable water quality standards (WDNR 2019). One of the tools WDNR biologists use to achieve this goal is to develop a total maximum daily load (TMDL) for an impaired waterbody. The primary objective of an approved TMDL is to establish pollutant load allocations to point and nonpoint sources in order to achieve pollutant load reductions needed to meet water quality goals (WDNR 2019). Meeting these water quality goals in turn should theoretically improve water quality and eventually lead to the delisting of the impaired waterbody from the impaired waters and restoration waters list.

The Wisconsin River TMDL study area extends from the headwaters in Vilas County to Lake Wisconsin in Columbia County, terminating at the Alliant Energy Hydrodam at Prairie du Sac. The TMDL area covers 9,156 square miles, approximately 15 percent of the state of Wisconsin. The U.S. EPA approved the Wisconsin River TMDL on April 26, 2019.

Mid Lake's watershed (red outline) lies within the WDNRs total maximum daily load (TMDL) project area (Figure 3.2-3. There are four regions within the project area, headwaters, upper, central and lower regions (Figure 3.2-1). Mid Lake composes a small area within the headwaters region. The headwaters region are characterized as primarily having glacial lakes, small connecting streams, rare aquatic species, widespread forests, and extensive wetlands (WDNR 2019). The Tomahawk River sub-watershed is 356,536 acres and is estimated to contribute 23,400 lbs of phosphorus to the Wisconsin River TMDL (WDNR 2019).

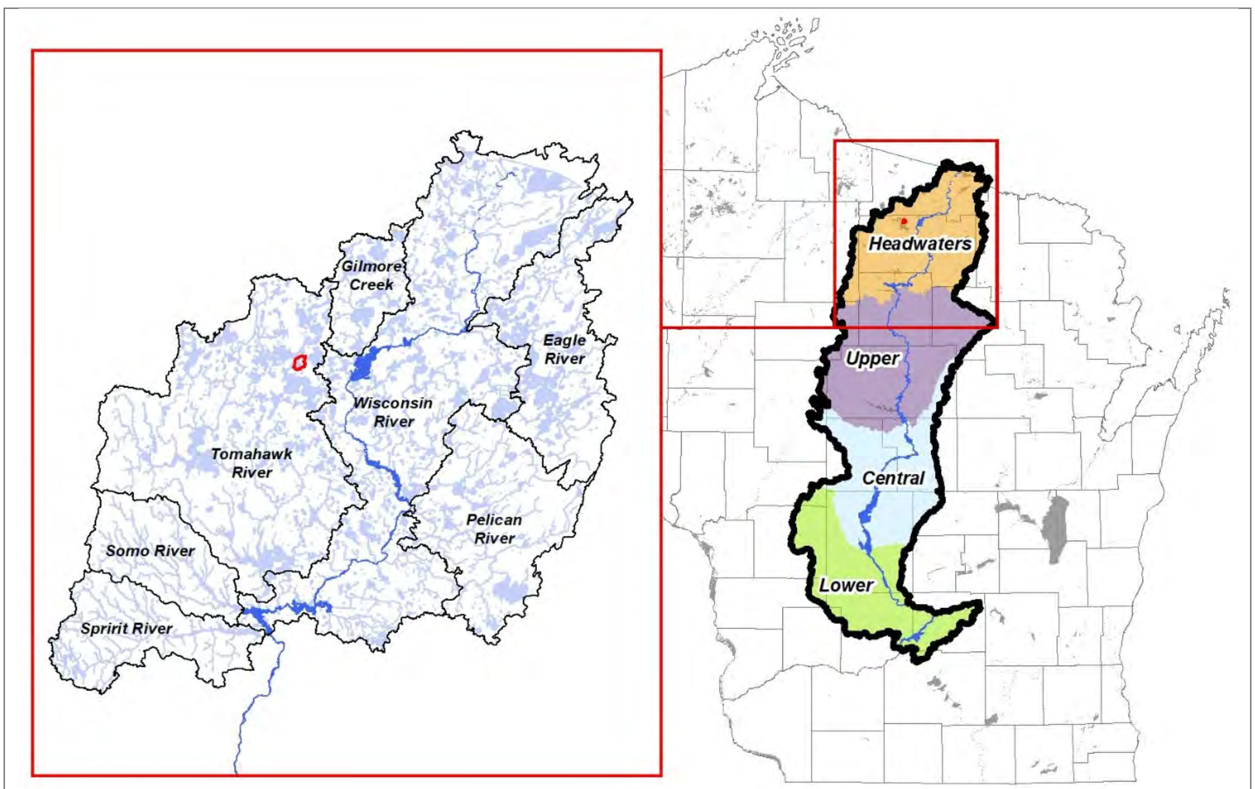


Figure 3.2-3. Wisconsin River TMDL. Headwaters sub-watershed shown within inset. WDNR 2019.

3.3 Shoreland Condition

Lake Shoreland Zone and its Importance

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) effects on the lake is important in maintaining the quality of the lake's water and habitat.

The intrinsic value of natural shorelands is found in numerous forms. Vegetated shorelands prevent polluted runoff from entering lakes by filtering this water or allowing it to slow to the point where particulates settle. The roots of shoreland plants stabilize the soil, thereby preventing shoreland erosion. Shorelands also provide habitat for both aquatic and terrestrial animal species. Many species rely on natural shorelands for all or part of their life cycle as a source of food, cover from predators, and as a place to raise their young. Shorelands and the nearby shallow waters serve as spawning grounds for fish and nesting sites for birds. Thus, both the removal of vegetation and the inclusion of development reduces many forms of habitat for wildlife.

Some forms of development may provide habitat for less than desirable species. Disturbed areas are often overtaken by invasive species, which are sometimes termed "pioneer species" for this reason. Some waterfowl, such as geese, prefer to linger upon open lawns near waterbodies because of the lack of cover for potential predators. The presence of geese on a lake resident's beach may not be an issue; however, the feces the geese leave are unsightly and pose a health risk. Geese feces may become a source of fecal coliforms as well as flatworms that can lead to swimmers' itch. Development such as rip rap or masonry, steel or wooden seawalls completely remove natural habitat for most animals, but may also create some habitat for snails; this is not desirable for lakes that experience problems with swimmers' itch, as the flatworms that cause this skin reaction utilize snails as a secondary host after waterfowl.

In the end, natural shorelines provide many ecological and other benefits. Between the abundant wildlife, the lush vegetation, and the presence of native flowers, shorelands also provide natural scenic beauty and a sense of tranquility for humans.

Shoreland Zone Regulations

Wisconsin has numerous regulations in place at the state level which aim to enhance and protect shorelands. Additionally, counties, townships and other municipalities have developed their own (often more comprehensive or stronger) policies. At the state level, the following shoreland regulations exist:

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted stricter shoreland ordinances. Revised in February of 2010, and again in October of 2014, the finalized NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below.

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed 35 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: In general, the amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit, up to 30% for residential land use. Exceptions to this limit do exist if a county has designated highly-developed areas, so it is recommended to consult county-specific zoning regulations for this standard.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet. Other specifications must be met as well, and local zoning regulations should be referenced.

Mitigation requirements: Language in NR-115 specifies mitigation techniques that may be incorporated on a property to offset the impacts of impervious surface, replacement of nonconforming structure, or other development projects. Practices such as buffer restorations along the shoreland zone, rain gardens, removal of fire pits, and beaches all may be acceptable mitigation methods. Mitigation requirements are county-specific and any such projects should be discussed with local zoning to determine the requirements.

Wisconsin Act 31

While not directly aimed at regulating shoreland practices, the State of Wisconsin passed Wisconsin Act 31 in 2009 in an effort to minimize watercraft impacts upon shorelines. This act prohibits a person from operating a watercraft (other than personal watercraft) at a speed in excess of slow-no-wake speed within 100 feet of a pier, raft, buoyed area or the shoreline of a lake. Additionally, personal watercraft must abide by slow-no-wake speeds while within 200 feet of these same areas. Act 31 was put into place to reduce wave action upon the sensitive shoreland zone of a lake. The legislation does state that pickup and drop off areas marked with regulatory markers and that are open to personal watercraft operators and motorboats engaged in waterskiing/a similar activity may be exempt from this distance restriction. Additionally, a city, village, town, public inland lake protection and rehabilitation district or town sanitary district may provide an exemption from the 100-foot requirement or may substitute a lesser number of feet.

Shoreland Research

Studies conducted on nutrient runoff from Wisconsin lake shorelands have produced interesting results. For example, a USGS study on several Northwoods Wisconsin lakes was conducted to determine the impact of shoreland development on nutrient (phosphorus and nitrogen) export to these lakes (Graczyk et al. 2003). During the study period, water samples were collected from surface runoff and ground water and analyzed for nutrients. These studies were conducted on several developed (lawn covered) and undeveloped (undisturbed forest) areas on each lake. The study found that nutrient yields were greater from lawns than from forested catchments, but also that runoff water volumes were the most important factor in determining whether lawns or wooded catchments contributed more nutrients to the lake. Groundwater inputs to the lake were found to be significant in terms of water flow and nutrient input. Nitrate plus nitrite nitrogen and total phosphorus yields to the ground-water system from a lawn catchment were three or sometimes four times greater than those from wooded catchments.

A separate USGS study was conducted on the Lauderdale Lakes in southern Wisconsin, looking at nutrient runoff from different types of developed shorelands – regular fertilizer application lawns (fertilizer with phosphorus), non-phosphorus fertilizer application sites, and unfertilized sites (Garn 2002). One of the important findings stemming from this study was that the amount of dissolved phosphorus coming off of regular fertilizer application lawns was twice that of lawns with non-phosphorus or no fertilizer. Dissolved phosphorus is a form in which the phosphorus molecule is not bound to a particle of any kind; in this respect, it is readily available to algae. Therefore, these studies show us that it is a developed shoreland that is continuously maintained in an unnatural manner (receiving phosphorus rich fertilizer) that impacts lakes the greatest. This understanding led former Governor Jim Doyle into passing the Wisconsin Zero-Phosphorus Fertilizer Law (Wis Statue 94.643), which restricts the use, sale, and display of lawn and turf fertilizer which contains phosphorus. Certain exceptions apply, but after April 1 2010, use of this type of fertilizer is prohibited on lawns and turf in Wisconsin. The goal of this action is to reduce the impact of developed lawns, and is particularly helpful to developed lawns situated near Wisconsin waterbodies.

Shorelands provide much in terms of nutrient retention and mitigation, but also play an important role in wildlife habitat. Woodford and Meyer (2003) found that green frog density was negatively correlated with development density in Wisconsin lakes. As development increased, the habitat for green frogs decreased and thus populations became significantly lower. Common loons, a bird species notorious for its haunting call that echoes across Wisconsin lakes, are often associated more so with undeveloped lakes than developed lakes (Lindsay, Gillum and Meyer 2002). And studies on shoreland development and fish nests show that undeveloped shorelands are preferred as well. In a study conducted on three Minnesota lakes, researchers found that only 74 of 852 black crappie nests were found near shorelines that had any type of dwelling on it (Reed 2001). The remaining nests were all located along undeveloped shoreland.

Emerging research in Wisconsin has shown that coarse woody habitat (sometimes called "coarse woody debris"), often stemming from natural or undeveloped shorelands, provides many ecosystem benefits in a lake. Coarse woody habitat describes habitat consisting of trees, limbs, branches, roots and wood fragments at least four inches in diameter that enter a lake by natural or human means. Coarse woody habitat provides shoreland erosion control, a carbon source for the lake, prevents suspension of sediments and provides a surface for algal growth which important for aquatic macroinvertebrates (Sass 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

Photograph 3.3-1. Example of coarse woody habitat in a lake.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area, as well as spawning habitat (Hanchin, Willis and St. Stauver 2003). In one study, researchers observed 16 different species occupying coarse woody habitat areas in a Wisconsin lake (Newbrey et al. 2005). Bluegill and bass species in particular are attracted to this habitat type; largemouth bass stalk bluegill in these areas while the bluegill hide amongst the debris and often feed upon many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. Newbrey et al. (2005) found that some fish species prefer different complexity of branching on coarse woody habitat, though in general some degree of branching is preferred over coarse woody habitat that has no branching.

With development of a lake's shoreland zone, much of the coarse woody habitat that was once found in Wisconsin lakes has disappeared. Prior to human establishment and development on lakes (mid to late 1800's), the amount of coarse woody habitat in lakes was likely greater than under completely natural conditions due to logging practices. However, with changes in the logging industry and increasing development along lake shorelands, coarse woody habitat has decreased substantially. Shoreland residents are removing woody debris to improve aesthetics or for recreational opportunities such as boating, swimming, and ironically, fishing.

National Lakes Assessment

Unfortunately, along with Wisconsin's lakes, waterbodies within the entire United States have shown to have increasing amounts of developed shorelands. The National Lakes Assessment (NLA) is an Environmental Protection Agency sponsored assessment that has successfully pooled together resource managers from all 50 U.S. states in an effort to assess waterbodies, both natural and man-made, from each state. Through this collaborative effort, over 1,000 lakes were sampled in 2007, pooling together the first statistical analysis of the nation's lakes and reservoirs.

Through the National Lakes Assessment, a number of potential stressors were examined, including nutrient impairment, algal toxins, fish tissue contaminants, physical habitat, and others. The 2007 NLA report states that "*of the stressors examined, poor lakeshore habitat is the biggest problem in the nations lakes; over one-third exhibit poor shoreline habitat condition*" (USEPA 2009).

Furthermore, the report states that "*poor biological health is three times more likely in lakes with poor lakeshore habitat.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to grow.

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 shoreland. 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 shoreland 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 3.3-2. 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.

Wisconsin's Healthy Lakes & Rivers Action Plan

Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forward shoreland restoration activities. This program provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program has identified five best practices aimed at improving habitat and water quality (Figure 3.3-1).

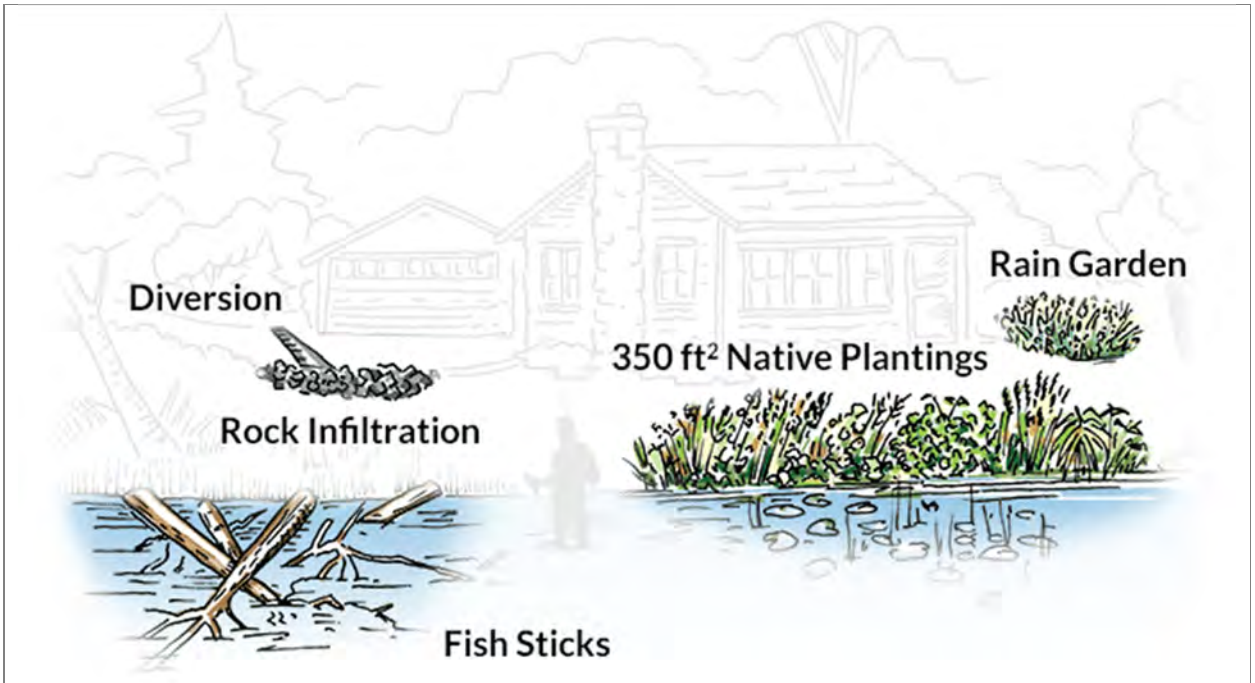


Figure 3.3-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

- Rain Gardens: This upland best practice consists of a landscaped and vegetated shallow depression aimed at capturing water runoff and allowing it to infiltrate into the soil.
- Rock Infiltration: This upland best practice is an excavated pit or trench, filled with rock, that encourages water to infiltrate into the soil. These practices are strategically placed at along a roof line or the downward sloping area of a driveway.
- Diversion: This best practice can occur in the transition or upland zone. These practices use berms, trenches, and/or treated lumber to redirect water that would otherwise move downhill into a lake. Water diversions may direct water into a Rock Infiltration or Rain Garden to provide the greatest reductions in runoff volumes.
- Native Plantings: This best practice aims to installing native plants within at least 350 square-foot shoreland transition area. This will slow runoff water and provide valuable habitat. One native planting per property per year is eligible.
- Fish Sticks: These in-lake best practices (not eligible for rivers) are woody habitat structures that provide feeding, breeding, and nesting areas for wildlife. Fish sticks consist of multiple whole trees grouped together and anchored to the shore. Trees are not felled from the shoreline, as existing trees are valuable in place, but brought from a short distance or dragged across the ice. In order for this practice to be eligible, an existing vegetated buffer or pledge to install one is required.

The Healthy Lakes and Rivers Grant Program allows partial cost coverage for implementing best practices. Competitive grants are available to eligible applicants such as lake associations and lake districts. The program allows a 75% state cost share up to $1,000 per practice. Multiple practices can be included per grant application, with a $25,000 maximum award per year. Eligible projects need to be on shoreland properties within 1,000 feet of a lake or 300 feet from a river. The landowner must sign a Conservation Commitment pledge to leave the practice in place and provide continued maintenance for 10 years. More information on this program can be found here:

https://healthylakeswi.com/

It is important to note that this grant program is intentionally designed for relatively simple, low-cost, and shovel-ready projects, limiting 10% of the grant award for technical assistance. Larger and more complex projects, especially those that require engineering design components may seek alternative funding sources potentially through the County. Small-Scale Lake Planning Grants can provide up to $3,000 to help build a Healthy Lakes and Rivers project. Eligible expenses in this grant program are surveys, planning, and design.

Mid Lake Shoreland Zone Condition

Shoreland Development

The Mid Lake Protection and Management District completed a *Comprehensive Management Plan* in 2013. Within that plan, a management action was outlined where the district would complete a shoreline condition assessment the next time an updated plan is created.

Mid Lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.3-2 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state.

On Mid Lake, the development stage of the entire shoreland was surveyed during Fall of 2019, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-3.

Mid Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.6 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.3-3). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.74 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Mid Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

Urbanized: This type of shoreline has essentially no natural habitat. Areas that are mowed or unnaturally landscaped to the water's edge and areas that are rip-rapped or include a seawall would be placed in this category.

Developed-Unnatural: This category includes shorelines that have been developed, but only have small remnants of natural habitat yet intact. A property with many trees, but no remaining understory or herbaceous layer would be included within this category. Also, a property that has left a small (less than 30 feet), natural buffer in place, but has urbanized the areas behind the buffer would be included in this category.

Developed-Semi-Natural: This is a developed shoreline that is mostly in a natural state. Developed properties that have left much of the natural habitat in state, but have added gathering areas, small beaches, etc. within those natural areas would likely fall into this category. An urbanized shoreline that was restored would likely be included here, also.

Developed-Natural: This category includes shorelines that are developed property, but essentially no modifications to the natural habitat have been made. Developed properties that have maintained the natural habitat and only added a path leading to a single pier would fall into this category.

Natural/Undeveloped: This category includes shorelines in a natural, undisturbed state. No signs of anthropogenic impact can be found on these shorelines. In forested areas, herbaceous, understory, and canopy layers would be intact.

Figure 3.3-2. Shoreland assessment category descriptions.

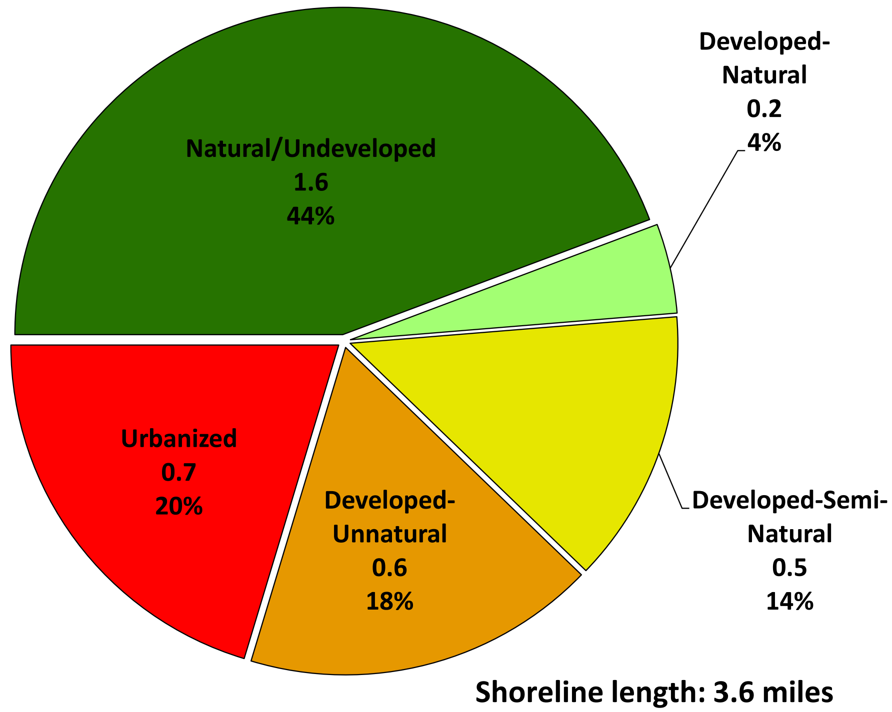


Figure 3.3-3. Mid Lake shoreland categories and total lengths. Based upon a Fall 2019 survey. Locations of these categorized shorelands can be found on Map 3.

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, un-sloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. And, allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

Coarse Woody Habitat

As part of the shoreland condition assessment, Mid Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

During this survey, 71 total pieces of coarse woody habitat were observed along 3.6 miles of shoreline (Map 4), which gives Mid Lake a coarse woody habitat to shoreline mile ratio of 20:1 (Figure 3.3-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Sixty-seven pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, four pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters of coarse woody habitat were found.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Mid Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Onterra has completed coarse woody habitat surveys on 111 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Mid Lake falls in the 36th percentile of these lakes. (Figure 3.3-4).

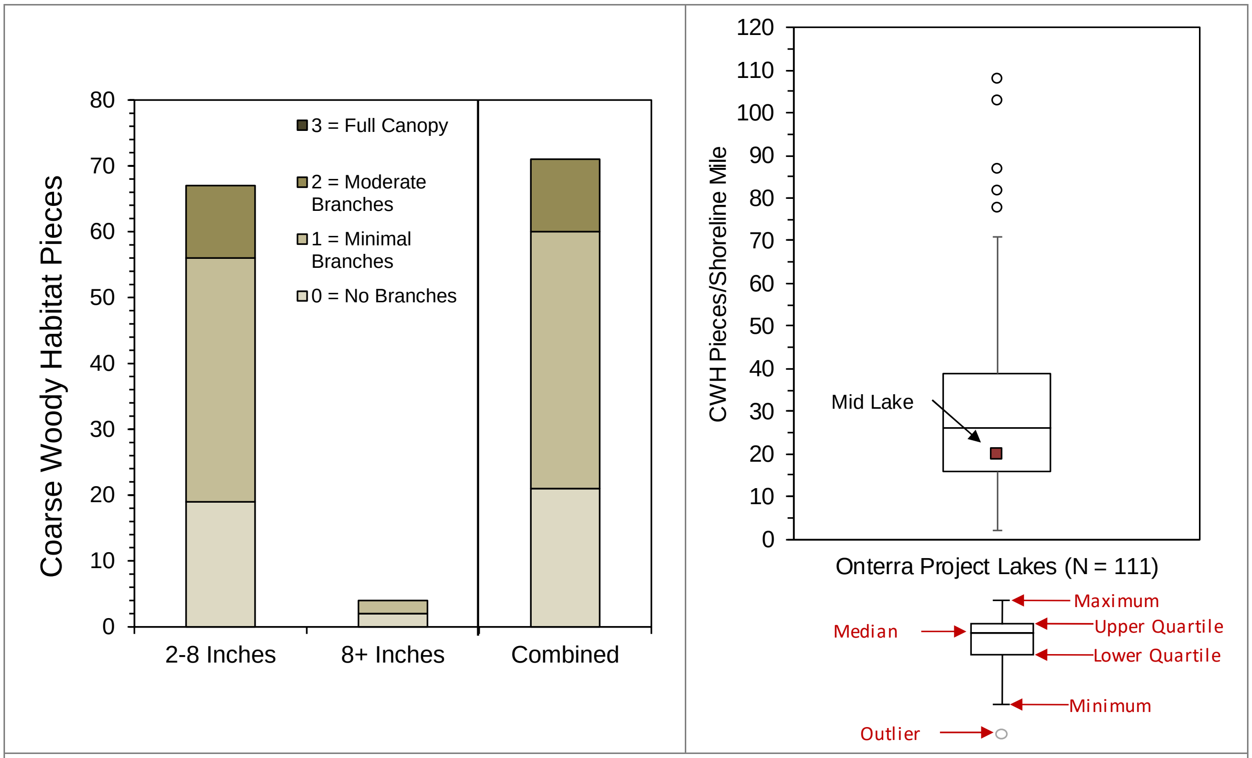


Figure 3.3-4. Mid Lake coarse woody habitat survey results. Based upon an Fall 2019 survey. Locations of the Mid Lake coarse woody habitat can be found on Map 4.

3.4 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.

Photograph 3.4-1. Example of emergent and floating-leaf plant community.

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 shoreland 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 predation by predator fish, which could result in a stunted pan-fish population. Exotic plant species, such as Eurasian watermilfoil (*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 species will be discussed further in depth in the Aquatic Invasive Species section. 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

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.

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.

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.

Manual Removal (Hand-Harvesting & DASH)

Photograph 3.4-2. Example of aquatic plants that have been removed manually.

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.

Manual removal or hand-harvesting of aquatic invasive species has gained favor in recent years as an alternative to herbicide control programs. Professional hand-harvesting firms can be contracted for these efforts and can either use basic snorkeling or scuba divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process.

Cost

Contracting aquatic invasive species removal by third-party firm can cost approximately $1,500 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,500 when DASH technology is used. Additional disposal, travel, and permitting fees may also apply.

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 depending on the size of the screen a Wisconsin Department of Natural Resources permit may be required.

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.

Mechanical Harvesting

Photograph 3.4-3. Mechanical harvester.

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.

Cost

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.

Herbicide Treatment

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers. Traditionally, herbicides were used to control nuisance levels of aquatic plants and algae that interfere with navigation and recreation. While this practice still takes place in many parts of Wisconsin, the use of herbicides to control aquatic invasive species is becoming more prevalent. Resource managers employ strategic management techniques towards aquatic invasive species, with the objective of reducing the target plant's population over time; and an overarching goal of attaining long-term ecological restoration. For submergent vegetation, this largely consists of implementing control strategies early in the growing season; either as spatially-targeted, small-scale spot treatments or low-dose, large-scale (whole lake) treatments. Treatments occurring roughly each year before June 1 and/or when water temperatures are below 60°F can be less impactful to many native plants, which have not emerged yet at this time of year. Emergent species are targeted with foliar applications at strategic times of the year when the target plant is more likely to absorb the herbicide.

While there are approximately 300 herbicides registered for terrestrial use in the United States, only 13 active ingredients can be applied into or near aquatic systems. All aquatic herbicides must be applied in accordance with the product's US Environmental Protection Agency (EPA) approved label. There are numerous formulations and brands of aquatic herbicides and an extensive list can be found in Appendix F of Gettys et al. (2009).

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

Aquatic herbicides can be classified in many ways. Organization of this section follows Netherland (2009) in which mode of action (i.e. how the herbicide works) and application techniques (i.e. foliar or submersed treatment) group the aquatic herbicides. The table below provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from Netherland (2009).

The arguably clearest division amongst aquatic herbicides is their general mode of action and fall into two basic categories:

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 in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.

Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

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.

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 and 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. Much information has been gathered in recent years, largely as a result of an ongoing cooperative research project between the Wisconsin Department of Natural Resources, US Army Corps of Engineers Research and Development Center, and private consultants (including Onterra). This research couples quantitative aquatic plant monitoring with field-collected herbicide concentration data to evaluate efficacy and selectivity of control strategies implemented on a subset of Wisconsin lakes and flowages. Based on their preliminary findings, lake managers have adopted two main treatment strategies: 1) whole-lake treatments, and 2) spot treatments.

Table 3.4-1. Common herbicides used for aquatic plant management.

General Mode of Action		Compound	Specific Mode of Action	Most Common Target Species in Wisconsin
Contact		Copper	plant cell toxicant	Algae, including macro-algae (i.e. muskgrasses & stoneworts)
		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; invasive watermilfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance species including duckweeds, targeted AIS control when exposure times are low
		Flumioxazin	Inhibits photosynthesis & destroys cell membranes	Nusiance species, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Florpyrauxifen -benzyl	arylpicolinate auxin mimic, growth regulator, different binding afinity than 2,4-D or triclopyr	Submersed species, largely for invasive watermilfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for invasive watermilfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	Emergent species with potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

Spot treatments are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant affects outside of that area. Spot treatments typically rely on a short exposure time (often hours) to cause mortality and therefore are applied at a much higher herbicide concentration than whole-lake treatments. This has been the strategy historically used on most Wisconsin systems.

Whole-lake treatments are those where the herbicide is applied to specific sites, but when the herbicide reaches equilibrium within the entire volume of water (entire lake, lake basin, or within the epilimnion of the lake or lake basin); it is at a concentration that is sufficient to cause mortality to the target plant within that entire lake or basin. The application rate of a whole-lake treatment is dictated by the volume of water in which the herbicide will reach equilibrium. Because exposure time is so much longer, target herbicide levels for whole-lake treatments are significantly less than for spot treatments.

Cost

Herbicide application charges vary greatly between $400 and $1,500 per acre depending on the chemical used, who applies it, permitting procedures, and the size/depth of the treatment area.

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • Herbicides can be economical at certain scales compared with other management options. • Herbicide type and application timing can increase selectivity towards target species. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fish kills 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 aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

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 water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata),* respectively.

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian watermilfoil 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 watermilfoil 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 watermilfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian watermilfoil.

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 watermilfoil 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, such as increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways. For example, there may be a loss of one or more species. Certain life forms, such as emergent or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. 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 assessing both native and non-native plant populations were completed on Mid Lake in 2019 as part of the management planning update. 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 subsequently.

Primer on Data Analysis & Data Interpretation

Species List

The species list is a list of all of the aquatic plant species, both native and non-native, that have been located in Mid Lake to date from surveys completed between 2008 and 2019. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, current statue in Wisconsin, 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 growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant 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 the whole-lake point-intercept surveys completed on Mid Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake's aquatic plant community is calculated using its native *species richness* and their *average conservatism*. Species richness is the number of native aquatic plant species that were physically encountered on the rake during the point-intercept survey. Average conservatism is calculated by taking the sum of the coefficients of conservatism (C-values) of the native species located and dividing it by species richness. Every plant in Wisconsin has been assigned a coefficient of conservatism, ranging from 1-10, which describes the likelihood of that species being found in an undisturbed environment. Species which are more specialized and require undisturbed habitat are given higher coefficients, while species which are more tolerant of environmental disturbance have lower coefficients.

For example, algal-leaf pondweed (*Potamogeton confervoides*) is only found in nutrient-poor, acid lakes in northern Wisconsin and is prone to decline if degradation of these lakes occurs. Because of algal-leaf pondweed's special requirements and sensitivity to disturbance, it has a C-value of 10. In contrast, sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity. Higher average conservatism values generally indicate a healthier lake as it is able to support a greater number of environmentally-sensitive aquatic plant species. Low average conservatism values indicate a degraded environment, one that is only able to support disturbance-tolerant species.

On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept surveys (equation shown below). This assessment allows the aquatic plant community of Mid Lake to be compared to other lakes within the region and state.

FQI = Average Coefficient of Conservatism * √ Number of Native Species

Species Diversity

Species diversity is often confused with species richness. As defined previously, species richness is simply the number of species found within a given community. While species diversity utilizes species richness, it also takes into account evenness or the variation in abundance of the individual species within the community. For example, a lake with 10 aquatic plant species that had relatively similar abundances within the community would be more diverse than another lake with 10 aquatic plant species were 50% of the community was comprised of just one or two species.

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. A lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. The diversity of a lake's aquatic plant community is determined using the Simpson's Diversity Index (1-D):

$$D = \sum (n/N)^2$$

where:
n = the total number of instances of a particular species
N = the total number of instances of all species and
D is a value between 0 and 1

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species.

The Simpson's Diversity Index value from Mid Lake is compared to data collected by Onterra and the WDNR Science Services on 212 lakes withn the Northern Lakes and Forests ecoregion and on 392 lakes throughout Wisconsin.

Emergent and Floating-leaf Aquatic Plant Community Mapping

A key component of any aquatic plant community assessment is the delineation of the emergent and floating-leaf aquatic plant communities within each lake as these plants are often underrepresented during the point-intercept survey. This survey creates a snapshot of these important communities within each lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. Examples of emergent plants include cattails, rushes, sedges, grasses, bur-reeds, and arrowheads, while examples of floating-leaf species include the water lilies. The emergent and floating-leaf aquatic plant communities in Mid Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

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 watermilfoil are the primary targets of this extra attention.

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian watermilfoil 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 watermilfoil 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 watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

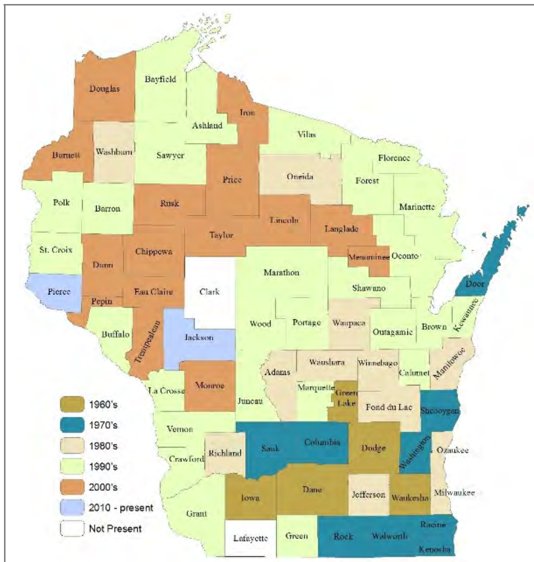


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2015 mapped by Onterra.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. Curly – leaf pondweed begins growing almost immediately after ice-out and by mid-June is at peak biomass. While it is growing, each plant produces many turions (asexual reproductive shoots) along its stem. By mid-July most of the plants have senesced, or died-back, leaving the turions in the sediment. The turions lie dormant until fall when they germinate to produce winter foliage, which thrives under the winter snow and ice. It remains in this state until spring foliage is produced in early May, giving the plant a significant jump on native vegetation. Like Eurasian watermilfoil, 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 watermilfoil 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.

Mid Lake Aquatic Plant Survey Results

The first whole-lake aquatic plant point-intercept survey was completed on Mid Lake in 2008 as part of the development of the lake's first management plan. Point-intercept surveys were also completed annually from 2013-2018 as part of a curly-leaf pondweed (CLP) management project. As is discussed later in this section, this project was intended to utilize early-season herbicide treatments to reduce the CLP population. However, unexpectedly, the CLP population was found to have declined significantly despite no management actions occurring in the years from 2014-2018. Thus, the herbicide control strategy was postponed indefinitely. As part of the lake management planning update project, point-intercept surveys were also completed in 2019 and 2020. The data collected from these point-intercept surveys can be used to examine the dynamics of Mid Lake's aquatic plant community over time.

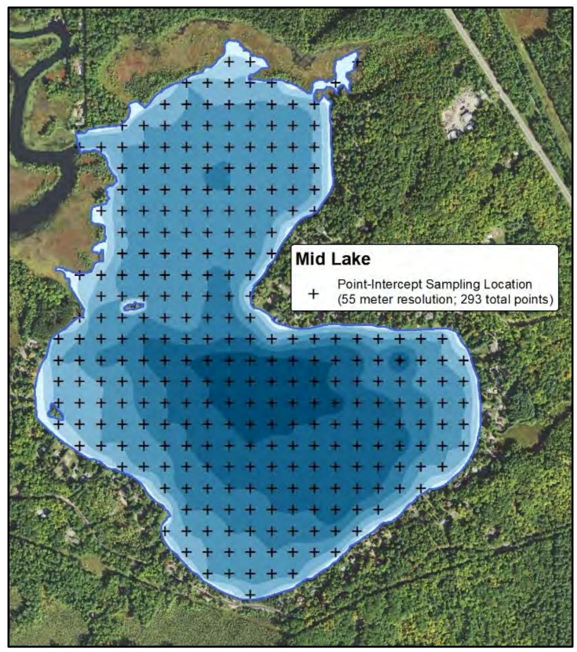


Figure 3.4-2. Mid Lake whole-lake point-intercept survey sampling locations.

In most instances, point-intercept surveys are completed in July or August to correspond with the peak growth of most of Wisconsin's native plant species. However, given most of the management activities on Mid Lake have been focused on CLP, all of the point-intercept surveys to date have been completed in June to correspond with its peak growth prior to senescence.

Since 2008, a total of 59 aquatic plant species have been located in Mid Lake (Table 3.4-2). Of these 59 species, five are considered to be non-native invasive species and include curly-leaf pondweed, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and flowering rush. Because of their ecological, economical, and sociological significance, these non-native species and their occurrence and management in Mid Lake is discussed in the subsequent *Non-Native Aquatic Plants in Mid Lake* subsection.

Table 3.4-2. Aquatic plant species located in Mid Lake during 2008-2020 surveys. Please note that in addition to point-intercept surveys, emergent/floating-leaf community mapping surveys were completed in 2008 and 2019, resulting in more of these species being recorded in these years.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2008	2013	2014	2015	2016	2017	2018	2019	2020
Emergent	*Calla palustris*	Water arum	Native	9	I								
	Carex pseudocyperus	Cypress-like sedge	Native	8								I	
	Decodon verticillatus	Water-willow	Native	7								I	
	Dulichium arundinaceum	Three-way sedge	Native	9									
	Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A	I							I	
	Juncus effusus	Soft rush	Native	4	I							I	
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A	I							I	
	Pontederia cordata	Pickerelweed	Native	9	I	X	X			X		X	X
	Sagittaria latifolia	Common arrowhead	Native	3	I								
	Sagittaria rigida	Stiff arrowhead	Native	8								I	
	Sagittaria sp.	Arrowhead sp.	Native	N/A								I	
	Schoenoplectus acutus	Hardstem bulrush	Native	5	I								
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4	I							I	
	Scirpus cyperinus	Wool grass	Native	4								I	
	Scutellaria galericulata	Common skullcap	Native	5	I								
	Sparganium americanum	American bur-reed	Native	8								I	
	Typha latifolia	Broad-leaved cattail	Native	1	I							I	
Floating-leaf	*Brasenia schreberi*	Watershield	Native	7	X	X	X	X	X	X	X	X	X
	Nuphar variegata	Spatterdock	Native	6	X	X	X	X	X	X	X	X	X
	Nymphaea odorata	White water lily	Native	6	X	X	X			X	X	X	X
	Persicaria amphibia	Water smartweed	Native	5	I							I	
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9	I								
	Sparganium fluctuans	Floating-leaf bur-reed	Native	10							X		
FL/E	*Sparganium emersum* var. *acaule*	Short-stemmed bur-reed	Native	8		I							
Submergent	*Bidens beckii*	Water marigold	Native	8	I				X	X	X	X	X
	Ceratophyllum demersum	Coontail	Native	3	X	X	X	X	X	X	X	X	X
	Chara spp.	Muskgrasses	Native	7	I		X	X	X	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3	X	X	X	X	X	X	X	X	X
	Elodea nuttallii	Slender waterweed	Native	7					X				
	Heteranthera dubia	Water stargrass	Native	6	X		X	X	X	X	X	X	
	Isoetes echinospora	Spiny-spored quillwort	Native	8	I								
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X	X	X	X	X	X	X	I	
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A						X		I	
	Najas flexilis	Slender naiad	Native	6	X	X	X	X	X	X	X	X	X
	Najas guadalupensis	Southern naiad	Native	7		X	X	X	X	X	X	X	X
	Nitella spp.	Stoneworts	Native	7		X							
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X	X	X	X	X	X	X	X
	Potamogeton berchtoldii/pusillus	Slender/Small pondweed	Native	7	X	X		X	X	X	X		X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X	X		X	X	X		X	
	Potamogeton gramineus	Variable-leaf pondweed	Native	7	X	X	X		X			X	
	Potamogeton illinoensis	Illinois pondweed	Native	6	X	X	X	X	X	X	X	X	X
	Potamogeton praelongus	White-stem pondweed	Native	8	X	X	X	X	X	X	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X	X	X	X	X	X	X	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	Native	8	X	X	X	X	X	X	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	Native	8					X			I	X
	Potamogeton strictifolius	Stiff pondweed	Native	8		X	X	X	X	X	X	I	X
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X	X	X	X	X	X	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8	X	X			X	X			
	Ranunculus flammula	Creeping spearwort	Native	9		X							
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A		X	X		X	X			
	Utricularia vulgaris	Common bladderwort	Native	7	X	X				X		I	X
	Vallisneria americana	Wild celery	Native	6	X			X		X		X	X
S/E	*Butomus umbellatus*	Flowering rush	Non-Native - Invasive	N/A								I	
	Eleocharis acicularis	Needle spikerush	Native	5	I	X				X	X	X	X
	Sagittaria cristata	Crested arrowhead	Native	9	I								
FF	*Lemna minor*	Lesser duckweed	Native	5	X				X				
	Lemna trisulca	Forked duckweed	Native	6	X	X	X	X	X	X	X	X	X
	Lemna turionifera	Turion duckweed	Native	2		X							X
	Spirodela polyrhiza	Greater duckweed	Native	5	I	X						I	

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL/E = Floating-leaf and Emergent; S/E = Submergent and/or Emergent; FF = Free-floating

Lakes in Wisconsin vary in their morphology, water chemistry, substrate composition, recreational use, and management, and all of these factors influence aquatic plant community composition and dynamics. Like terrestrial plants, aquatic plant species are adapted to grow in certain substrate types – some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. A diversity of substrate types increases the number of habitat types for aquatic plants and generally results in a higher number of species within the lake.

During the 2020 whole-lake point-intercept survey on Mid Lake, information regarding substrate type was collected at locations sampled with a pole-mounted rake. These data indicate that most of Mid Lake contains soft, organic sediments, with 91% of the sampling locations containing this substrate type (Figure 3.4-3). Seven percent of the sampling locations contained sand, while the remaining 2% contained rock. Areas of harder substrates are located around the island and in shallow near-shore areas around the lake.

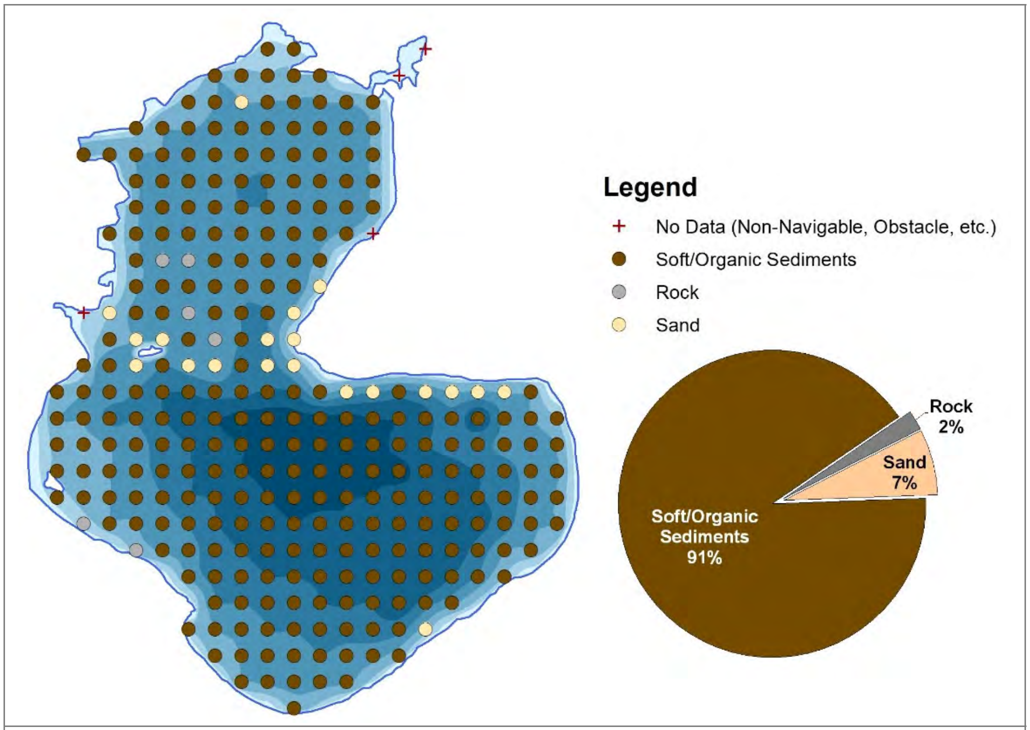


Figure 3.4-3. Mid Lake substrate types. Created using data from 2020 whole-lake point-intercept survey.

During all nine point-intercept surveys, aquatic plants were recorded growing to the maximum depth of the lake (13-15 feet), indicating that the entire area of Mid Lake is considered to be littoral zone. Aquatic plants typically grow to a depth two to three times the average Secchi disk depth, and Mid Lake's average growing season Secchi disk depth is relatively high at around 7.0 feet. The point-intercept data also show that aquatic plant abundance is high across littoral depths in Mid Lake. In 2020, nearly 100% of the sampling locations within 1-13 feet of water contained aquatic vegetation, while 75% of the sampling locations in 13-15 feet of water contained vegetation. The combination of high water clarity and soft substrates create ideal conditions for lush aquatic plant growth. As is discussed later in this section, while aquatic plant growth can grow to levels which interferes with recreation and navigation in Mid Lake, these plants are essential for maintaining the lake's clear water state (see discussion on shallow lakes and alternative stable states in Water Quality Section 3.1).

Of the 59 aquatic plant species that have been recorded since 2008, 27 were physically encountered on the rake during the 2020 point-intercept survey (Figure 3.4-4). Of these 27 species, fern-leaf pondweed, forked duckweed, coontail, flat-stem pondweed, and common waterweed were the five-most frequently encountered. Fern-leaf pondweed was the most abundant aquatic plant in Mid Lake in 2020 with a littoral frequency of occurrence of 89%. As its name indicates, this plant resembles a terrestrial fern frond in appearance (Figure 3.4-5), and is often a dominant species in plant communities of northern Wisconsin lakes. Fern pondweed is generally found growing in thick beds over soft substrates, where it stabilizes bottom sediments and provides a dense network of structural habitat for aquatic wildlife. In 2020, fern pondweed was abundant throughout littoral areas of Mid Lake, and was only absent from the deepest area of the lake.

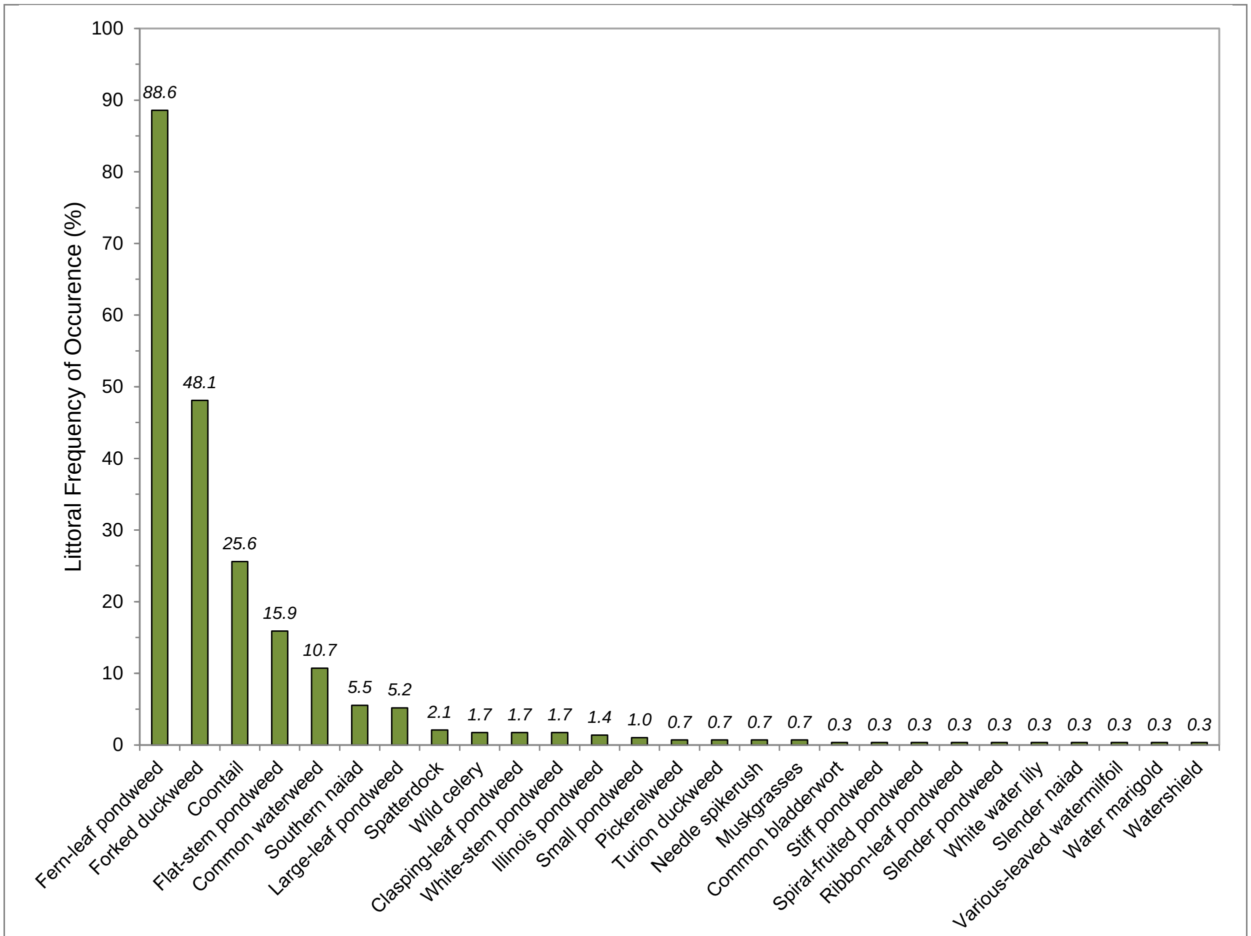


Figure 3.4-4. Littoral frequency of occurrence of aquatic plant species in Mid Lake in 2020. Non-native species indicated with red. N = 288.

The second-most frequently encountered aquatic plant in 2020 was forked duckweed with a littoral frequency of occurrence of 48% (Figures 3.4-4 and 3.4-5). Like the other six species of duckweed found in Wisconsin, forked duckweed is rootless and is found free-floating within the water; however, forked duckweed is found growing below the surface along the bottom or entangled among other plants as opposed to floating on the surface like the other duckweed species. Forked duckweed obtains all of its nutrients directly from the water and is found in waters with sufficient nutrients to sustain its growth. But because it grows beneath the surface, it also requires water with adequate light transparency.

Figure 3.4-5. Five most frequently encountered aquatic plant species in Mid Lake. Clockwise from upper left: fern-leaf pondweed, forked duckweed, coontail, flat-stem pondweed, and common waterweed. Photo credit Onterra.

Coontail was the third-most frequently-encountered aquatic plant species in Mid Lake in 2020 with a littoral frequency of occurrence of 26% (Figure 3.4-4 and 3.4-5). As its name indicates, the shape of this plant resembles the tail of a racoon. Coontail possess whorls of leaves which fork into two to three segments, and provides ample surface area for the growth of periphyton and habitat for invertebrates. Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives most of its nutrients directly from the water (Gross, Erhard and Ivanyi 2003). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in eutrophic waterbodies with higher nutrients and low water clarity. Coontail has the capacity to form dense beds that can float and mat on the water's surface.

The fourth-most frequently encountered species in Mid Lake in 2020 was flat-stem pondweed with a littoral frequency of occurrence of 16% (Figure 3.4-4 and 3.4-5). Flat-stem pondweed is often more abundant in productive lakes with soft sediments like Mid Lake. Flat-stem pondweed, as its name implies, can be distinguished from other thin-leaved pondweeds by its conspicuously flattened stem. Flat-stem pondweed can attain heights of 10 feet or greater, and provides excellent structural habitat for aquatic wildlife.

Common waterweed was the fifth-most frequently encountered aquatic plant in Mid Lake in 2019 with a littoral frequency of occurrence of 11% (Figure 3.4-4 and 3.4-5). Like coontail, common waterweed can be found in waterbodies across Wisconsin, is tolerant of high-nutrient, low-light conditions, and can grow to nuisance levels under ideal conditions. Common waterweed has blade-like leaves in whorls of three produced on long, slender stems. Like other submersed aquatic plants, common waterweed helps to stabilize bottom sediments and provides structural habitat and food for wildlife.

Because nine whole-lake point-intercept surveys have been completed on Mid Lake since 2008, these data can be compared to determine if and how the aquatic plant community has changed over time. The littoral occurrence of all aquatic vegetation time period from 2008-2020 ranged from 99% in 2008 and 2016 to 94% in 2015, with an average annual occurrence of 97% (Figure 3.4-6).

Total rake fullness (TRF) data were not recorded in 2008, and the TRF data from 2013-2020 have remained relatively consistent, with the proportion of combined TRF values of 2 and 3 ranging from 78-88% indicating high plant biomass throughout this six-year period. The proportion of TRF ratings of 2 and 3 in 2020 was 69%, lower than any previous survey since 2013 and indicating aquatic plant biomass was lower in 2020 when compared to previous years. Overall, these data indicate that the overall amount of vegetation in Mid Lake has not changed over time. As will be subsequently explored, changes in certain aquatic plant species have resulted in less aquatic plant biomass near the water's surface and more biomass lower in the water column.

While the distribution and abundance of vegetation in Mid Lake has changed little over the period from 2008-2019, there have been significant changes the distribution and abundance of individual native aquatic plant species. Overall, most native aquatic plant species have exhibited a declining trend in littoral occurrence. The data show that the number of native aquatic plant species recorded per sampling location has been declining, from an average of 3.3 and 3.5 in 2008 and 2013 to 2.2 in 2020 (Figure 3.4-7). Point-intercept data from five other northern Wisconsin lakes show similar rates of decline in the average number of native aquatic plant species per sampling location over this period, indicating regional environmental conditions may be driving these declines.

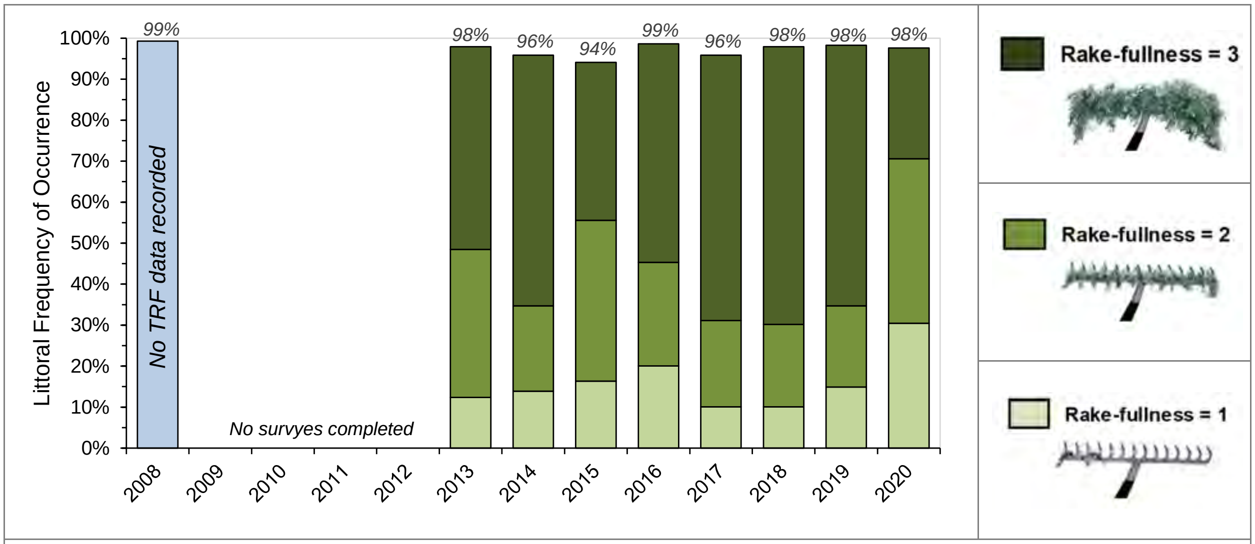


Figure 3.4-6. Mid Lake littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF) data from 2008 and 2013-2020. Please note TRF data were not recorded in 2008.

A Chi-Square Test was utilized to determine if changes in the littoral occurrence between surveys are statistically valid ($\alpha = 0.05$). Simple linear regression was also utilized to determine the presence of trends in littoral occurrence over time and if these trends were statistically valid ($\alpha = 0.05$). Aquatic plant species which had a littoral occurrence of at least 5% in one of the eight surveys were included in this analysis. Figure 3.4-7 illustrates the littoral occurrences of these aquatic plant species in Mid Lake over the period from 2008-2020. Please note that southern naiad (*Najas guadalupensis*) and slender naiad (*N. flexilis*) were combined for this analysis given their morphological similarity and occasional difficulty in separating in the field.

The littoral frequency of occurrence charts also include the littoral occurrences of these species from two other northern Wisconsin lakes (Boot Lake, Vilas Co. and Little Bearskin Lake, Oneida Co.) which have point-intercept data over this time period. Please note that data from these lakes in 2020 were not available at the time of this writing. Herbicides used to control non-native aquatic plants are known to cause changes in the occurrence of certain native aquatic plants following application. Mid Lake, Boot Lake, and Little Bearskin lake have not had any applications of herbicide for aquatic plant control over this period.

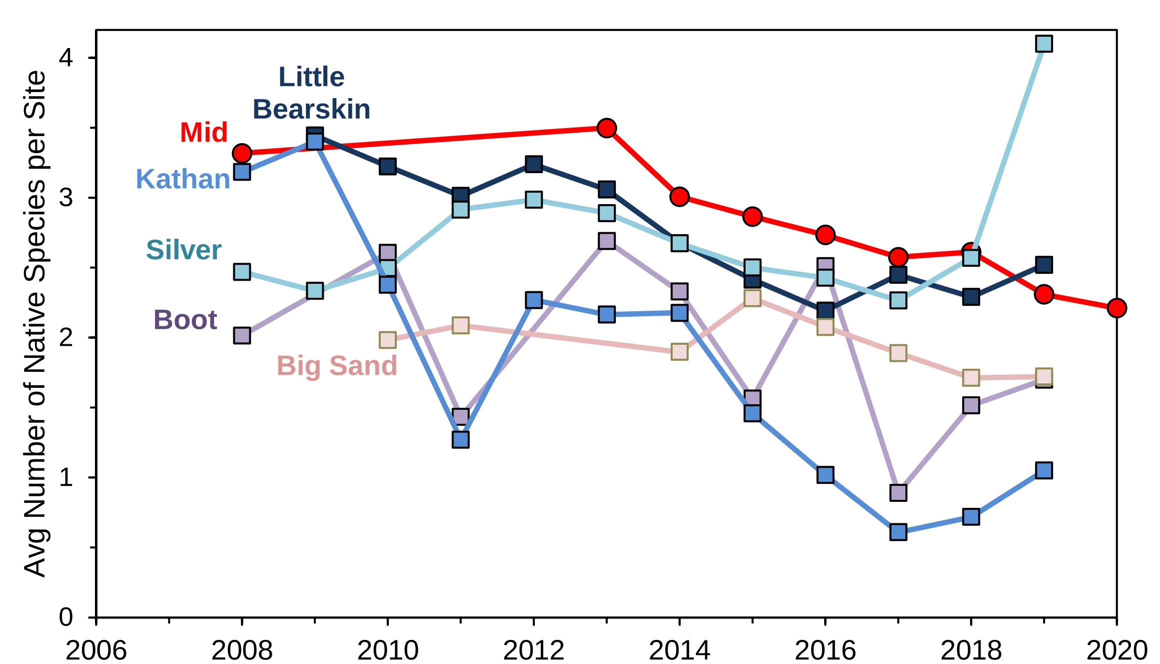


Figure 3.4-7. Average number of native aquatic plant species per sampling location in Mid Lake and four other regional lakes. Please note that large-scale 2,4-D treatments occurred on Big Sand Lake in 2008, 2009, and 2010, on Silver Lake in 2007 and 2016, and on Kathan Lake in 2010 and 2016. No herbicide treatments have occurred in Mid Lake, Boot Lake, or Little Bearskin Lake.

Of the nine native aquatic plant species included in this analysis, four have exhibited statistically valid decreasing trends in occurrence from 2008-2020, one has exhibited a statically valid increasing trend, and four have not exhibited a trend (positive or negative) in occurrence over this period. Fern-leaf pondweed was the only species to exhibit a statistically valid increasing trend (R^2 = 0.85; p-value < 0.001) in occurrence from 2008-2019 (Figure 3.4-8). Fern-leaf pondweed has increased in occurrence from 51% in 2008 to 89% in 2020, an average increase in occurrence of over 3 % per year. In contrast, fern-leaf pondweed has seen a slight decreasing trend in occurrence in Boot Lake, while no trend was detected over time in Little Bearskin Lake.

Coontail, flat-stem pondweed, white-stem pondweed, and southern/slender naiad have exhibited statistically valid decreasing trends in their littoral occurrences in Mid Lake from 2008-2020 (Figure 3.4-9). Coontail was the most frequently encountered aquatic plant species in Mid Lake in 2008 with a littoral occurrence of 65%. Coontail has since declined to an occurrence of 26% in 2020, an average decrease in occurrence of 3% per year (R^2 = 0.85; p-value = < 0.001). The occurrence of coontail in Boot and Little Bearskin lakes has also been declining at a similar rate to Mid Lake over this same time period.

Flat-stem pondweed has exhibited a statistically valid decreasing trend in occurrence from 2008-2019 in Mid Lake (R^2 = 0.74; p-value = 0.002), declining from an occurrence of 58% in 2008 to

16% in 2020 (Figure 3.4-8). While flat-stem pondweed saw a slight increase in occurrence from 2015-2017, it has seen a steep decline from 2017-2020. Overall, flat-stem pondweed has declined at a rate of 4% per year. A similar rate in decline in the occurrence of flat-stem pondweed over this period has also been observed in Boot Lake. The occurrence of flat-stem pondweed in Little Bearskin Lake has fluctuated over this time period, but no trends in occurrence were observed.

White-stem pondweed has declined in occurrence from 18% in 2008 to 2% in 2020, a decline of nearly 1.3% per year (R^2 = 0.81; p-value = < 0.001) (Figure 3.4-8). White-stem pondweed in Little Bearskin Lake has seen a similar rate of decline in occurrence to Mid Lake, while in Boot Lake white-stem pondweed has seen a lower rate of decline over this period.

While the decline in the occurrences of coontail, flat-stem pondweed, and white-stem pondweed have been relatively constant from 2008-2019, southern/slender naiad exhibited an abrupt decline in occurrence over a shorter period of time (Figure 3.4-8). From 2008-2015, the occurrence of southern/slender naiad was relatively consistent, ranging from 55% to 65%. However, its occurrence rapidly declined from 59% in 2015, to 27% in 2016, and 10% in 2017. Since 2017, its occurrence has increased slightly to 17% and 15% in 2018 and 2019, respectively, but declined to 6% in 2020. Overall, southern/slender naiad has exhibited a statistically valid decline in occurrence over this time period, declining at an average rate of 3.5% per year (R^2 = 0.62, p-value = 0.011).

There has been a slight increasing trend in the occurrence of forked duckweed in Mid Lake from 2008-2019, but this trend is not statistically valid (p-value = 0.071) (Figure 3.4-8). Boot and Little Bearskin lakes do not support large populations of forked duckweed, so comparisons with these lakes is not possible. Common waterweed, large-leaf pondweed, and small pondweed have seen decreasing trends from 2008-2019, but these trends were not statistically valid (p-value = 0.089, 0.621, and 0.120, respectively). Trends in the occurrences of these three species in Boot and Little Bearskin lakes are similar to those observed in Mid Lake.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations can be driven by a combination of natural factors including variations in temperature, ice and snow cover (winter light availability), nutrient availability, water levels and flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul and Freedman 2006). Adding to the complexity of factors which affect aquatic plant community dynamics, human-related disturbances such as the application of herbicides for non-native plant management, mechanical harvesting, watercraft use, and pollution runoff also affect aquatic plant community composition (Asplund and Cook 1997; Lacoul and Freedman 2006).

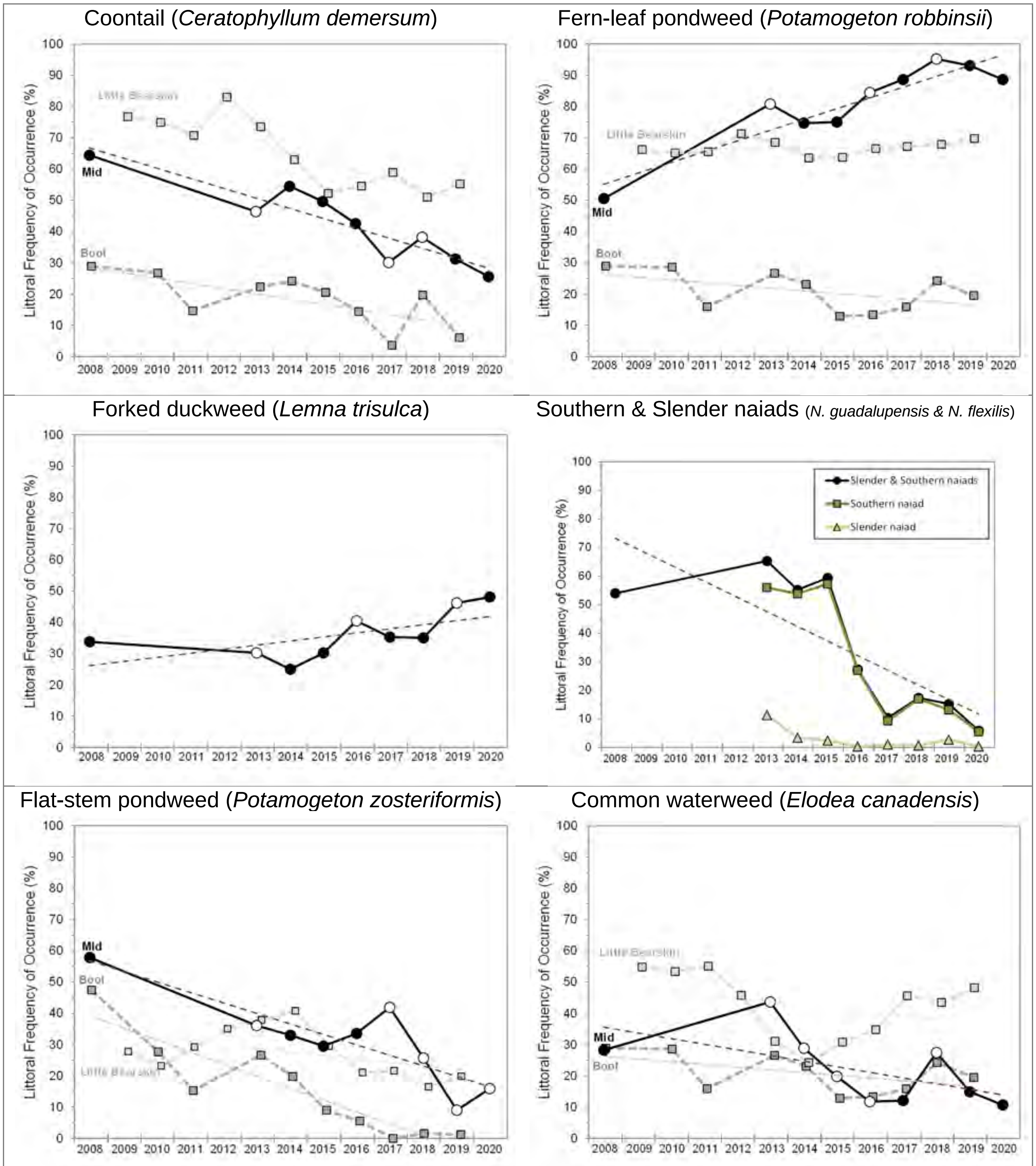


Figure 3.4-8. Littoral frequency of occurrence of select aquatic plant species in Mid Lake from 2008-2020. Open circles indicate occurrence is statistically different from previous survey (Chi-Square α = 0.05). Red dashed line indicates trend of species in Mid Lake (simple linear regression). Gray boxes and lines indicate occurrences of species in Boot and Little Bearskin lakes. Mid Lake data collected by Onterra. Little Bearskin Lake and Boot Lake data collected by Onterra and WDNR. Data from 2020 for Little Bearskin and Boot lakes were not available at the time of this writing.

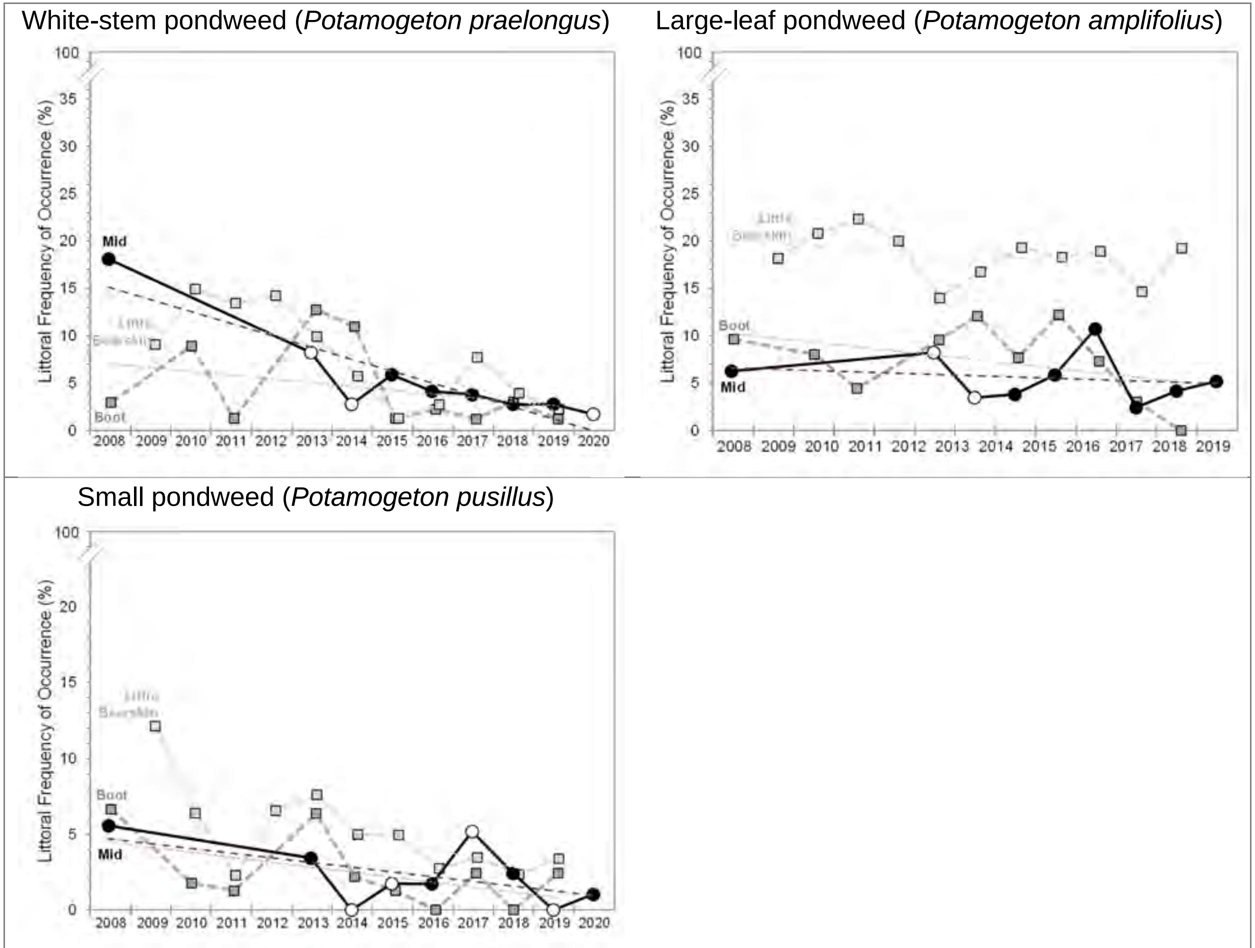


Figure 3.4-8 continued. Littoral frequency of occurrence of select aquatic plant species in Mid Lake from 2008-2020. Open circles indicate occurrence is statistically different from previous survey (Chi-Square α = 0.05). Red dashed line indicates trend of species in Mid Lake (simple linear regression). Gray boxes and lines indicate occurrences of species in Boot and Little Bearskin lakes. Mid Lake data collected by Onterra. Little Bearskin Lake and Boot Lake data collected by Onterra and WDNR. Data from 2020 for Little Bearskin and Boot lakes were not available at the time of this writing.

Some comments from the stakeholder survey questioned whether high-speed boating and wake boats could be contributing to the decline in aquatic plants observed. Studies have shown that these activities can have an impact on aquatic plant biomass, particularly in areas less than 10 feet in depth. Changes in water clarity, largely as a product of sediment resuspension, have been documented in several studies during periods of heavy recreation but are often short lived. Summer water clarity of Mid Lake has not been decreasing, with increases noted from 2013-2019. The primary mechanism for aquatic plant declines surrounding watercraft use has been direct cutting of the plant from the propeller, and secondarily from uprooting or scouring. Some pondweeds and turf-like species (isoetids) are likely most susceptible to cutting or uprooting, whereas largely non-rooted species like coontail and southern naiad are likely not impacted by boat traffic. The fact that susceptible and non-susceptible species are in decline on Mid Lake may suggest that watercraft activity is not the primary factor of the decline.

The similarity between the trends in occurrence of native plant species in Mid Lake with those in Boot and Little Bearskin lakes suggests that Mid Lake's plant community dynamics are likely being influenced to a greater extent by variations in regional environmental conditions than factors isolated to Mid Lake alone. While the changes Mid Lake's plant community from 2008-2020 are likely due to a combination of interacting factors, correlation analysis was used to explore relationships between native plant species' occurrences and environmental variables. Environmental variables included were mean annual growing season and summer air temperature, average daily winter snow depth, and growing season and summer total phosphorus, chlorophyll, and Secchi disk depth.

The occurrence of fern-leaf pondweed had a strong positive correlation with mean summer air temperature (r = 0.81) and mean summer Secchi disk depth (r = 0.75), and a strong negative correlation with mean summer chlorophyll (r = -0.88) (Table 3.4-3). In contrast, coontail had a strong negative relationship with mean summer temperature (r = -0.63) and mean summer Secchi disk depth (r = -0.71), and a strong positive relationship with summer chlorophyll (r = 0.86). While no statistically valid trends were detected for forked duckweed, its occurrence was most strongly correlated, negatively, with daily average winter snow depth (r = -0.47).

The occurrence of southern naiad had a strong negative correlation with mean summer air temperature (r = -0.65) and summer Secchi disk depth (r = -0.55), and a strong positive relationship with growing season chlorophyll (r = 0.78). Similarly, flat-stem pondweed had a strong negative correlation with mean summer air temperature (r = -0.55) and summer Secchi disk depth (-0.94), and strong positive correlation with summer total phosphorus (r =0.73) and summer chlorophyll (r = 0.90). White-stem pondweed had a strong negative correlation with mean summer temperature (r = -0.64) and mean summer Secchi disk depth (r = -0.88), and a strong positive correlation with mean summer chlorophyll (r = 0.97).

Common waterweed had moderate positive correlations with average daily winter snow depth (r = 0.51) and mean summer chlorophyll (r = 0.57), while it had a moderate negative correlation with mean summer Secchi disk depth (r = -0.44). Large-leaf pondweed had a strong negative correlation with average daily winter snow depth (r = -0.66) and a moderate negative correlation with mean summer Secchi disk depth (r = -0.44). Small pondweed had a strong negative correlation with mean summer Secchi disk depth (r = -0.79) and a moderate negative correlation with average daily winter snow depth (r = -0.45), while it had a strong to moderate positive correlations with mean summer chlorophyll (0.68) and mean summer total phosphorus (r = 0.50).

Table 3.4-3. Pearson correlation of select Mid Lake aquatic plant species littoral frequencies of occurrence and environmental variables. Air temperature and snow depth (Nov-April) obtained from Midwestern Regional Climate Center, Minocqua Station NWS 475516. Water quality data collected by Mid Lake CLMN volunteers and Onterra. Plant data collected by Onterra.

Scientific Name	Common Name	Mean Summer Air Temp (°F)	Avg Daily Snow Depth (in)	Mean Summer Total Phosphorus (μg/L)	Mean Summer Chlorophyll-α (μg/L)	Mean Summer Secchi Disk Depth (ft)
Ceratophyllum demersum	Coontail	-0.64	0.37	0.62	0.87	-0.73
Elodea canadensis	Common waterweed	-0.23	0.51	-0.19	0.57	-0.44
Lemna trisulca	Forked duckweed	0.18	-0.47	0.04	-0.14	0.08
Najas guadalupensis	Southern naiad	-0.65	0.37	0.30	0.72	-0.55
Potamogeton amplifolius	Large-leaf pondweed	-0.22	-0.66	0.02	0.26	-0.44
Potamogeton praelongus	White-stem pondweed	-0.64	-0.03	0.61	0.97	-0.88
Potamogeton pusillus	Small pondweed	-0.26	-0.45	0.50	0.68	-0.79
Potamogeton robbinsii	Fern-leaf pondweed	0.81	-0.20	-0.65	-0.88	0.75
Potamogeton zosteriformis	Flat-stem pondweed	-0.52	-0.11	0.73	0.90	-0.94

r value

-1 0 1

Strong Negative Correlation No Correlation Strong Positive Correlation

Of the aquatic plant species which have seen the greatest changes in their occurrence from Mid Lake from 2008-2020, most had the strongest correlation with mean summer Secchi disk depth and mean summer chlorophyll. Or in other words, these species had the strongest correlation with summer water clarity. As is discussed in the Water Quality Section (Section 3.1), as chlorophyll concentrations, or planktonic algal abundance increases, water clarity (Secchi disk depth) declines. While correlation analysis reveals whether a relationship exists between two variables, it does not determine if changes in one variable, water clarity for instance, causes changes in another, such as the occurrence of a given plant species. Another variable may be responsible for causing changes in both water clarity and a given species' occurrence. However, studies have shown that light availability, determined by water clarity, is one of the primary factors influencing aquatic plant community composition (Vestergaard and Sand-Jensen 2000).

As is discussed in the Water Quality Section (Section 3.1), summer water clarity has increased in Mid Lake by nearly 2.0 feet over the period from 2013-2019. Figure 3.4-9 illustrates the relationship between some of the dominant plant species in Mid Lake and mean summer Secchi disk depth. Coontail, white-stem pondweed, small pondweed, and flat-stem pondweed have all declined in occurrence with increasing water clarity, while fern-leaf pondweed has increased.

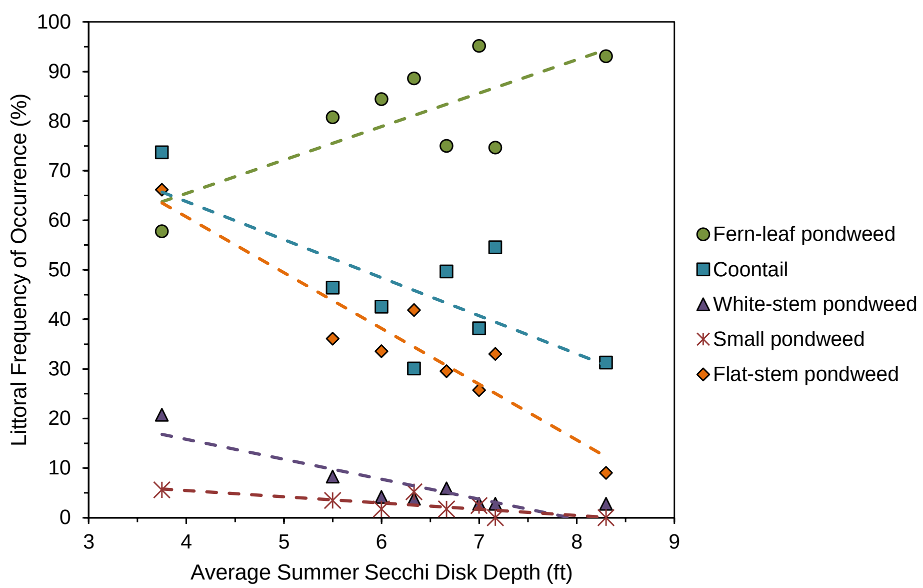


Figure 3.4-9. Littoral frequency of occurrence of select aquatic plant species from Mid Lake plotted against average summer Secchi disk depth from 2008-2019. Dashed trend lines created using simple linear regression.

Coontail is considered to be tolerant of eutrophic conditions, becoming dominant in lakes with higher nutrients and low water clarity (Davis and Brinson 1980). The decline in the occurrence of coontail with increasing water clarity in Mid Lake aligns with previous observations. Similarly, small pondweed is also considered to be more tolerant of low-light conditions and is able to persists in disturbed systems (Davis and Brinson 1980). The occurrences of both coontail and small pondweed in Mid Lake have been higher in years with lower water clarity.

However, white-stem pondweed and flat-stem pondweed are considered to be less tolerant of low-light conditions, often disappearing in disturbed systems (Davis and Brinson 1980). Yet, like coontail and small pondweed, the occurrences of these species in Mid Lake were also at their highest in years with lower water clarity. Fern-leaf pondweed is considered one of the deepest growing pondweeds in Wisconsin (Borman, Korth and Temte 1997), and is tolerant of lower-light conditions. Unlike the other pondweed species in Mid Lake, fern-leaf pondweed grows lower in the water column and along the lake bottom. The increasing trend in the occurrence of fern-pondweed in Mid Lake may be the result of this species 'filling the gaps' where other taller plant species such as coontail and southern naiad have declined.

As discussed previously, southern naiad exhibited a significant reduction in occurrence between 2015 and 2017. Though southern naiad is native to North America, it has been observed to be exhibiting aggressive growth in some northern Wisconsin lakes in recent years. In Big Sand Lake, Vilas County, southern naiad increased in occurrence to become one of the most abundant plant species in the lake between 2006 and 2016, increasing in littoral occurrence from <5% to 37%, respectively (Onterra 2017). It has since declined somewhat to a littoral occurrence of 27%, but remains one of the most abundant plants in the lake. Similarly, in downstream Long Lake, southern naiad was first recorded in 2012 with a littoral occurrence of 1%. By 2017, it had become the most frequently encountered plant in the lake with a littoral occurrence of 29%.

The rapid population growth of southern naiad in some northern Wisconsin lakes has some ecologists questioning whether this species was historically present in these waterbodies or if it represents a recent introduction, likely via watercraft. The rapid decline in the southern naiad population in Mid Lake lends some support to this theory as it aligns with the 'boom-bust concept' in invasive species ecology. This concept presents the idea that invasive species undergo an initial outbreak (boom phase) where their population grows rapidly before declining to a smaller population size (bust or collapse phase) (Strayer et al. 2017). Otherwise, if southern naiad is naturally occurring in Mid Lake, some change in environmental conditions around 2016 resulted in a rapid decrease in its abundance and has maintained a lower occurrence through 2020. The ability of this species rapidly increase in occurrence in northern Wisconsin lakes warrants further study.

As is discussed in the Water Quality Section (Section 3.1), Mid Lake and the Minocqua Chain are one of 21 Wisconsin Valley Improvement Company (WVIC) water storage reservoirs used to maintain a nearly uniform flow of water as practicable in the Wisconsin river by storing surplus water in reservoirs for discharge when water supply is low to improve the usefulness of the rivers of the rivers for hydropower, flood control, and public use. Natural lake reservoir water levels are maintained within a relatively narrow range in comparison to the five man-made reservoirs which exhibit changes of water levels that could span 10-20 feet in a single year. The Minocqua Chain is one of the natural lake reservoirs in the WVIC system, and has an operational range of 0.5 feet during the summer months. The water levels need to be kept between 1,584.05 and 1,585.05 between June 1 and September 30 of each year. Winter drawdowns cannot go below 1,582.72, which is 2.33 feet below full pool.

Figure 3.4-10 displays available water level data from the Minocqua Dam provided by WVIC from 1996-2019. The pattern of lowering water levels in the winter and raising them in the summer was fairly consistent between 1996-2002, with an annual water level fluctuation of approximately 2.0 feet between winter and summer. The range of water levels and annual minimums and maximums were more variable from 2003-2012. In some years like 2006, 2009, and 2010, summer water levels were mostly below the summer minimum water level. And in other years, like 2011, summer water levels were above the summer target water level. Summer water levels in 2013 and 2014 were above the target water level for a longer duration than any year within the dataset. From 2013-2019, the annual fluctuation between maximum and minimum water levels has been smaller at an average of 1.5 feet per year. Even though the dam is quite a distance from Mid Lake, it is generally believed that the winter drawdown has a 12-inch impact on Mid Lake, which may only be slightly muted compared to what occurs at the dam.

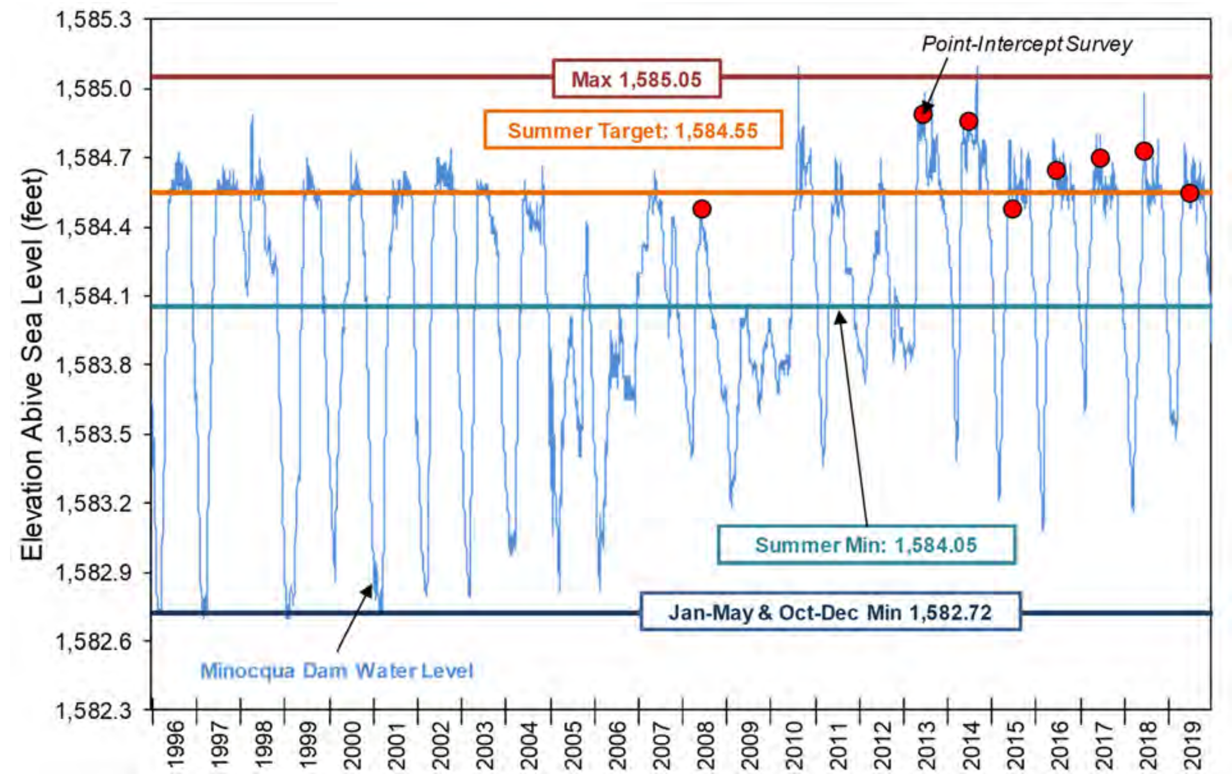


Figure 3.4-10. Minocqua Dam water levels from 1996-2019 and operational targets. Figure created using data provided by WVIC.

The dates of the point-intercept surveys completed on Mid Lake are also displayed on Figure 3.4-11. In 2008, summer water levels never reached the summer target level. Surveys completed in 2013, 2014, 2016, 2016, and 2018 were above the summer target water level, while 2016 was slightly below and 2019 was near the target level. It is possible that these changes in water level regimes over this period may also be playing a role in the changes observed in Mid Lake's plant community. However, to what extent these water level fluctuations play in the composition of Mid Lake's plant community is unknown.

These relationships bring to light the difficulty in determining a cause for changes in aquatic plant community composition. While the occurrences of some of the dominant plant species in Mid Lake were strongly correlated with water clarity, it is more probable that a multitude of interacting environmental factors are causing the observed changes the aquatic plant community. Continued monitoring of Mid Lake's aquatic community will reveal if these trends continue or are more cyclical in nature.

As explained in the previous section, lakes with diverse aquatic plant communities are believed to have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. One may assume that because a lake has a high number of aquatic plant species that it also has high species diversity. However, species diversity is influenced by both the number of species and how evenly they a distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Mid Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 3.4-11). The Simpson's Diversity Index values were calculated for Mid Lake using the 2008 and 2013-2020 point-intercept survey data. As expected, based on the decline in occurrence of a number of dominant species in Mid Lake, Simpson's Diversity has also declined over this period, ranging from 0.89 in 2013 to 0.76 in 2020. In 2008 and 2013, Mid Lake's species diversity was similar to the ecoregional median, but has since fallen near and below the 25th percentile.

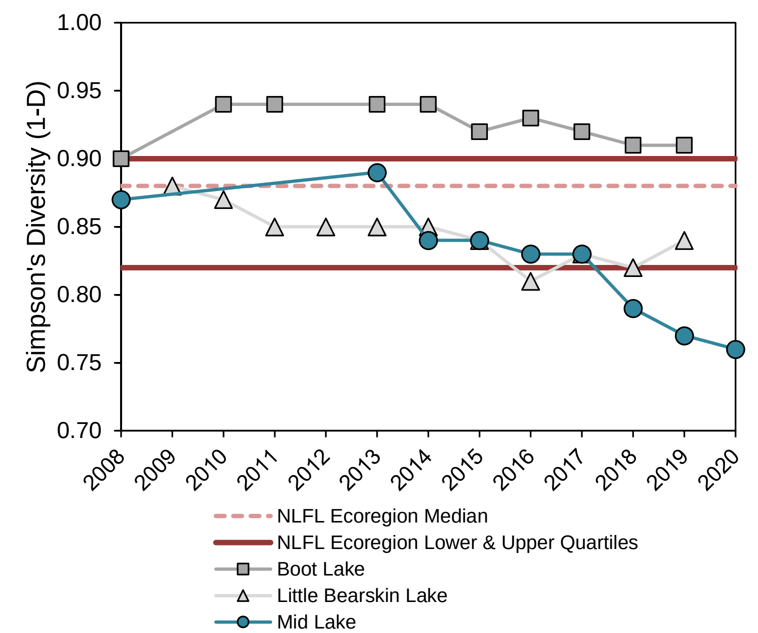


Figure 3.4-11. Mid Lake Simpson's Diversity Index. Created using data from Onterra 2008 and 2013-2019 point-intercept surveys. Regional and state values calculated with Onterra & WDNR data.

The Simpson's Diversity Index values for Boot and Little Bearskin lakes are also displayed on Figure 3.4-11. Boot Lake's diversity has remained high over this period, declining slightly around 2015. Little Bearskin Lake's diversity has shown a decreasing trend over this time period, more similar to that observed in Mid Lake. One way to visualize these changes in diversity in Mid Lake is to look at the aquatic plant species relative frequency of occurrence.

Relative frequency of occurrence is used to evaluate how often each plant species is encountered in relation to all the other species found. For example, while fern-leaf pondweed was found at 89% of the littoral sampling locations in Mid Lake in 2020 (littoral occurrence), its relative frequency of occurrence was 41%. Explained another way, of 100 plants were randomly sampled from Mid Lake in 2020, 89 of them would be fern-leaf pondweed. Looking at the relative occurrence of aquatic plant species in Mid Lake from 2008-2020 shows that the majority of the plant community is comprised of just three species: fern-leaf pondweed, coontail, and forked duckweed. (Figure 3.4-12). And the proportion of the community that these species comprise has been increasing over this period, from 60% in 2008 to 81% in 2020, while the proportion of all the remaining species have been declining. Most of this increase is due to the increase in fern-leaf pondweed, which has seen in increase in relative occurrence from 15% in 2008 to 41% in 2020. The increasing dominance by just a few species in Mid Lake has resulted in decreasing species diversity.

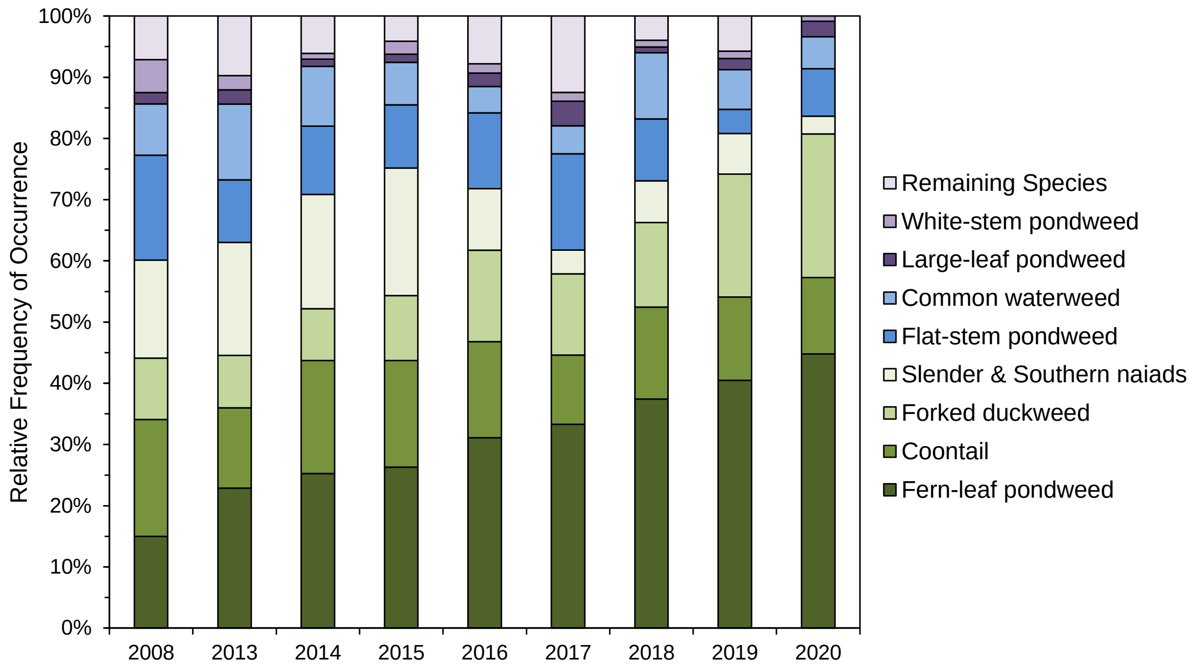


Figure 3.4-12. Mid Lake aquatic plant relative frequency of occurrence. Created using data from Onterra 2008 and 2013-2020 point-intercept surveys.

Using the aquatic plant species recorded on the rake during the point-intercept surveys completed on Mid Lake, the Floristic Quality Index (FQI) was also calculated for 2008 and 2013-2020 (Figure 3.4-13). Native plant species richness, or the number of native species recorded on the rake, ranged from 20 in 2015 to 27 in 2013 and 2020, with an average of 23 per survey. Average species conservatism ranged from 6.2 in 2008 to 6.7 in 2017, with an average of 6.4. The FQI ranged from 28 in 2015 to 34 in 2017, with an average of 31. Mid Lake's average species richness of 23 falls slightly above the median value for other lakes in the Northern Lakes and Forests Ecoregion (21) and above the median for lakes statewide (19). Mid Lake's average conservatism of 6.4 falls below the median for lakes in the ecoregion (6.7) and is slightly above the median for the state (6.3). And finally, Mid Lake's average FQI of 31 is equal to the ecoregional median (31) and above the state median (27). Despite the compositional changes in Mid Lake's aquatic plant community over this period, there are no detectable trends in the FQI components over this time period.

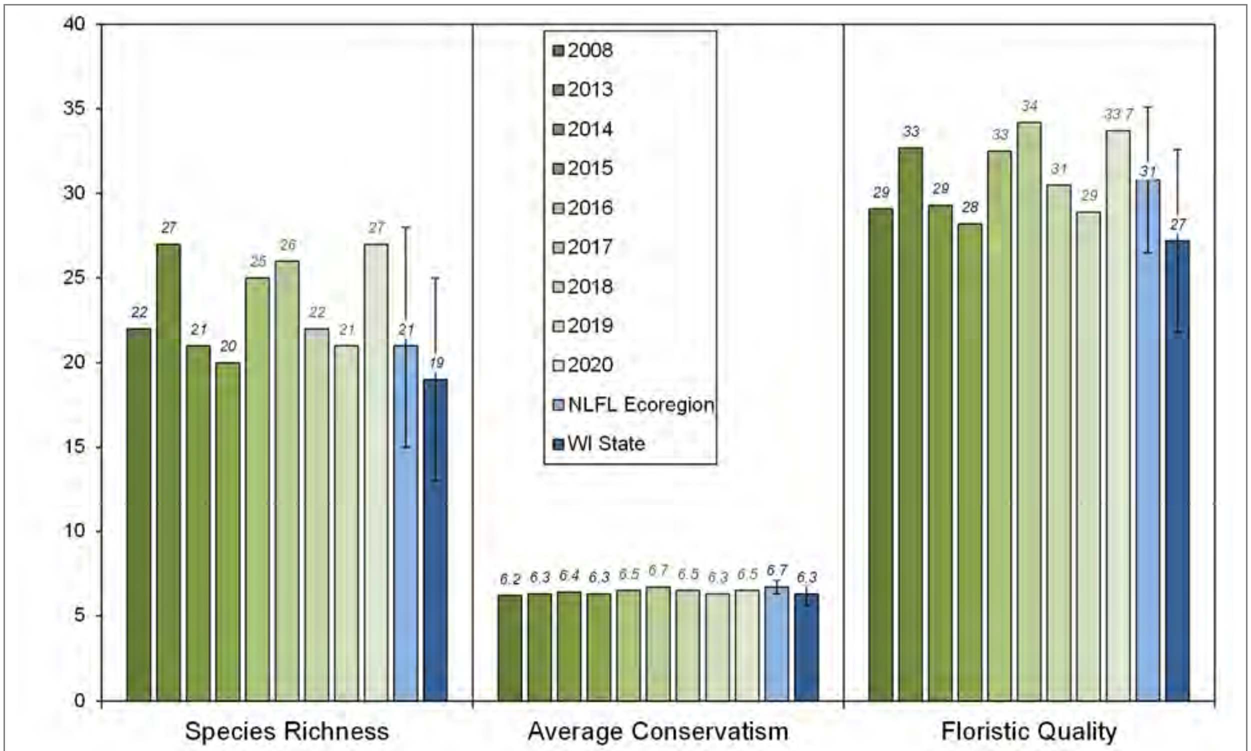


Figure 3.4-13. Mid Lake Floristic Quality Assessment. Error bars represent interquartile range. Created using data from Onterra 2008 and 2013-2020 point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data. Analysis follows Nichols 1999.

Onterra ecologists also repeated the aquatic plant community mapping survey in 2019 aimed at remapping communities of emergent and floating-leaf vegetation. During this survey, approximately 8.7 acres of these communities were delineated (Table 3.4-4), comprised of 16 different species (Table 3.4-1). The acreage of these communities in 2019 was slightly lower than the 9.5 acres mapped in 2008. Map 5 illustrates that the extents of some of the larger communities have retracted shoreward when compared to 2008. These communities have been shown to expand and retract with changes in water levels, and the changes observed between 2008 and 2019 are not believed to be due to intentional removal. Figure 3.4-11 shows that water levels were higher in 2019 and years prior when compared to 2008, and it is possible these communities retracted as water levels were slightly deeper.

Table 3.4-4. Acres of emergent and floating-leaf aquatic plant communities in Mid Lake in 2008 and 2019. Created using data from Onterra community mapping surveys.

	Acres	
Plant Community	**2008**	**2019**
Emergent	0.2	0.1
Floating-leaf	0.8	0.4
Mixed Emergent & Floating-leaf	8.5	8.2
Total	**9.5**	**8.7**

Continuing the analogy that the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a continued understanding of the dynamics of these communities within Mid. 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.

As presented in this section, Mid Lake's submersed aquatic plant community has seen some significant changes over the period from 2008-2020, primarily the reduction in the occurrence of a number of dominant species and an overall reduction in species diversity. The reductions observed in Mid Lake have also been observed in Boot and Little Bearskin lakes, suggesting these changes are likely being driven by regional changes in environmental conditions. While the MLPMD employs mechanical harvesting to create approximately 24 acres of navigational lanes in Mid Lake, it is not believed that this level of harvesting has the capacity to cause the plant population-level declines that have been observed. Continued monitoring of the plant community will reveal if these trends represent longer-term cycles in these plant populations.

Non-Native Aquatic Plants in Mid Lake

Curly-leaf Pondweed (Potamogeton crispus)

Curly-leaf pondweed (CLP) is a non-native, invasive submersed aquatic plant native to Eurasia, and was discovered in Mid Lake in 1979. Like our native pondweeds, CLP produces alternating leaves along a long, slender stem. The leaves are linear in shape with a blunt tip, and the margins are wavy and conspicuously serrated (saw-like). The plants are often brownish/green in color. Mid Lake has a number of native pondweed species, some of which are similar in appearance to and make be mistaken for CLP (Figure 3.4-14).

Figure 3.4-14. Curly-leaf pondweed and native pondweed 'look-a-likes' found in Mid Lake. Photo credit Onterra.

Like some of Wisconsin's native pondweeds, CLP's primary method of propagation is through the production of numerous asexual reproductive structures called turions. Once mature, these turions break free from the parent plant and may float for some time before settling and overwintering on the lake bottom. Once favorable growing conditions return (i.e., spring), new plants emerge and grow from these turions (Photograph 3.4-4). Many of the turions produced by CLP begin to sprout in the fall and overwinter as small plants under the ice. Immediately following ice-out, these plants grow rapidly giving them a competitive advantage over native vegetation. Curly-leaf pondweed typically reaches its peak biomass by mid-June, and following the production of turions, most of the CLP will naturally senesce (die back) by mid-July.

If the CLP population is large enough, the natural senescence and the resulting decaying of plant material can release sufficient nutrients into the water to cause mid-summer algal blooms. In some lakes, CLP can reach growth levels which interfere with navigation and recreational activities. However, in other lakes, CLP appears to integrate itself into the plant community and does not grow to levels which inhibit recreation or have apparent negative impacts to the lake's ecology. Because CLP naturally senesces in early summer, surveys are completed early in the growing season in an effort to capture the full extent of the population.

Because a portion of the CLP turions produced each year do not sprout and lie dormant in the sediment to sprout in subsequent years, chemical management of CLP typically includes numerous, repeat annual herbicide applications completed a few weeks following ice-out. The goal of the herbicide treatment is to kill the CLP plants before they are able to produce turions. Following multiple years of herbicide application, the turion supply in the sediment becomes exhausted and the CLP population decreases significantly to levels that may be better managed with finer-scale strategies such as manual removal. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species.

Early-season herbicide treatments, particularly low-concentration whole-lake or whole-basin treatments, have shown large reductions in CLP biomass and decreased recurrence of CLP populations after multiple consecutive treatments (Skogerboe et al. 2008). Johnson et al. (2012) investigated nine midwestern lakes that received five consecutive annual large-scale endothall treatments to control CLP. The greatest reductions in CLP frequency, biomass, and turions was observed in the first two years of the control program, but continued reductions were observed following all five years of the project. The authors noted that they saw no clear indication of the number of consecutive treatments needed to achieve long-term control, with viable turions (represented through sprouting) persisting greater than five years (Johnson, Jones and Newman 2012).

Photograph 3.4-4. A single curly-leaf pondweed turion sprouting several new plants. Photo credit Onterra.

Five consecutive years of large-scale CLP treatment also occurred on Half Moon Lake (Eau Claire County, WI). Following the five-year control strategy, CLP occurrence was documented to quickly rebound to pretreatment levels, with the authors indicating that "the turion bank in the sediment was still viable after five consecutive years of control" (James 2017). It is unclear how the ongoing internal phosphorus management activities (alum treatments) and subsequent changes in water quality may be impacting turion sprouting and corresponding CLP populations. Half Moon Lake has entered into another five-year CLP control program, which will result in large-scale endothall treatments occurring in ten out of eleven years. From the existing scientific literature, it is unclear how many consecutive years of directed herbicide treatments are needed in a given waterbody to exhaust the base of turions present to meet management goals.

In Mid Lake, the WNDR had historically placed a condition on the district's mechanical harvesting permit such that harvesting operations could not be undertaken in areas of CLP until after the population's natural senescence. Because of the extent of the CLP population in Mid Lake, this meant that nuisance aquatic plant growth created by excessive native plant growth, could not be addressed by mechanical harvesting until mid-July. In addition, the CLP population was also creating nuisance conditions and interfering with recreation and navigation in many areas around the lake.

Because the district could not implement mechanical harvesting until mid-summer, they began considering management options for reducing Mid Lake's CLP population. As discussed previously, chemical management of CLP involves the repetitive annual application of herbicides, and resource managers question whether or not this strategy places more strain on the environment (native species reductions) than the existing CLP population. Instead, the district adopted an alternative strategy that involved early-season mechanical harvesting of CLP. The goal was to remove as much CLP biomass as possible before the production of turions, and in theory, would over time reduce the lake's turion reserve. A three-year trial of this strategy was conducted in the early summers of 2009-2011. While there were noted declines in recreational interferences during these years, the footprint the CLP population continued to expand (Map 5).

Around that time, research conducted by John Skogerboe at the US Army Corps of Engineers Research and Development Center found that any management strategy that fails to kill the entire CLP plant (including rhizomes and root crowns) does not prevent new turion formation. The research found that stressed CLP plants actually produced more turions, and when above-ground biomass has been removed, the plants produced turions in the sediment along the rhizomes. Based on this new research and the fact that the CLP population continued to increase in Mid Lake, the early-season harvesting of CLP ceased and an herbicide management strategy was developed.

The strategy developed would include the implementation of early-season herbicide treatments for three to five consecutive years beginning in 2014. A series of WDNR grants were received to provide cost share for the implementation and monitoring of this program (AEP-390-13 & ACEI-147-14). However, surveys completed in 2014 and 2015 found that the CLP population had declined to levels that the population was undetectable (Map 5). The lack of CLP in these years postponed the proposed herbicide control strategy. Surveys completed in 2016 and 2017 found a slight resurgence in the CLP population, but not to a level to warrant the implementation of the herbicide control strategy (Map 5). Given the unpredictable nature of the CLP population in Mid Lake in addition to emerging data regarding the sensitivity of some native plants in Mid Lake to the proposed herbicide strategy, this strategy was suspended.

A meeting was held with the MLPMD, Onterra, and WDNR in February 2018 to discuss the future CLP management strategy for Mid Lake. The WDNR agreed to issue the district a one-year mechanical harvesting permit that would allow mechanical harvesting within the designated areas even if CLP was present. The new language treats CLP as any other plant creating nuisance conditions in the lake and would allow the district to start the nuisance management strategy in early June after concerns of impacting spawning fish habitat has passed.

To reflect this new CLP and mechanical harvesting management strategy, the WDNR encouraged the MLPMD to update their comprehensive management plan. In addition, they are restricted from granting a multi-year mechanical harvesting permit without an updated (within five years) and approved management plan. Because herbicide treatments did not occur as originally proposed, the district's open AIS-Established Population Control Grant (ACEI-147-14) contained remaining opportunities of cost-share. A strategy for continued AIS monitoring (2018-2020) and updating the management plan (2019-2020) was devised utilizing these remaining funds. This strategy was approved by the MLPMD and WDNR.

CLP was again below detectable levels in 2018. Map 7 shows the results of the 2019 and 2020 CLP mapping surveys, where only low-density occurrences were located.

As discussed previously, the whole-lake point-intercept surveys completed on Mid Lake in 2008 and 2013-2020 were completed in June in an effort to capture the full extent of the CLP population prior to its natural senescence. Figure 3.4-15 displays the littoral frequency of occurrence of CLP over this period along with the acreage of mapped colonies (polygons). Unlike the native aquatic plants in Mid Lake which have exhibited discernable trends in occurrence over this period, CLP occurrence has been sporadic. This indicates that conditions in some years are more favorable for turion germination than others.

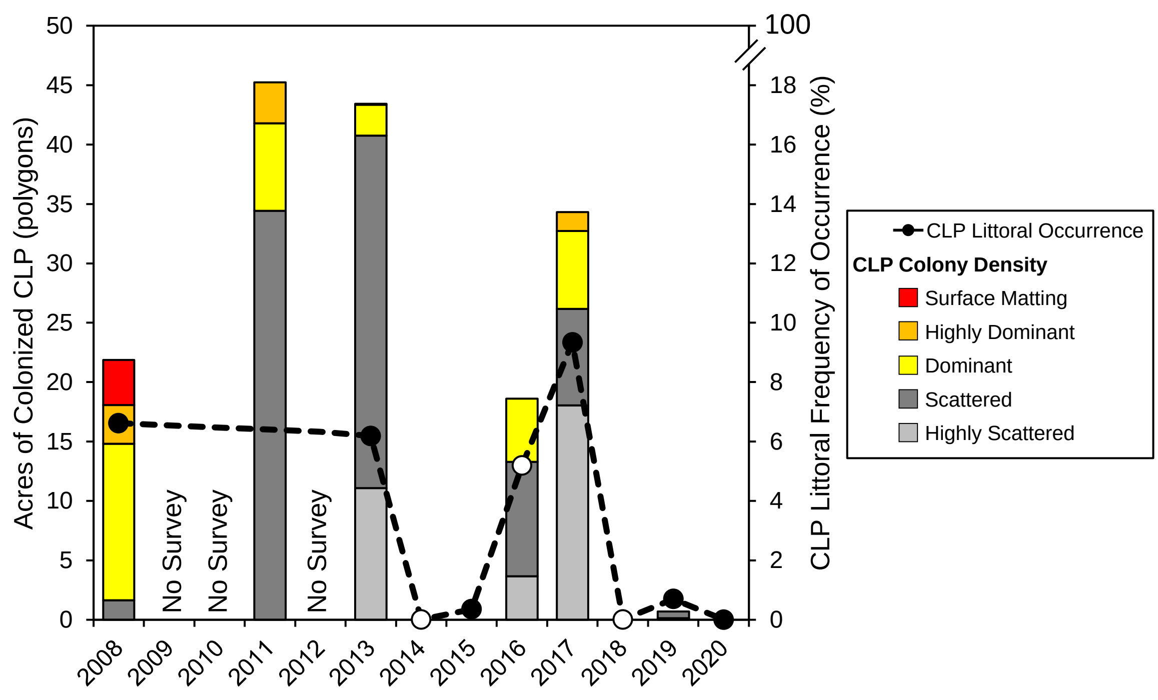


Figure 3.4-15. Mid Lake CLP littoral frequency of occurrence and acreage of mapped colonies from 2008-2020. Created using data from Onterra point-intercept and ESAIS mapping surveys. Open circles indicate occurrence is statistically different from previous survey (Chi-Square α = 0.05).

To explore what environmental factors may be influencing the CLP population in Mid Lake, correlation analysis was utilized using the same environmental variables used in the analysis for native aquatic plants. This analysis found that the littoral occurrence of CLP was most strongly correlated, negatively, with average daily winter snow depth from the previous season (r = -0.64). Linear regression indicates that the relationship between CLP occurrence and winter snow depth was nearly statistically valid with a p-value of 0.08 (statistically valid at ≤ 0.05) (Figure 3.4-16).

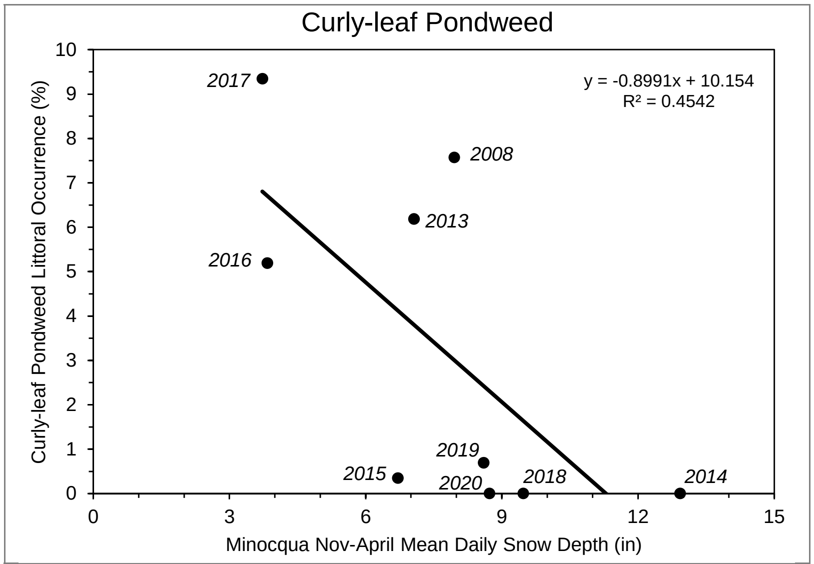


Figure 3.4-16. Mid Lake CLP littoral occurrence plotted against average daily winter snow depth from previous season.

A study completed in Minnesota (Valley and Heiskary 2012) found a significant relationship between CLP occurrence and winter snow depth from the previous season. They concluded that given CLP turions sprout in the fall and overwinter as small plants, they have a greater need for light for winter survival when compared to native plants. In addition to greater snow cover on the ice significantly reducing light availability to these plants in winter, reduced rates of photosynthesis will result in stronger and longer periods of anoxia (without oxygen). Wu et al. (2009) found that the growth of sprouted CLP turions was reduced under anoxic sediment conditions and light availability was reduced to 1% (Wu et al. 2009). In shallow productive lakes, like Mid Lake, snow-cover and reduced dissolved oxygen concentrations are often associated. Mid Lake is known to have periodic fish kills related to low oxygen during more severe winters.

In summary, greater snow depth over the ice is believed to lessen CLP survivability due to reduced light availability and the development of anoxic conditions. Valley and Heiskary (2012) found that for every additional inch of daily average snow depth, CLP occurrence the following summer was reduced by 1%. While data from Mid Lake are relatively limited, this relationship was very similar with CLP occurrence declining by 0.8% for every additional inch of daily snow depth (Figure 3.4-16). The sporadic nature of the CLP population in Mid Lake is believed to largely driven by the effects created by differing amounts of snow cover over the ice during the previous winter. As more data are collected from Mid Lake, it may be possible to estimate what the upcoming summer's CLP population will look like based on the previous winter's snowfall. Management and monitoring strategies for CLP beyond 2020 are discussed in the Implementation Plan (Section 5.0).

Pale-yellow Iris (Iris pseudacorus)

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers (Photograph 3.4-5). Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species.

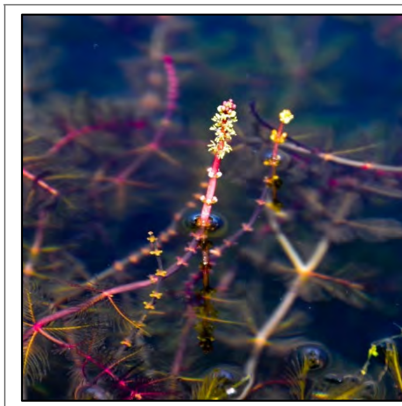
Photograph 3.4-5. Clump of the non-native pale-yellow iris mixed with the native blue-flag iris (left) and large, contiguous colony of pale-yellow iris on the shores of Mid Lake (right). Photo credit Onterra.

Pale-yellow iris is typically in flower during the second half of June. The foliage of pale-yellow iris and northern blue flag iris (valuable native species) is too similar to make a definitive identification based off of this alone. Positive ID really needs to come from the flowers or the seed pods, which come after the flower is pollinated.

A survey completed in 2019 found that PYI has spread significantly in shoreland areas around Mid Lake (Map 5), including large, contiguous colonies (Photograph 3.4-5, right frame). Control of PYI includes digging and removing the entire plant, cutting leaves below the water's surface, cutting flowers before they can go to seed, and herbicide applications for larger colonies.

Eurasian Watermilfoil (Myriophyllum spicatum)

Eurasian watermilfoil (EWM; Photograph 3.4-6), another non-native aquatic plant species, was located in Mid Lake by Onterra ecologists in 2011 despite being present in connected lakes since at least the early 2000s. The initial occurrence found in 2011 consisted of a clump of plants in the northern portion of the lake. Since its discovery, the EWM population has remained small in Mid Lake, with a littoral frequency of occurrence ranging from non-detectable at 0% in 2013-2016, 2018, and 2019 to just 0.7% in 2017. Given the low occurrence of EWM in Mid Lake, Onterra recommended that the EWM be targeted with professional-based hand-harvesting. The MLPMD contracted with Aquatic Plant Management, LLC (APM) to conduct hand-harvesting efforts in 2016. The divers spent a combined 17.75 hours removing approximately 0.75 cubic feet of EWM.



Photograph 3.4-6. Eurasian watermilfoil, a non-native invasive aquatic plant.

As part of the updated mechanical harvesting permit in 2018, the WDNR encouraged the district to take measures to avoid mechanical harvesting of EWM, which could potentially accelerate its spread in Mid Lake. In 2018 and 2019, EWM population was located near a main mechanical harvesting lane, where higher watercraft use could contribute to further fragmentation and spread (Map 8). To reduce the chance of spread, Onterra again recommended that the population be targeted with hand-harvesting in 2019. Aquatic Plant Management, LLC visited Mid Lake on August 6 and 14, 2019 to conduct hand-harvesting of the EWM mapped by Onterra (Figure 3.4-17). Over the course of these two days, they were able to remove 2.0 cubic feet of EWM. If the EWM population remains small, continued hand-harvesting will likely be the optimal management strategy to prevent the population from spreading. During an ESAIS Survey in June of 2020, Onterra ecologists were unable to locate any EWM in Mid Lake, indicating that the population is currently below detectable levels.

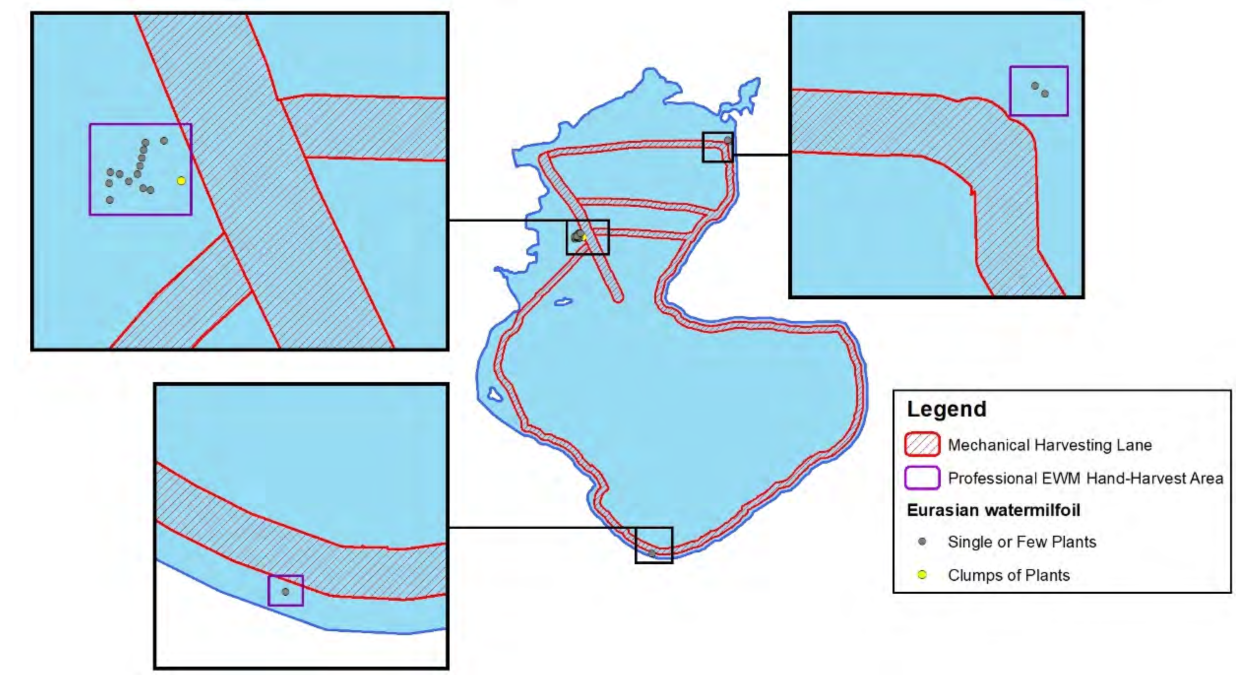


Figure 3.4-17. Mid Lake 2019 EWM locations and professional hand-harvesting areas.

Purple Loosestrife (Lythrum salicaria)

Like pale-yellow iris, purple loosestrife is a perennial, herbaceous wetland plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but can also spread from root or stem fragments.

Photograph 3.4-7. The non-native wetland plant, purple loosestrife. Photo credit Onterra.

In 2008, large colonies of purple loosestrife were located mainly along Mid Lake's western and northern shorelines. One of the management goals developed during the development of Mid Lake's management plan was to initiate efforts to reduce the occurrence of purple loosestrife beginning in 2010. The survey in 2019 found that the occurrence of purple loosestrife appears to be lower than in 2008, with the larger colonies along the western and portions of the northern shore no longer present.

The Tomahawk Lake Association initiated a purple loosestrife management program in 2012. This initially consisted of removing flowering heads from areas in Tomahawk Lake and the Thoroughfare. In 2013, *Galerucella* beetles were released in the Thoroughfare, but high water was thought to limit the success of these activities.

Flowering Rush (Butomus umbellatus)

Flowering rush an invasive wetland/aquatic plant that is native to Europe (Photograph 3.4-8). This perennial plant flowers in late summer to early fall. It ranges in size from 1-5 feet, generally growing it shallow water, though it can be found growing submersed up 10 feet deep. Like other non-native invasive plants, flowering rush displaces native aquatic and wetland plants and can alter ecosystem functions.

Photograph 3.4-8. The non-native wetland/aquatic plant flowering rush. Photo credit Onterra.

Flowering rush was documented for the first time in Mid Lake during the 2019 emergent and floating-leaf community mapping survey (Map 5). The population on Mid Lake was comprised of two clumps growing in shallow water amongst water lilies on the lake's west side (Photograph 3.4-8). Flowering rush populations have been known from downstream Lake Minocqua since 1985 and Kawaguesaga Lake since 2010. While herbicides have been used to control larger populations of flowering rush on Wisconsin lakes, the current population in Mid Lake likely lends itself to manual hand-removal for control.

Nuisance Aquatic Plants

Aquatic invasive species have not been the only aquatic plants which can negatively impact navigation and recreation on Mid Lake. Native plants have also contributed to these issues. With the mean depth in Mid Lake being six feet and water clarity being considered *excellent*, aquatic plants can thrive under these conditions. During the past decade, southern naiad has been the primary species causing the navigation impediments, with coontail and common waterweed also contributing to the nuisance. In some years, curly-leaf pondweed populations also contribute to the nuisance conditions. In recent years, particularly in 2019, the populations of these species were reduced.

Because Mid Lake is a high-use waterbody that supports many types of recreation, the aquatic plant control efforts being managed by the MLPMD are important for ensuring continued enjoyment of the lake. Nuisance aquatic plant controls actions have spanned over many years at Mid Lake and the more recent efforts are discussed in further detail below.

The MLPMD supports reasonable and environmentally sound actions to facilitate navigability on Mid Lake. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those which meet WDNR regulatory and permitting requirements and do not impact any more shoreland or lake surface area than absolutely necessary. Figure 3.4-17 (above) and Map 8 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 WDNR has historically provided permits for mechanical harvesting on Mid Lake. Multi-year permits have been issued when an approved and updated (within 5 years) has been in place and single year permits have been issued while the plan is in the process of being updated. The mechanical harvesting plan allows for cutting of CLP as needed, and continued maintenance to keep clear navigation channel within the lake. Specifics regarding the mechanical harvesting plan is included within the Implementation Plan Section (5.0).

Mechanical harvesting occurs every ear on Mid Lake with a district-owned harvester. Mid Lake purchased their latest harvester during the spring of 2019. Plants are unloaded via a conveyor system at Grundy Point. Table 3.4-5 outlines the available mechanical harvesting records from Mid Lake, with some records not able to be recovered. From 2004 to 2013, the district would remove between 200 and 300 loads of aquatic plants from Mid Lake. As discussed in the section above, changes in aquatic plant occurrence have been noted on Mid Lake during the period of study. Plants that typically occupy the upper layer of the water column have declined, with plants growing along the bottom increasing. Based upon the incomplete records shown in Table 3.4-5, less aquatic plant biomass is being removed from the lake in recent years.

Table 3.4-5. Summary of available mechanical harvesting records. Complied by the MLPMD. Missing years do not mean harvesting did not occur, but that the records cannot be found.

Year	Date Harvesting Began	Summary of Loads	Loads from Saturday Pickup	Date Harvesting Stopped	Notes
2004	6/18/2004	312	29	9/11/2004	
2009	6/2/2009	252		9/4/2009	CLP Early Cutting. GPS Used and Very Helpful
2010	5/17/2010	237		8/30/2010	Early cut of CLP until 6-6-10,then stopped for a while
2011	6/6/2011	282	16	9/7/2011	82 loads of CLP by 7-11-11
2012	6/20/2012	300			
2013	7/8/2013	239	14.5		
2014	7/10/2014	95			Road construction cut harvest season short. Some loads counted were observed to be less than full loads
2015	6/24/2015	56.75		9/17/2015	Observation of less than normal weed growth
2016	6/16/2016	20.3		9/2/2016	On daily reports, 3 different dates operators failed to report loads harvested
2017	late June	48		8/29/2017	First and only report by Jon Stein
2019	6/22/2019	10		9/7/2019	Least amount of weeds harvested ever.

Figure 3.4-18 shows that excessive aquatic plant growth was ranked as the highest concern about Mid Lake by stakeholder survey respondents. Figure 3.4-19 displays the level of riparian respondent support or opposition toward past mechanical harvesting on Mid Lake. The respondents indicated 97% have supported past mechanical harvesting, with 92% *strongly support* and 5% *moderately support.* No respondents indicated opposition of the past mechanical harvesting activities, with 3% being *neutral*.

Question23: From the list below, please rank your top three concerns regarding Mid Lake, with 1 being your greatest concern.

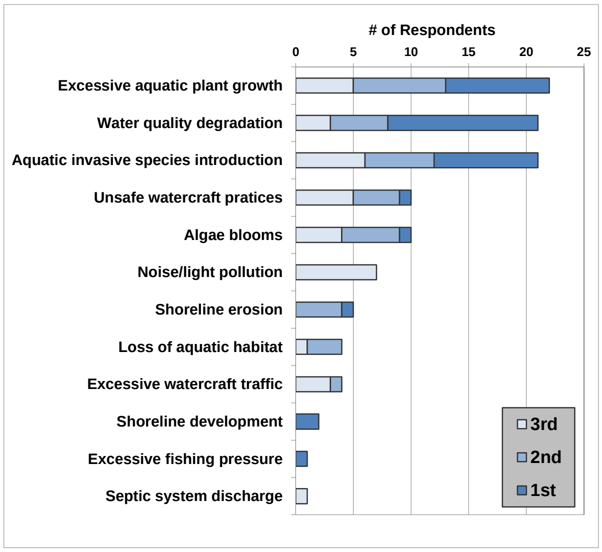


Figure 3.4-18. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 26: How do you feel about the past use of mechanical harvesting to control nuisance aquatic plants in previous years?

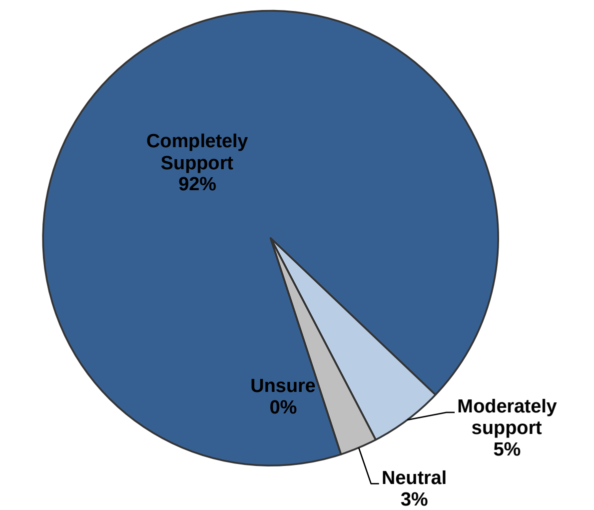


Figure 3.4-19. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

In both 2008 and 2019, riparian district members were asked how often aquatic plant growth negatively impacted their enjoyment of Mid Lake (Figure 3.4-20). Respondents perceptions have shifted, with aquatic plant growth impacting enjoyment less in recent years. This could be due to lower amounts of vegetation in the top of the water column than was present in 2008.

Question 16 (2015) & 24 (2019): During open water season how often does aquatic plant growth negatively impact your enjoyment of Mid Lake?

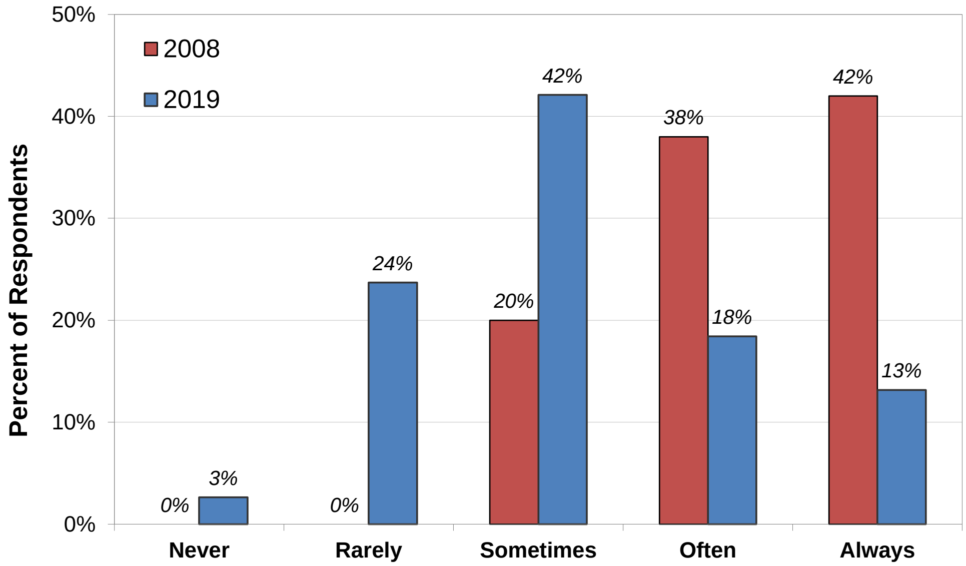


Figure 3.4-20. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.5 Aquatic Invasive Species in Mid Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Mid Lake within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are eight AIS present (Table 3.5-1).

Table 3.5-1. AIS present within Mid Lake

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.4 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 3.4 – Aquatic Plants
	Pale-yellow iris	*Iris pseudacorus*	Section 3.4 – Aquatic Plants
	Flowering rush	*Butomus umbellatus*	Section 3.4 – Aquatic Plants
Invertebrates	Rusty crayfish	*Orconectes rusticus*	Section 3.5 - Aquatic Invasive Species
	Banded mystery snail	*Viviparus georgianus*	Section 3.5 - Aquatic Invasive Species
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.5 - Aquatic Invasive Species

Aquatic Animals

Rusty Crayfish

Photograph 3.5-1. Rusty crayfish. Photo credit: GLIFWC

Rusty crayfish (*Orconectes rusticus*) are originally from the Ohio River basin and are thought to have been transferred to Wisconsin through bait buckets. These crayfish displace native crayfish and reduce aquatic plant abundance and diversity. Rusty crayfish can be identified by their large, smooth claws, varying in color from grayish-green to reddish-brown, and sometimes visible rusty spots on the sides of their shell (Photograph 3.5-1). They are not eaten by fish that typically eat crayfish because they are more aggressive than the native crayfish. Rusty crayfish reproduce quickly but with intensive harvesting their populations can be greatly reduced within a lake.

Mystery snails

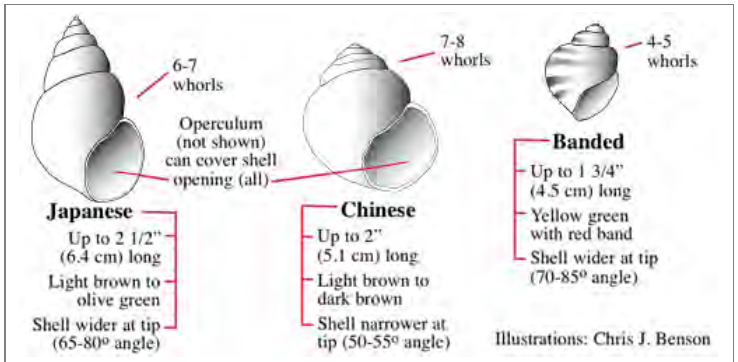


Figure 3.5-1. Identification of non-native mystery snails. Courtesy of Minnesota Sea Grant: (http://www.seagrant.umn.edu/ais/mysterysnail).

There are four types of mystery snails found within Wisconsin waters, with the brown mystery snail (*Campleoma decisum*) being the only native species. They are called mystery snails because the give birth to fully developed snails that mysteriously appear in spring. The two primary non-native mystery snails in Wisconsin are the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow. They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009). Currently the Japanese mystery snail (*Cipangopaludina japonica*) has only been documented from a handful of waterbodies in northwestern Wisconsin. Chinese and banded mystery snail have both been documented from Mid Lake, whereas Japanese mystery snail has not.

Figure 3.5-2 displays the aquatic invasive species that Mid Lake stakeholders believe are in Mid Lake. Only the species present in Mid Lake are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

- http://dnr.wi.gov/topic/invasives/
- https://nas.er.usgs.gov/default.aspx
- https://www.epa.gov/greatlakes/invasive-species

Question #22: Which aquatic invasive species do you believe are in Mid Lake?

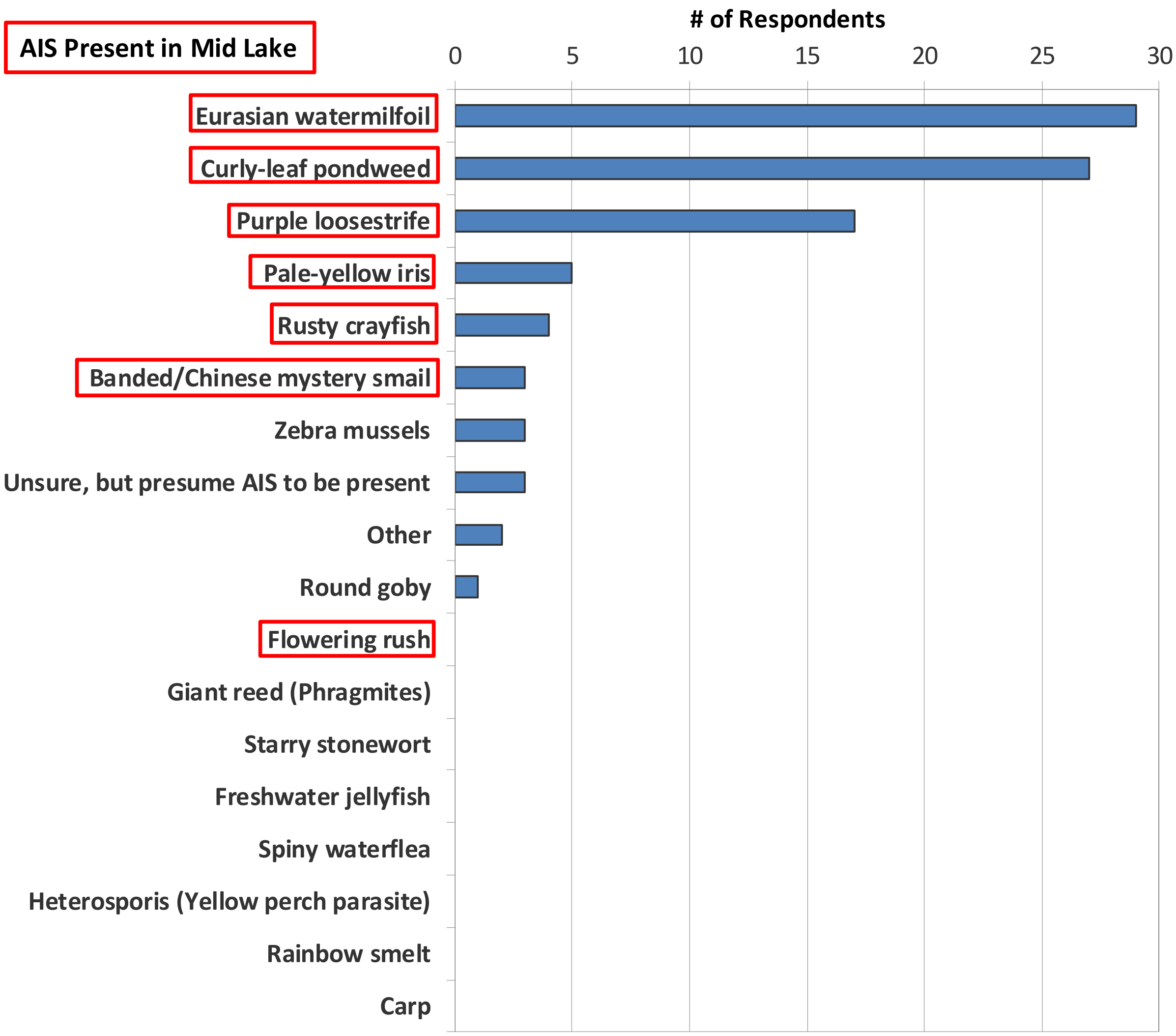


Figure 3.5-2. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.6 Fisheries Data Integration

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 a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Mid Lake. Mid Lake falls within the management plan for the entire Minocqua Chain, which includes Kawaguesaga Lake, Minocqua Lake, Mid Lake, Mud Lake, Tomahawk Lake, and Little Tomahawk Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Zach Woiak (WDNR 2020 & GLIFWC 2019).

Mid Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in Mid Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.6-1.

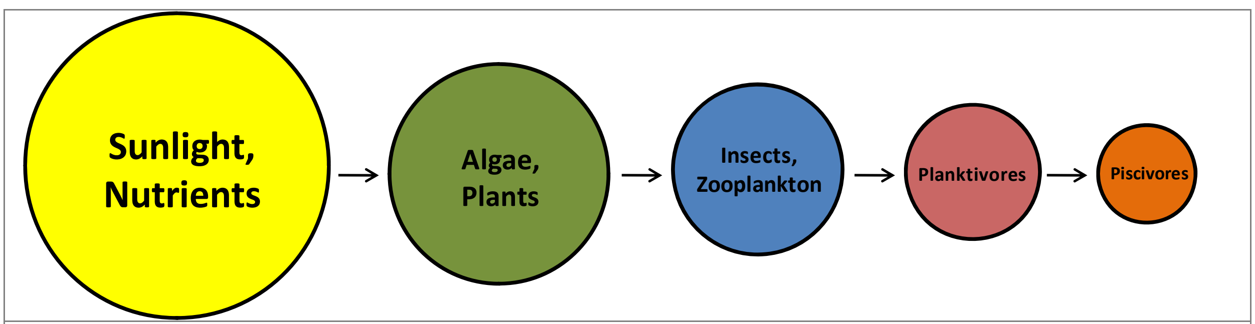


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Mid Lake is on the boarder of a mesotrophic and eutrophic system, meaning it has moderate to high nutrient content and thus a moderate to high primary productivity. Simply put, this means Mid Lake should be able to support appropriately populations of predatory fish (piscivores) when compared to an oligotrophic system. Table 3.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional species documented in past WDNR surveys of Mid Lake include bluegill x pumpkinseed hybrid (*Lepomis macrochirus* x *gibbosus*) and golden shiner (*Notemigonus crysoleucas*).

Table 3.6-1. Gamefish present in Mid Lake 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 invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed 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 veg	Small fish, aquatic invertebrates

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electrofishing (Photograph 3.6-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easier to net and place into a livewell to recover. Contrary to what some may believe, electrofishing does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

The mark-recapture data collected between these two surveys is placed into a statistical model to calculate the population estimate of a fish species. Fisheries biologists can then use this data to make recommendations and informed decisions on managing the future of the fishery.

Photograph 3.6-1. Fyke net an electroshocking boat.

Fish Stocking

Photograph 3.6-2. Muskellunge fingerling.

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). Stocking a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Mid Lake has been stocked intermittently with muskellunge dating back to 1972 (Table 3.6-2). Most recently, approximately 175 large fingerling muskellunge have been released directly into Mid Lake since 2019. Lake Tomahawk, Minocqua Lake, and Kawaguesaga Lake have also received stocking of large fingerling muskellunge, with five stocking events occurring since 2011 in these lakes.

The entire Minocqua Chain has received increased walleye stocking in an effort to bolster recruitment of young of the year walleye. Starting in the early 2000's, walleye fry survival from age-0 to age-1 has drastically diminished within the chain. Since 2012, Kawaguesaga Lake, Minocqua Lake, and Tomahawk Lake have received over 200,000 extended growth walleye (Table 3.6-3). It is likely Mid Lake has also benefited from these stocking events. Two direct walleye stocking events in Mid Lake occurred in 1975 and 1976. 1,000,000 fry were released in 1975 and 10,000 fingerlings were released in 1976.

Table 3.6-2. Stocking data available for muskellunge in Mid Lake 1972-2021. Data provided by WDNR.

Lake	Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Mid Lake	1972	Muskellunge	Unspecified	Fingerling	467	13
Mid Lake	1974	Muskellunge	Unspecified	Fingerling	717	8
Mid Lake	1977	Muskellunge	Unspecified	Fingerling	600	9
Mid Lake	1979	Muskellunge	Unspecified	Fingerling	433	8.67
Mid Lake	1983	Muskellunge	Unspecified	Fingerling	400	10
Mid Lake	1984	Muskellunge	Unspecified	Fingerling	350	12
Mid Lake	1986	Muskellunge	Unspecified	Fingerling	400	10.33
Mid Lake	1988	Muskellunge	Unspecified	Fingerling	526	10
Mid Lake	1990	Muskellunge	Unspecified	Fingerling	400	10
Mid Lake	1992	Muskellunge	Unspecified	Fry	44,500	1
Mid Lake	1997	Muskellunge	Unspecified	Fry	25,000	0.5
Mid Lake	2019	Muskellunge	Upper Wisconsin River	Large Fingerling	118	11.2
Mid Lake	2021	Muskellunge	Upper Wisconsin River	Large Fingerling	55	12.3

Table 3.6-3. WDNR Extended Growth Walleye Stocking for Minocqua Chain 2012-2019. Data provided by WDNR.

Lake	2012	2013	2014	2015	2016	2017	2018	2019	Totals
Tomahawk	16,954		34,603		34,588		34,571		120,716
Minoqua		13,596		13,377		13,842		13,383	54,198
Kawaguesaga		6,70		6,996		7,097		6,997	27,790
									202,704

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water and ice) was the third most important reason for owning property on or near Mid Lake. Figure 3.6-2 displays the fish that Mid Lake stakeholders enjoy catching the most, with largemouth bass, bluegill/sunfish, and crappie being the most popular. Approximately 75% of these same respondents believed that the quality of fishing on the lake ranged from fair to excellent (Figure 3.6-3). Approximately 78% of respondents who fish Mid Lake believe the quality of fishing has remained the same or gotten worse since they first started to fish the lake (Figure 3.6-4).

Question 9: What species of fish do you like to catch on Mid Lake?

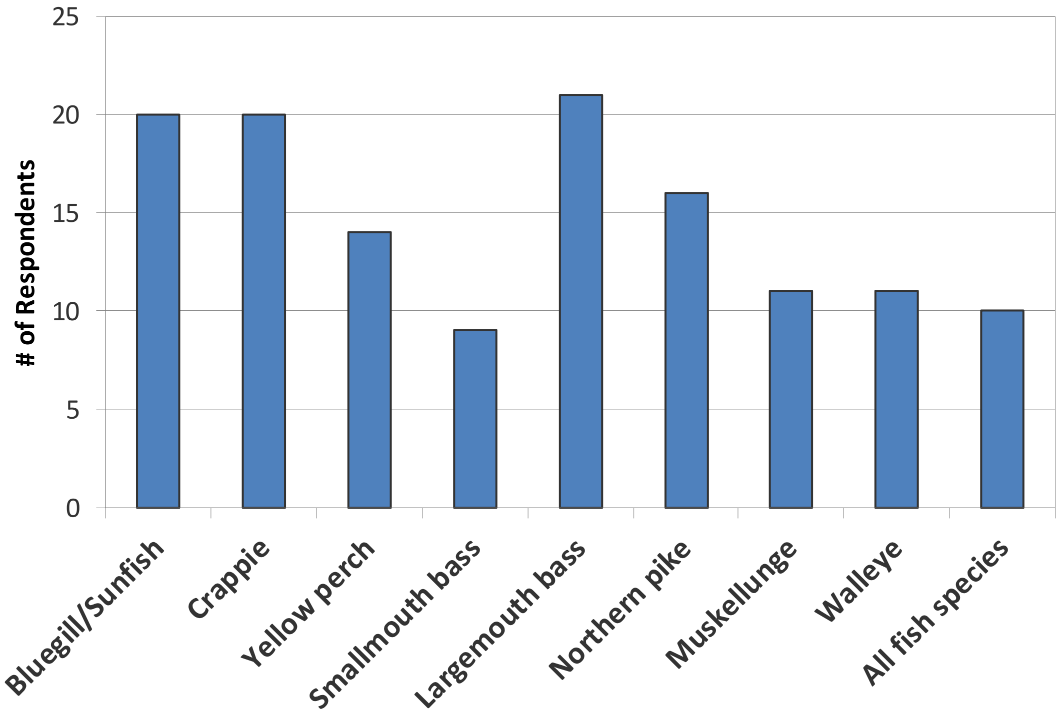


Figure 3.6-2. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 10: How would you describe the current quality of fishing on Mid Lake?

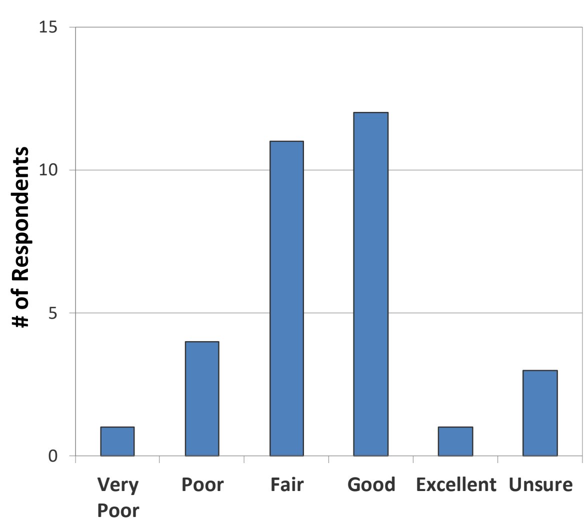


Figure 3.6-3. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 11: How has the quality of fishing changed on Mid Lake since you started fishing the lake?

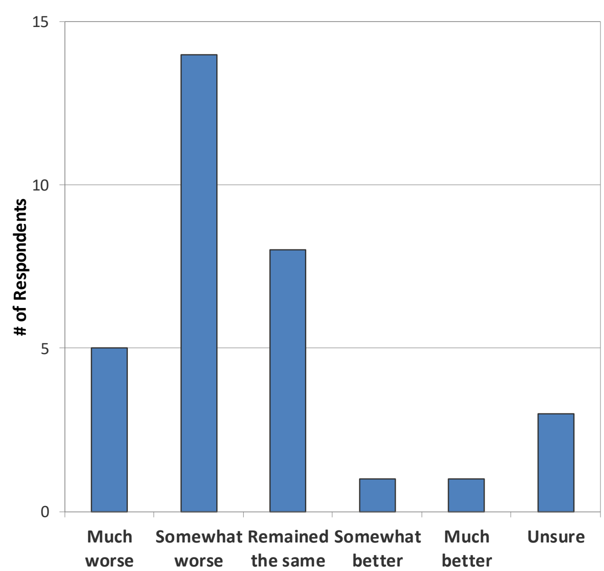


Figure 3.6-4. Select survey responses from the Mid Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). Data is analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed.

In spring of 2015, a bass and panfish electroshocking survey was completed on Mid Lake by the DNR (Appendix E). In total, 3.3 miles of shoreline were surveyed. Gamefish species were collected for the entirety of the survey, while panfish were collected on two, half-mile long sections of shoreline.

Gamefish

The gamefish present on Mid Lake represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch bass and several different panfish species on Mid Lake (Figure 3.6-2).

Walleyes are a valued sportfish in Wisconsin. However, walleye populations have declined in the Minocqua Chain in recent years. A cooperative rehabilitation program was created in 2014 to cease all harvest of walleye in the chain for both anglers and spearers. Currently, catch and release angling for walleyes is open on the Minocqua Chain during the traditional gamefish season. Depending on approval from current legislature, the catch and release regulation would be extended until 2025. If no further action is taken, a one walleye per day regulation would be implemented in May 2025. The minimum size to keep a walleye would be 18 inches, and walleye 22 to 28 inches could not be kept. Fall recruitment surveys are currently taking place annually to assess age-0 walleye populations, as well as monitoring survival rates of that year's stocking class. Current goals are set at 3 fish/ acre for Kawaguesaga and Minocqua Lakes and 2 fish/acre for Tomahawk Lake. Size regulations for largemouth bass and smallmouth bass have been removed to decrease predation on young walleye and to reduce interspecific competition for resources. Spawning habitat improvement projects have been completed on Minocqua Lake as well. In the 2015 survey of Mid Lake, five walleye were captured ranging from 9.5 to 16.3 inches long. It was not specifically stated if these captured fish were from stocking events or natural reproduction.

Largemouth bass were the most common gamefish encountered in the 2015 survey. 83 individuals were captured, ranging from 8 to 17.7 inches. The average size was approximately 13 inches.

Northern Pike are present in Mid Lake. Only three individuals were captured in the 2015 survey. All three fish measured under 20 inches in length.

Muskellunge, while not present in the 2015 survey, have been recorded in Mid Lake in the past. Muskellunge reproduction is listed as category two for Mid Lake, meaning both natural reproduction and stocking is occurring. The angling quality classification for Mid Lake is A1, meaning the chances of catching a "trophy" sized fish is higher than most other Wisconsin waters that hold muskellunge (WDNR). In personal communications with Zach

Woiak, muskellunge within the Minocqua Chain utilize the spawning habitat that Mid Lake provides.

Panfish

Pumpkinseed and bluegill were common during the 2015 WDNR fisheries survey (WDNR 2015). The results for the stakeholder survey show anglers prefer to catch bluegill and crappie on Mid Lake.

Pumpkinseed were the most common panfish captured in 2015. During the 2015 survey, 243 pumpkinseed were captured measuring between 4.0 to 7.2 inches.

Bluegill were another common catch in the 2015 survey. 194 fish were captured, ranging between 4.0 to 8.2 inches, with an average size of approximately 6 inches. 24 bluegill x pumpkinseed hybrids were also recorded.

Several **yellow perch** and **black crappie** were also captured during the 2015 survey. Six crappies between 5.0 to 9.2 inches and four perch between 5.5 and 6.7 inches were recorded.

Fish Kill

Mid Lake has experienced minor fish kills in the winters of 2009 and 2018 due to a lack of dissolved oxygen in the water. These anoxic conditions can develop during the winter months when dissolved oxygen is depleted from biological processes in which oxygen is consumed. According to WDNR fisheries biologist for Oneida County, Zach Woiak, it is likely that the majority of adult fish migrate into the thoroughfare or neighboring Tomahawk Lake and Minocqua Lake during low dissolved oxygen periods. No efforts have been made to restock Mid Lake after these events.

Mid Lake Spear Harvest Records

Figure 3.6-5. Location of Mid Lake within the Native American Ceded Territory (GLIFWC 2017). 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 3.6-5). 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 lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake by tribal harvest is a highly regimented and dictated process. This highly structured procedure begins with bi-annual meetings between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest represents the number of fish that can be harvested by tribal members through the use of high efficiency gear such as spearing or netting without influencing the sustainability of the population. This does not apply to angling harvest which is considered a low-efficiency harvest regulated statewide by season length, size and bag limits. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through high efficiency methods. By March 15th of each year the relevant Native American communities may declare a proportion of the total safe harvest on each lake; this declaration represents the maximum number of fish that can be harvested by tribal members annually. Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

Tribal members may harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2017). 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. 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. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Spearfishing of a particular species ends once the declared harvest is reached in a given lake. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

As previously stated, walleye spear harvest has been suspended on the Minocqua Chain since 2015. Current plans are to resume walleye spear harvest in spring 2021. Small quotas for walleye harvest have been declared for Mid Lake in the past, but no walleye harvest has been reported. The Minocqua Chain had experienced consistent spear harvest prior to 2015, with roughly 800 fish/year harvested from the entire system. Lake Tomahawk saw the most walleye harvest pressure.

Muskellunge open water spear harvest has remained open. While Mid Lake has had quota declarations in the past, no muskellunge harvest has been recorded in the lake directly. As a whole, approximately 12 muskellunge are speared in a given year on the entire Minocqua Chain (Figure 3.6-7). Lake Tomahawk receives the most muskellunge harvest pressure.

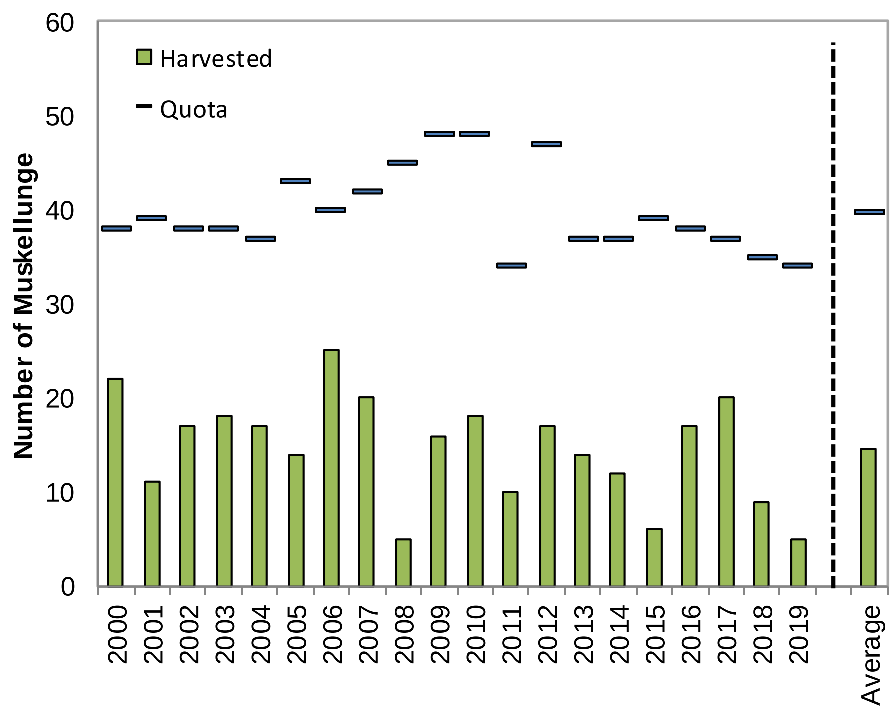


Figure 3.6-6. Minocqua Chain muskellunge spear harvest data. (GLIFWC 2000-2019).

Mid Lake Fish Habitat

Substrate Composition

Just as forest wildlife require proper trees and understory growth to flourish, fish require certain substrates and habitat types to nest, spawn, escape predators, and search for prey. Lakes with primarily a silty/soft substrate, many aquatic plants, and coarse woody debris may produce a completely different fishery than lakes that are largely sandy/rocky, and contain few aquatic plant species or coarse woody habitat.

Substrate and habitat are critical to fish species that do not provide parental care to their eggs. Northern pike is one species that does not provide parental care to its eggs (Becker 1983). Northern pike 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 are not buried in sediment and suffocate as a result. Walleye are 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 and care for their eggs in muck as well.

According to the point-intercept survey conducted by Onterra in 2019, 95% of the substrate sampled in the littoral zone of Mid Lake were soft sediments, 3% was composed of sand sediments, and 2% were composed of rock substrate.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2009). A fall 2019 survey documented 71 pieces of coarse woody along the shores of Mid Lake, resulting in a ratio of approximately 20 pieces per mile of shoreline. Fisheries biologists do not suggest a specific number of fish sticks for a lake but rather highly encourage their installation wherever possible. To learn how Mid Lake's coarse woody habitat is compared to other lakes in its region please refer to section 3.3.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats and spawning areas. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.


Photograph 3.6-3. Examples of fish sticks (left) and half-log habitat structures. (Photos by WDNR)

Fish cribs are a type of fish habitat structure placed on the lakebed. These structures are more commonly utilized when there is not a suitable shoreline location for fish sticks. Installing fish cribs may also be cheaper than fish sticks; however some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure. Having multiple locations of fish cribs can help mitigate that issue.

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 3.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills, Bremigan and Haynes 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

An additional form of fish habitat structure is spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline for mainly walleye habitat. Rock reefs are sometimes utilized by fisheries managers when attempting to enhance spawning habitats for some fish species. However, a 2004 WDNR study of rock habitat projects on 20 northern Wisconsin lakes offers little hope the addition of rock substrate will improve walleye reproduction (Neuswanger and Bozek 2004).

Placement of a fish habitat structure in a lake may be exempt from needing a permit if the project meets certain conditions outlined by the WDNR’s checklists available online:

(https://dnr.wi.gov/topic/waterways/Permits/Exemptions.html)

If a project does not meet all of the conditions listed on the checklist, a permit application may be sent in to the WDNR and an exemption requested.

If interested, the Mid Lake Protection & Management District, may work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for Mid Lake.

For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.6-4. WDNR fishing regulations for Mid Lake (As of February 2022).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass and smallmouth bass	5	None	June 19, 2021 to March 6, 2022
Smallmouth bass	5	None	June 19, 2021 to March 6, 2022
Largemouth bass	5	None	May 1, 2021 to March 6, 2022
Muskellunge and hybrids	1	50"	May 29, 2021 to December 31, 2021
Northern pike	5	None	May 1, 2021 to March 6, 2022
Walleye, sauger, and hybrids	0	Catch and release only	May 1, 2021 to March 6, 2022
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	10 fish	None	Open All Year

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.6-7. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

Fish Consumption Guidelines for Most Wisconsin Inland Waterways		
	Women of childbearing age, nursing mothers and all children under 15	**Women beyond their childbearing years and men**
Unrestricted*	-	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout
1 meal per week	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout	Walleye, pike, bass, catfish and all other species
1 meal per month	Walleye, pike, bass, catfish and all other species	Muskellunge
Do not eat	Muskellunge	-

**Doctors suggest that eating 1-2 servings per week of low-contaminant fish or shellfish can benefit your health. Little additional benefit is obtained by consuming more than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 3.6-7. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

Fishery Management & Conclusions

Currently, annual fall walleye recruitment surveys are scheduled to keep monitoring walleye reproduction on the Minocqua Chain. Goals for the Minocqua Chain include rehabilitation of the walleye fishery while maintaining a trophy muskellunge fishery. GLIFWC conducted spring walleye population estimates on Kawaguesaga Lake and Minocqua Lake in 2019. This survey is scheduled to occur again on Kawaguesaga Lake and Tomahawk Lake in 2020. Additionally, a full comprehensive survey and creel survey is planned for the entire Minocqua Chain fishery in 2025 by the WDNR.

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 Eurasian watermilfoil and 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 the Mid Lake ecosystem, the folks that care about the lakes, and what steps can be taken by the MLPMD to protect and enhance the system.

A volunteer group of MLPMD members formed a planning committee and were instrumental in the development of the Implementation Plan for this management project. The planning committee served to provide the local sociological perspective related to Mid Lake's use and in developing the MLPMD's role in protecting, enhancing, and managing Mid Lake for the years to come. Pairing the understanding of the technical data that has been collected over time as well as the MLPMD's sociological needs through this planning project has led to the creation of a realistic management plan for the MLPMD to implement in managing Mid Lake.

The Minocqua Chain falls within the headwaters of the Wisconsin River Watershed which ultimately drains to the Mississippi River in Prairie du Chien. Mid Lake contains a small watershed compared to the size of the lake, with approximately four acres of land draining to each acre of the lake. Water quality in Mid Lake is largely a function of the watershed draining to the lake. Mid Lake's watershed is mainly comprised of forests, grasslands, and wetlands which impart the least amount of nutrients to the lake compared to other landcovers like agriculture or urbanization. Having a small watershed, the land uses around the immediate shoreline areas are going to have a large influence over the lake's water quality. Approximately 38% of Mid Lake's shoreline consists of the two most impactful categories (*urbanize*d and *developed–unnatural* shoreland, whereas 48% consists of shorelines in the two most ecologically beneficial categories (*developed–natural* and *undeveloped*). It is fundamental to the health of Mid Lake to preserve natural shorelands and take steps towards shifting the proportion of developed shorelines into less impactful categories.

MLPMD's participation in the Citizens Lake Monitoring Network program since 2007 has allowed for consistent water quality data being available. Parameters including phosphorous, nitrogen, chlorophyll-*a*, and water clarity were analyzed during this project and indicate that Mid Lake has *excellent* water quality. Occasional additional phosphorus inputs to Mid Lake come from the early-summer die back of curly-leaf pondweed, and from backflow of water from the Thoroughfare. Many different types of algae blooms have been documented on Mid Lake, including cyanobacteria (blue-green algae). Whether or not the cyanobacteria were producing toxins during the bloom is unknown. Understanding algae dynamics in lakes is complicated because so many factors control growth rates of algae, such as light availability, nutrient levels, water temperatures, zooplankton populations, and interactions between algal species themselves. While most stakeholders would like a simple answer with a single reason as to why these blooms occur, that answer does not exist. Studies are being conducted all over the world to understand algal dynamics within lakes and while our general understanding is very good, detailing why blooms of certain species or a group of species occur within a lake is often impossible because so many factors come into play. It is important to understand that these algal blooms, including blue-green algae, can be natural parts of a lake ecosystem. If blooms are increasing in frequency and intensity, then there would be reason for more study. When blue-green algae blooms occur, it is important to take safety precautions and avoid exposure until the bloom resides.

Mid Lake is considered to be in a borderline mesotrophic-eutrophic state with moderately high productivity characterized by nutrient and chlorophyll-*a* levels sufficient to sustain a healthy plant population and fishery. Mid Lake's shallow nature in combination with nutrient-rich sediments creates ideal conditions for aquatic plant growth. However, these plants are essential for maintaining Mid Lake's high water clarity.

The Minocqua Chain is an extremely popular destination for anglers that target plentiful gamefish, including trophy-sized muskellunge that rely on Mid Lake for important spawning habitat. Riparian stakeholder respondents believe the fishery is currently *fair* to *good* and that the fishery has *remained the same* or has become *somewhat* worse since they first started fishing the lake. Walleye populations have declined in the Minocqua Chain in recent years, with WDNR and tribal partners engaged in a cooperative rehabilitation program since 2014 to cease all harvest of walleye and attempt to understand why the system is underperforming. The next comprehensive fisheries survey is planned to occur in 2021 or 2022.

Since 2008, approximately 60 different species of plants were located within and along the margins of Mid Lake, higher than many Wisconsin systems. While the total biomass of Mid Lake may be unchanged over time, there has been a shift in recent years from species higher in the water column to species along the bottom. Fern-leaf pondweed, a low-growing species, was the only species to exhibit a statistically valid increasing trend in occurrence from 2008-2020. During this timeframe, coontail, flat-stem pondweed, white-stem pondweed, and naiads have exhibited statistically valid decreasing trends. Many of these species have historically contributed to the need for mechanical harvesting on Mid Lake and now have low populations.

As a part of this planning project, great effort was made to better understand the driving forces of these population changes. It is known that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations can be driven by a combination of natural factors including variations in temperature, ice and snow cover (winter light availability), nutrient availability, water levels and flow, water clarity, length of the growing season, herbivory, disease, and competition. Adding to the complexity of factors which affect aquatic plant community dynamics, human-related disturbances such as the application of herbicides for non-native plant management, mechanical harvesting, watercraft use, and pollution runoff also affect aquatic plant community composition. The reductions observed in Mid Lake have also been observed in other nearby lakes, suggesting these changes are likely being driven by regional changes in environmental conditions. While the MLPMD employs mechanical harvesting to create approximately 24 acres of navigational lanes in Mid Lake, it is not believed that this level of harvesting has the capacity to cause the plant population-level declines that have been observed. Continued monitoring of the plant community will reveal if these trends represent longer-term cycles in these plant populations.

The shorelines of Mid Lake contain a few non-native emergent plans, including purple loosestrife, pale-yellow iris, and flowering rush. Two primary non-native submergent aquatic plant species are known to exist in Mid Lake: Eurasian watermilfoil and curly-leaf pondweed. Curly-leaf pondweed (CLP) has been observed in Mid Lake since 1979, with some years having high populations and others being low. Repeated annual herbicide treatments are required to deplete the asexual "seed bank" (turion bank) of a lake to manage the CLP population. Many resources managers question whether or not this strategy places more strain on the environment, particularly in regards to impacts to native plant species, than the existing CLP population. In 2009-2011, the district adopted an alternative strategy that involved early-season mechanical harvesting of CLP. The goal was to remove as much CLP biomass as possible before the production of turions, and in theory, would over time reduce the lake's turion reserve. The three-year trial study indicated that the nuisance conditions could be reduced, but meaningful lake-wide CLP population reductions could not. The district may consider an early-season mechanical harvesting strategy if CLP populations increase back to levels that impact navigation and recreation. But in recent years, the CLP population has been extremely low, even being undetectable in some years.

Eurasian watermilfoil (EWM) is well established in the Minocqua Chain, with large amounts of money being spent each year on herbicide treatments, mechanical harvesting, and hand-harvesting. Since its discovery in 2011, the EWM population has remained small in Mid Lake. In some lakes, the EWM population remains small without intervention, on other lakes in increases exponentially with no clear answers of why. The MLPMD does not want to take the chance and have EWM populations explode in Mid Lake, therefore have acted swiftly and aggressively with paid divers to remove the EWM plants as soon as they have been identified. If EWM is found within the mechanical harvesting lanes, that segment would not be harvested until the EWM is removed. Further, this plan supports an annual monitoring strategy to trigger follow-up management if EWM is located.

Through the process of this lake management planning effort, the MLPMD has learned much about their system, both in terms of its positive and negative attributes. The MLPMD continues to be tasked with properly maintaining and caring for this resource. It is particularly important to protect high quality aspects of the Mid Lake ecosystem.

5.0 IMPLEMENTATION PLAN

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

Management Goal 1: Increase the MLPMD's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Give consideration to the creation of an *Education Committee*
Timeframe:	Ambition to discuss in progress
Facilitator:	MLPMD Board of Commissioners
Description:	By demonstrating a clear mission, the *Education Committee* would be responsible for marketing and public relations, educating its constituents, and overall increasing the MLPMD's capacity to influence Mid Lake. The *Education Committee* would be the facilitator for a number of management actions outlined below. The *Education Committee* would deliver an oral report at the district's annual meeting of the previous year's accomplishments and the direction being considered for the following year. This committee would be comprised of 2-4 individuals, with at least one member being on the MLPMD board of directors.
Action Steps:	
	See description above.

Management Action:	Bolster communication abilities and pursue additional communication avenues
Timeframe:	In Progress
Facilitator:	Education Committee or Board of Commissioners
Description:	Education represents an effective tool to address many lake issues. The MLPMD aims to send out regularly distributed newsletters (at least once per year) and maintain an updated website (midlakeprotection.org). The webpage can become a useful repository for district information;

	including meeting minutes and announcement, general district information, and educational materials. However, it requires that the interested individual check back for updates periodically; therefore, it is not reliable for disseminating information quickly. The committee would also investigate creating and moderating a dedicated MLPMD Facebook Page, allowing another resource for building a sense of community, as well as providing information on upcoming events or providing links to educational pieces posted on the website. This can include announcements, pictures, short videos, and links to websites. Links to websites are useful because they allow the district to keep their followers informed regarding updates and additions made to the MLPMD webpage. The disadvantage to utilizing Facebook is that it requires users to have a subscription, which is free, and check their newsfeed regularly. As social media platforms and use evolves, investigate opportunities for the MLPMD to use additional and/or alternative platforms to provided content to its audience. Email is another useful form of electronic communication that allows the district to disseminate news quickly at low cost. Emails can contain short informational pieces, pictures, and links to information on the web. The MLPMD has made it a priority to build a complete and updated email list, which will allow more rapid and cost-effective means of providing information to district members. The district is considering additional ways to improve upon its communication capacity, such as employing a Constant Contact email marketing campaign. These mediums allow for exceptional communication with district members. This level of communication is important within a management group because it facilitates the spread of important district news, educational topics, and even social happenings.
Action Steps:	
	See description above

<u>Management Action:</u>	Participate in annual Wisconsin Lakes and Rivers Convention
Timeframe:	Annually
Facilitator:	MLPMD Board of Commissioners
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events throughout the state. The primary event is

	the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the nation and is specifically suited to the needs of lake associations and districts. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/district. The MLPMD will sponsor the attendance of 1-3 district members annually at the convention. Following the attendance of the convention, the members will report specifics to the board of commissioners regarding topics that may be applicable to the management of Mid Lake and operations of the MLPMD. The attendees will also create a summary in the form of a newsletter article and if appropriate, update the district membership at the annual meeting. Information about the convention can be found at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/default.aspx In addition to the state-wide conference, local counties occasionally hold more focused conferences where MLPMD would attempt to have representation present.
Action Steps:	
	See description above.

Management Action:	Routinely educate and communicate with all lake stakeholders
Timeframe:	Starting 2021
Facilitator:	Education Committee or Board of Commissioners
Description:	The MLPMD will make the education of lake-related issues a priority. One of the first tasks would be to disseminate the information contained within this *Comprehensive Management Plan*, allowing it to be better understood by district members. To accomplish this task, the Education Committee plans to highlight key topics from the plan and share educational materials on the subjects over time. The MLPMD believes that creating smaller modules of information and spreading out the delivery over time will be an effective educational initiative. As a part of the planning process, the MLPMD identified key topics which they believe the district members would appreciate additional educational opportunities. These may include educational materials,

	awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. *Example Educational Topics* • Importance of natural landscapes • Boating regulations & safety • Responsible watercraft use/harmful effects of excessive watercraft use • Development of a courtesy code • General lake ecology • Aquatic invasive species identification • Septic system maintenance • Boating safety (promote existing guidelines) • Shoreline habitat restoration and protection • Litter • Noise and light pollution • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Recreational use of the lakes • Shoreline erosion – individuals, wildlife • Bluegreen algae
Action Steps:	
	See description above.

<u>Management Action:</u>	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Every 5-6 years
Facilitator:	Education Committee or Board of Commissioners
Description:	Approximately once every 5-6 years, an updated stakeholder survey would be distributed to the Mid Lake riparians. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. This information would be critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during 2019, with modified or additional questions as appropriate. The survey would again receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.
Action Steps:	

	See description above

Management Action:	Continue MLPMD's involvement with other entities that have responsibilities in managing (management units) Mid Lake
Timeframe:	Continuation of current efforts
Facilitator:	Board of Commissioners
Description:	The purpose of the MLPMD is to maintain, protect, and improve the quality of lakes for the landowners and those that use the lake for recreation purposes. The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the MLPMD actively engage with all management entities to enhance the district's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page. Often referred to as the Minocqua Chain of Lakes, Mid Lake is part of a contiguous waterbody that spans over 6,000 acres. In addition to the Mid Lake Protection and Management District, the Tomahawk Lake Association (TLA) and the Minocqua-Kawaguesaga Lake Protection Association (MKLPA) are local lake organizations leading the management on this system (Table 5.0-1). The MLPMD will reach out to the lake groups from these connecting waterbodies and aim to identify areas of overlap that may result in shared resources or singular messaging.

Table 5.0-1. Management entities of the Minocqua Chain of Lakes.

	Acres	Management Group
Tomahawk	3,462	TLA
Little Tomahawk	163	
Mud	41	
Inkwell	13	
Paddle Pond	5	
Thoroughfare	79	
	36	MKLPA
Minocqua	1,339	
Kawaguesaga	700	
Mid Lake	225	MLPRD
	6,063	

Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Wisconsin Department of Natural Resources	Fisheries Biologist (Royce Zehr – 715-531-8054)	Manages the fishery of the Chain.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Scott Van Egeren 715-471-0007)	Oversees management plans, grants, all lake activities.	Once a year, or more as necessary.	Information on updating a lake management plans, submitting grants r permits, and to seek advice on other lake issues.
	Warden (Audrey Royce – 715-614-3288)	Oversees regulations handed down by the state.	As needed. May contact WDNR Tip Line (1.800.847.9367) as needed also.	Suspected violations pertaining to recreational activity, including fishing, boating safety, ordinance violations, etc.
	CLMN Director (Sandra Wickman – 715.365.8951)	Training and assistance on CLMN activities.	Twice a year or more as needed.	Contact to arrange for training as needed, in addition to planning out monitoring and reporting of data.
Oneida County LWCD	AIS Coordinator (Steph Boismenue – sboismenue@co.oneida.wi.us)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	<u>Spring:</u> AIS training and ID, AIS monitoring techniques <u>Summer</u>: Report activities to Ms. Boismenue.
	County Conservationist (Michele Sadauskas - msadauskas@co.oneida.wi.us)	Oversees conservation efforts for land and water projects.	Twice a year or more as needed.	Can provide assistance with shoreland restorations and habitat improvements.
Town of Woodruff	Town Clerk (Julie Huotari - 715.356.9421)	Local unit of government	As needed. Visit website (townofwoodruff.org)	Contact regarding grant applications, CBCW, town events, ordinances etc.
Oneida County Lakes & Rivers Association	Secretary (Connie Anderson – 715.282.5798)	Protects Oneida Co. waters through facilitating discussion and education.	Twice a year or as needed.	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Oneida Co. waterways.
UW-Extension	Program Coordinator (Erin McFarlane – 715.346.4978)	Clean Boats Clean Waters Program	As needed.	May be contacted to set up CBCW training sessions, report data, etc.
Minocqua Kawaguesaga Protection Association	Commission Chair (Sally Murwin - niwrum@charter.net)	Oversees management of downstream lakes.	Once a year or as needed. (minocquakawaga.org)	Understand management objectives and actions, look for ways to dovetail existing programs and/or share resources
Tomahawk Lake Association	President (Noah Lottig - nrlottig@gmail.com)	Oversees management of upstream lakes.	Once a year or as needed. (tomahawklake.org)	
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and	As needed. May check website (wisconsinlakes.org) often for updates.	May attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist

	assistance on lake issues.	on grant issues, training, habitat enhancement techniques, etc.

Management Goal 2: Manage Aquatic Invasive Species and Prevent Establishment of New Aquatic Invasive Species

Management Action:	Give consideration to the creation of an *Aquatic Plant and AIS Management Committee*
Timeframe:	Ambition to consider in progress
Facilitator:	Board of Commissioners
Description:	The creation of a dedicated committee will ensure that division of labor occurs within the MLPMD. The *Aquatic Plant and AIS Management Committee* would be charged with AIS management, Clean Boats Clean Waters watercraft inspections, and future AIS aquatic plant and animal (e.g. rusty crayfish, zebra-mussel) monitoring activities as situations present. The MLPMD would continue to provide education and direction to riparians on how to monitor around their docks and recreational footprint for new AIS. The *Aquatic Plant and AIS Management Committee* would also deal with funding, cost analysis, risk assessment, treatment strategy, and data review. This committee would be comprised of 2-4 individuals, with at least one member being on the MLPMD board of directors.
Action Steps:	
	See description above.

Management Action:	Monitor Mid Lake entry points for AIS.
Timeframe:	Ongoing
Facilitator:	Aquatic Plant & AIS Management Committee or Board of Commissioners
Description:	The intent of a watercraft inspection program would not only be to prevent additional invasive species from entering the Minocqua Chain through its public access locations, but also to prevent the infestation of other waterways with invasive species that originated in the Minocqua Chain. The goal would be to cover the landings during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread. While Mid Lake does have a single access location (Grundy Point), this undeveloped entry 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 Minocqua Lake. The MLPMD has focused efforts toward monitoring the boat landing located on the thoroughfare. The Tomahawk Thoroughfare landing has been monitored through funding by the Tomahawk Lake Association (TLA) and the MLPMD with additional funding from a streamlined WDNR grant program.
Action Steps:	
	See description above.

Management Action:	Eradication management strategy towards EWM
Timeframe:	Ongoing
Facilitator:	Aquatic Plant & AIS Management Committee or Board of Commissioners
Description:	Eurasian watermilfoil (EWM) was located in Mid Lake by Onterra ecologists in 2011 despite being present in connected lakes since at least the early 2000s. Since its discovery, the EWM population has remained small in Mid Lake and has been managed through contracting professional hand-harvesting services. Unfortunately, eradication of EWM from any system in Wisconsin has likely not occurred and therefore eradication is an unrealistic goal. Specific to Mid Lake, upstream and downstream connected waterbodies harbor hundreds of acres of EWM, serving as a large source population for new entry into Mid Lake. The MLPMD will always be dealing with EWM. The MLPMD's objective is to keep EWM from establishing in the lake. The term *eradication strategy* is used here as it intends to control every and all EWM occurrences that are discovered within Mid Lake. The location of identified EWM occurrences would be forwarded to a profession hand-harvesting company for hand-removal. Depending on the amount of EWM removed, the addition of Diver-Assisted Suction Harvesting (DASH) equipment may be utilized. The use of DASH requires a WDNR permit. If at a future point in time, the EWM population reaches a level where prioritization of hand-harvesting efforts or consideration of alternative management methods (i.e. herbicide treatment) is needed, the MLPMD would need to create an updated management action for EWM management.
Action Steps:	
	See description above.

Management Goal 3: Monitor Aquatic Vegetation on Mid Lake

Management Action:	Conduct professional EWM Mapping Surveys
Timeframe:	Annually
Facilitator:	Aquatic Plant & AIS Management Committee or Board of Commissioners
Description:	When at extremely low levels the best way to monitor an EWM population is through systematic mapping surveys. This survey would include a complete meander survey of the lake's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). EWM typically is at lower biomass at the beginning of the growing season and reaches peak biomass at the end of the summer. The MLPMD would like to have Mid Lake surveyed each year in the early-to mid-summer. The MLPMD does not want the survey to occur too early in the season that the EWM plants are small and go undetected by the survey. But the MLPMD wants to ensure there is sufficient time to contract a hand-harvesting firm to visit the lake that same summer if EWM locations are identified. It is likely that this survey would occur between the end of June and mid-July. If EWM is found within a mechanical harvest lane, that portion of the lane would be omitted until hand-harvesting occurs. If volunteer-based surveys identify potential EWM occurrences from Mid Lake, these locations would be forwarded on to the professional surveying firm for field confirmation and mapping. Preferably this would be prior to the early-summer lake-wide mapping survey.
Action Steps:	
	See description above.

Management Action:	Periodically monitor the CLP population
Timeframe:	Periodic or when prompted
Facilitator:	Aquatic Plant & AIS Management Committee or Board of Commissioners
Description:	As discussed in the Aquatic Plant Section (3.4), CLP was first "officially" recorded from Mid Lake during 1979. Since that time, the CLP population has fluctuated greatly from being at undetectable levels in some years to imparting great recreational impediments in other years. CLP control strategies typically employ multiple years of directed herbicide treatments to exhaust the base of turions present within a waterbody. In instances where a

	large turion base may have already built up, such as in Mid Lake, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species. The MLPMD does not feel that CLP management is appropriate for Mid Lake. As will be discussed in a subsequent management goal, the WDNR allows the MLPMD to treat CLP as any other plant and harvest it within predefined areas if it is present The MLPMD would give consideration to periodically monitoring the CLP population within Mid Lake, particularly during years where widescale and dense populations are being observed. These surveys will help further the understanding of this species within Mid Lake. A lake-wide CLP mapping survey would be completed during mid- to late-June while the plant is at its peak growth stage for the year. It may be possible to couple the CLP mapping survey with the early-summer EWM Mapping Survey discussed within the previous management action.
Action Steps:	
	See description above

<u>Management Action:</u>	Coordinate Periodic Point-Intercept Surveys
Timeframe:	Every 3-5 years depending on management strategies being employed
Facilitator:	Aquatic Plant & AIS Management Committee or Board of Commissioners
Description:	The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) has been conducted on Mid Lake in 2008 and 2013-2020. At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance (rake fullness) on the sampling rake is recorded. The WDNR generally indicates that repeating a point-intercept survey every five years will generally suffice to meet WDNR planning requirements unless large-scale aquatic plant management is taking place and more frequent monitoring is requested for the specifically targeted areas. The MLPMD has noticed some relatively large aquatic plant population changes in Mid Lake during the time period of study. A large portion of the Aquatic Plant Section (3.4) is devoted to investigating these changes. By continuing to periodically conduct

	these surveys, the MLPMD may gain more insight into the factors that are causing the plant shifts. The 2008 point-intercept survey was conducted in mid-July, consistent with the WDNR recommendations for this survey taking place in July-August when most native plants are at stable populations for the growing season. The 2013-2020 point-intercept survey were conducted during the last days of June. This survey timing balances being early enough in the season to capture the CLP population before it naturally dies off (senescence) for the year, but late-enough that most native aquatic plants have progressed to stable populations for the year. The MLPMD will conduct point-intercept surveys at roughly 5-year intervals during this late-June timeframe to assess CLP and the native plant community. If native plant populations continue to be a concern, consideration should be given to conducting point-intercept surveys later in July or August to alleviate seasonality (phenology) concerns associated with late-June data sets.
Action Steps:	
	See description above.

<u>Management Action:</u>	Coordinate Periodic Community Mapping (floating-leaf and emergent) Surveys
Timeframe:	Every 10 years unless prompted
Facilitator:	Aquatic Plant & AIS Management Committee or Board of Commissioners
Description:	This survey would delineate the margins of floating-leaf (e.g. water lilies) and emergent (e.g. cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system. The most recent survey in 2019 delineated approximately 8.7 acres of these communities, down from 9.5 acres in 2008. In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in Mid Lake, a community mapping survey would be conducted approximately every 10 years unless a specific rationale prompts a shorter interval. Such a rationale would include timing the survey to occur at near high and near low water levels. Surveys were completed in 2008 and 2019 near the peak of the water level/flow. If another survey takes place in 2025 or 2026 this would again be near the low water level according to recent predictions (Watras et al. 2013). It would be good to collect repetitive data in both

	the highest and lowest water levels to determine if changes are due to water level or some other environmental or human cause.
Action Steps:	
	See description above.

Management Goal 4: **Maintain Current Water Quality Conditions**

<u>Management Action:</u>	Monitor water quality parameters through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	Dennis Hirtz or new volunteer
Description:	Monitoring water quality is an important 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 of why the trend is occurring. Volunteer water quality monitoring should be completed annually by Mid Lake riparians through the Citizen Lake Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. The MLPMD currently monitor a single site in Mid Lake (at the deep hole) under the advanced CLMN program. This includes collecting Secchi disk transparency, as well as sending in water chemistry samples (chlorophyll-*a*, and total phosphorus) to the Wisconsin State Laboratory of Hygiene (WSLH) for analysis. The samples are collected three times during the summer and once during the spring. It is important to note that 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). It also must be noted that the CLMN program may be changing in the near future with sample analysis cost coverage not available annually. Recently there has been a move to have new CLMN volunteers collect samples for three years and then stop so that additional lakes can be funded. If a long-term record is desired by the MLPMD then it will be important to maintain the volunteer data collection without a lapse. The MLPMD board will need to review the specifics of the revised program when available and potentially modify this management action.
Action Steps:	
1.	Trained CLMN volunteer(s) collects data, enters data into SWIMS, and report results to association members during annual meeting.

2.	CLMN volunteer and/or MLPMD board would facilitate new volunteer(s) as needed

Management Action:	Monitor winter dissolved oxygen levels.
Timeframe:	Annually during late-winter
Facilitator:	Dennis Hirtz or new volunteer
Description:	Dissolved oxygen is critical for supporting a healthy fish population in any lake. Mid Lake is known to have periodic fish kills related to low oxygen during long winters. (Photograph 5.0-1). Understanding the dissolved oxygen levels during the winter months in Mid Lake will help drive fisheries management decisions including such topics as the potential need of installing an aeration system.  **Photograph 5.0-1. Winter fish kill during early-March 2018.** (Photo by Jon Stein) The MLPMD would periodically conduct dissolved oxygen profiles during the late-winter (late-February, early-March when ice is safe). A dissolved oxygen probe would be lowered through the ice and measurements would be collected every foot.
Action Steps:	
1.	Secure access to a dissolved oxygen reader, either through borrowing a unit (e.g. Oneida County, regional WDNR) or purchasing one.
2.	Enter data into SWIMS and to the local WDNR fisheries biologist.

Management Action:	Educational initiative aimed at raising awareness of blue-green algae blooms on Mid Lake
Timeframe:	Continuation of current effort.
Facilitator:	Education Committee or Board of Commissioners
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 (dhs.wisconsin.gov/water/bg-algae/index.htm) 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. The MLPMD 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 MLPMD may decide to have samples collected. Blue-green algae samples can be shipped to the Wisconsin State Laboratory of Hygiene for toxin analysis. The cost of the analysis is approximately $400 a sample. 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 MLPMD 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 (dnr.wisconsin.gov/topic/lakes/bluegreenalgae)
Action Steps:	
	See description above.

Management Goal 5: **Improve Lake and Fishery Resource**

Management Action:	Educate stakeholders on the importance of shoreland condition and shoreland restoration and protection
Timeframe:	Summer 2021
Facilitator:	Education Committee or Board of Commissioners
Description:	The shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. As discussed in the Shoreland Condition Section (3.3), the Healthy Lakes & Rivers Grant program provides cost share for implementing the following best practices: • Rain Garden • Rock Infiltration • Diversion • Native Plantings • Fish Sticks The cost share allows $1,000 per practice, up to $25,000 per annual grant application. More details and resources for the program are included within the Shoreland Condition Section (3.3) and can be found at: https://healthylakeswi.com The *Education Committee* would focus specific education on the importance of shoreland condition and the resources that are available (planning and funding). Partial funding for shoreland restoration activities is available through the WDNR Healthy Lakes Initiative. The *Education Committee* would also strive to initiate a Healthy Lakes shoreline restoration project to serve as a demonstration site, being publicized to lake users so they may want to follow suit on their properties. Approximately 48% of Mid Lake's shoreline is *natural/undeveloped.* While a portion of this shoreline is already protected by being owned by the State of Wisconsin as American Legion State Forest, the privately owned areas could be the focus of preservation efforts. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the

	WDNR, UW-Extension, and Oneida County Land & Water Conservation Department. Several websites of interest include: • Conservation easements or land trusts: (www.northwoodslandtrust.org) • UW-Extension Shoreland Restoration: (https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/ecology/shoreland/default.aspx) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/) WDNR land acquisition grants are available to pay for the costs of property purchases and conservation easements. Scott Van Egeren (WDNR lakes biologist) or Jill Sunderland (WDNR environmental grants specialist) can be contacted with questions about this specific grant program.
Action Steps:	
	See description above

Management Action:	Initiate a Loon Watch program
Timeframe:	Ambition to consider in progress
Facilitator:	Education Committee or Board of Commissioners
Description:	The Loon Watch Program is operated through the Sigurd Olson Environmental Institute from Northland College. The purpose of the program is to provide a picture of common loon reproduction and population trends on northern Wisconsin lakes. Loon watch volunteers send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen. The MLPMD has passively monitored Loon activity and has interest in enrolling in the Loon Watch Program in conjunction with the Sigurd Olson Environmental Institute from Northland College. This program would include placement of artificial loon nesting platforms, as well as monitoring according to the Loon Watch Program. The MLPMD would ensure that a dedicated volunteer is in place to send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen.
Action Steps:	
	See description above

Management Goal 6: Maintain Navigability on Mid Lake

Management Action:	Maintain recreational use through planned and permitted mechanical harvesting activities
Timeframe:	Continuation of Current Effort
Facilitator:	Board of Commissioners
Description:	The MLPMD understands the importance of native aquatic vegetation within Mid Lake. However, nuisance aquatic plant conditions exist in certain parts of the lake, sometimes caused by curly-leaf pondweed, and loosely-rooted native vegetation (coontail, common waterweed, southern naiad) that becomes entangled on taller growing plants. The MLPMD supports the reasonable and environmentally sound actions to facilitate navigability on the Mid Lake. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area than absolutely necessary. The WDNR oversees the management of aquatic plants on inland lakes. The manual cutting and raking of native aquatic plant species within a 30-foot-wide area containing a pier, boatlift, or swim raft is exempt from a state permit provided that the cut plants are removed from the lake. However, the use of mechanized or mechanical devices requires a WDNR permit. The MLPMD periodically conducts "weed pickup," where piles of aquatic vegetation raked by property owners consistent with the previous paragraph are placed along their shoreline and eventually pitchforked onto the mechanical harvester. The vegetation piles need to be free of sticks and rocks, as they damage the harvesting equipment. The MLPMD announces these weed pickup times on their website. Historically, land owners would place the piles at the end of docks. For the safety of the harvester and the riparian's pier this practice has discontinued. No longer will piles be removed from piers. Current management of nuisance levels of aquatic plants occurs on Mid Lake using a district-owned mechanical harvester. The MLPMD is investigating onboard GPS guidance to increase efficiency and assist with tracking.

	The WDNR granted 1-year permits in 2019 and 2020 while the MLPMD was completing an updated lake management plan. With an approved plan, the MLPMD anticipated obtaining 3-year permits moving forward until an updated aquatic plan management plan is requested, likely in 2026. The bulleted list below outlines a condensed version of the WDNR's conditions on the MLPMD's recent Mechanical Harvesting Permit: • No harvesting of native species shall occur before June 1st as Mid Lake provides important Musky spawning habitat for the Minocqua Chain. • Harvesting operations shall not disturb spawning or nesting fish. Harvesting shall be done in a manner to minimize accidental capture of fish. Any game fish accidentally captured shall be released immediately. Attempts should be made to release all other species. • Harvesting locations are limited to areas on the permit map (Map 8). • Submerged plants are the target for this permit and removal of (e.g. bulrushes) and floating-leaf (e.g. water lilies) species needs to be limited because of their ecological value and niche occupation. • Harvest of curly-leaf pondweed is acceptable within permitted areas. • Aquatic plants that are cut must be removed from the water. • Reports summarizing harvesting activities shall be given to the Department by November 30, each harvesting season. The report shall include a map showing the areas harvested, the total acres harvested and the total amount of plant material removed from the body of water. The report shall also include a summary of the composition and quantity of plants removed by species. This can be done by recording the daily percent of the total of individual species harvested (primary species that are causing the need for harvesting), and then calculating the pounds harvested per day. At the end of the month, you can then calculate the percentage and weight of all species harvested.
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 (CLMN) protocols which occurred once in spring and three times during the summer. In addition to the samples collected by MLPMD members, professional water quality samples were collected with a 3-liter Van Dorn bottle at subsurface (S) and near bottom (B) depths once in spring, summer, winter, and fall. Although MLPMD members collected a spring total phosphorus sample, professionals also collected a near bottom sample to coincide with the bottom total phosphorus sample. During each professional sampling event, a temperature and dissolved oxygen profile was completed using a HQ30d with a LDO probe. Secchi disk transparency was also included during all monitoring visits.

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 the table below.

	Spring		**June**	**July**		**August**	**Fall**		**Winter**	
Parameter	**S**	**B**	**S**	**S**	**B**	**S**	**S**	**B**	**S**	**B**
Dissolved Phosphorus	●	●							●	●
Total Phosphorus	●♦	●	♦	●♦	●	♦	●	●	●	●
Total Nitrogen	●	●	■	●		■			●	●
Chlorophyll-*a*	●		♦	●♦		♦	●			
True Color	●			●						
Hardness	●									
Total Suspended Solids	●	●					●	●		
Laboratory Conductivity	●	●		●	●					
Laboratory pH	●	●		●	●					
Total Alkalinity	●	●		●	●					
Calcium	●									

♦ indicates samples collected as a part of the Citizen Lake Monitoring Network.
■ indicates samples collected by volunteers under proposed project.
●indicates samples collected by consultant under proposed project.

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 National Land Cover Database (NLCD – (Homer et al. 2016)) 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)

Point-Intercept Macrophyte Survey

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 the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) (Hauxwell et al. 2010) was used to complete this study.

Floating-Leaf & Emergent Plant Community Mapping

During the species inventory work, the aquatic vegetation community types within Mid Lake (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) receiver 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.

AIS Mapping Surveys

During these surveys, the entire littoral area of the lake was surveyed through visual observations from the boat. Field crews may supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to EWM locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*

7.0 LITERATURE CITED

Asplund, T. R., and C. M. Cook. 1997. Effects of motor boats of submerged aquatic macrophytes. *Lake and Reserv. Manage.*, 1997: 13(1): 1-12.

Bajer, P. G., and P. W. Sorensen. 2015. Effects of common carp on phosphorus concentrations, water clarity, and vegetation density: a whole system experiement in a thermally stratified lake. *Hydrobilogia*, 2015: 746: 30-311.

Becker, G.C. 1983. *Fishes of Wisconsin.* London, England: The University of Wisconsin Press, 1983.

Borman, Susan, Robert Korth, and Jo Temte. 1997. *Through the Looking Glass, A Field Guide to Aquatic Plants.* Wisconsin Lakes Partnership, 1997.

Canter, L. W., D. I. Nelson, and J. W. Everett. 1994. Public perception of water qality risks-influencing factors and enhancement opportunities. *Journal of Environmental Systems*, 1994: 22(2).

Carlson, R.E. 1977. A trophic state index for lakes. *Limnology and Oceanography*, 1977: 22:361-369.

Davis, G J, and M M Brinson. 1980. Responses of submerged vascular plant communities to environmental change. *USGS report publication*, 1980.

Dinius, S.H. 2007. Public Perceptions in Water Quality Evaluation. *Journal of the American Water Resource Association*, 2007: 17(1): 116-121.

Elias, J. E., and M. W. Meyer. 2003. Comparisons of Undeveloped and Developed Shorelands, Northern Wisconsin, and Recommendations of Restoration. *Wetlands*, 2003: 23(4): 800-816.

Garn, H.S. 2002. *Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Two Lakeshore Lawns, Lauderdale Lakes, Wisconsin.* Water-Resources Investigations Report 02-4130, USGS, 2002.

Garrison, P., et al. 2008. *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest.* PUB-SS-1044, Wisconsin Department of Natural Resources Bureau of Sciences Services , 2008.

Gettys, L.A., Haller, W.T., Bellaud, M. 2009. *Biology and Control of Aquatic Plants: A Best Management Handbook.* Marietta, GA: Aquatic Ecosystem Restoration Foundation, 2009.

GLIFWC. 2017. *Great Lakes Indian Fish and Wildlife Service Wisconsin 1837 & 1842 Ceded Territories Regulation Summaries – Open-water Spearing.* 2017. http://www.glifwc.org/Enforcement/regulations.html (accessed January 2018).

Graczyk, D.J., R.J. Hunt, S.R. Greb, C.A. Buchwald, and J.T. Krohelski. 2003. *Hydrology, Nutrient Concentrations, and Nutrient Yields in Nearshore Areas of Four Lakes in Northern Wisconsin, 1999-2001.* Water-Resources Investigations Report 03-4144, USGS, 2003.

Gross, E. M., D. Erhard, and E. Ivanyi. 2003. Allelopathic activity of Ceratophyllum demersum L. and Najas marina spp. intermedia (Wolfgang) Casper. *Hydrobiologia*, 2003: 506:583.

Gross, Elisabeth M. 2003. Allelopathy of Aquatic Autotrophs. *Critical Reviews in Plant Sciences* 22, no. 3-4 (2003): 313-339.

Hanchin, P.A., D.W. Willis, and T. R. St. Stauver. 2003. Influence of introduced spawning habitat on yellow perch reproduction, Lake Madison South Dakota. *Journal of Freshwater Ecology*, 2003: 18.

Hauxwell, J., et al. 2010. *Recommended baseline monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry and Analysis, and Applications.* PUB-SS-1068, Madison, WI: Wisconsin Department of Natural Resources, 2010.

Homer, Collin G., et al. 2016. Conternimous United States land cover change patterns 2001-2016 from the 2016 National Land Cover Database. *ISPRS Journal of Photogrammetry and Remote Sensing*, 2016: 162:184-199.

Jennings, M. J., Emmons E. E., G. R. Hatzenbeler, C. Edwards, and M. A. Bozek. 2003. Is littoral habitat affected by residential development and landuse in watersheds of Wisconsin lakes? *Lake and Reservoir Management*, 2003: 19(3): 272-279.

Johnson, J. A., A. R. Jones, and R. M. Newman. 2012. Effects of repeated early season herbicide treatments of curly-leaf pondweed on native macrophyte assemblages in Minnesota Lakes. *Lake and Reservoir Management*, 2012: 28(4):364-374.

Johnson, P. T. J., J. D. Olden, C. T. Solomon, and M. J. Vander Zanden. 2009. Interactions among invaders: community and ecosystem effects of multiple invasive species in an experimental aquatic system. *Oecologia*, 2009: 159:161-170.

Lacoul, P., and B. Freedman. 2006. Environmental influences on aquatic plants in freshwater ecosystems. *Environmental reviews*, 2006: 14(2):89-136.

Lindsay, A., S. Gillum, and M. Meyer. 2002. Influence of lakeshore development on breeding bird communities in a mixed northern forest. *Biological Conservation 107*, 2002: 1-11.

Netherland, M.D. 2009. Chapter 11, "Chemical Control of Aquatic Weeds.". In *Biology and Control of Aquatic Plants: A Best Management Handbook*, by W.T. Haller, & M. Bellaud (eds.) L.A. Gettys, 65-77. Marietta, GA.: Aquatic Ecosystem Restoration Foundation, 2009.

Neuswanger, D., and M. A. Bozek. 2004. *Preliminary assessment of Effects of Rock Habitat Projects on Walleye Reproduction in 20 Northern Wisconsin Lakes.* A Summary of Case Histories, Wisconsin Department of Natural Resources, 2004.

Newbrey, M.G., M.A. Bozek, M.J. Jennings, and J.A. Cook. 2005. Branching complexity and morphological characteristics of coarse woody structure as lacustrine fish habitat. *Canadian Journal of Fisheries and Aquatic Sciences*, 2005: 62: 2110-2123.

Panuska, J.C., and J.C. Kreider. 2003. *Wisconsin Lake Modeling Suite Program Documentation and User's Manual Version 3.3.* PUBL-WR-363-94, Wisconsin Department of Natural Resources, 2003.

Radomski, P., and T. J. Goeman. 2001. Consequences of Human Lakeshore Development on Emergent and Floating-leaf Vegetation Abundance. *North American Journal of Fisheries Management*, 2001: 21: 46-61.

Reed, J. 2001. *Influence of Shoreline Development on Nest Site Selection by Largemouth Bass and Black Crappie.* North American Lake Management Conference, Madison, WI. 2001.

Sass, G.G. 2009. Coarse Woody Debris in Lakes and Streams. In *Encyclopedia of Inland Waters*, by Gene E. Likens, 1: 60-69. Oxford: Elsevier, 2009.

Scheuerell, M. D., and D. E. Schindler. 2004. Changes in the Spatial Distribution of Fishes in Lakes Along a Residential Development Gradient. *Ecosystems*, 2004: 7: 98-106.

Shaw, B.H. and N. Nimphius. 1985. Acid Rain in Wisconsin: Understanding Measurements in Acid Rain Research (#2). *UW-Extension, Madison*, 1985: 4pp.

Skogerboe, J.G., A. Poovey, K.D. Getsinger, W. Crowell, and Macbeth E. 2008. Early-season, low-dose applications of endothall to selectively control curlyleaf pondweed in Minnesota lakes. *U.S. Army Engineer Research and Development Center*, 2008: ERDC/TN APCRP-CC-08.

Smith, D. G., A. M. Cragg, and G. F. Croker. 1991. Water Clarity Criteria for Bathing Waters Based on User Perception. *Journal of Environmental Management*, 1991: 33(3): 285-299.

Solomon, C.T., J.D. Olden, Johnson. P.T.J, R.T. Dillion Jr., and M.J Vander Zander. 2010. Distribution and commmunity-level effects of the Chinese mystery snail (Bellamya chinensis) in northern Wisconsin lakes. *Biological Invasions*, 2010: 12:1591-1605.

Sondergaard, M., et al. 2007. Lake restoration: successes, failures, and long-term effects. *Journal of Applied ecology*, 2007: 44(6):1095-1105.

Strayer, David, et al. 2017. Boom-bust dynamics in biological invasions: towards an improved application of the concept. *Ecology Letters* 20, no. 10 (2017): 1337-1350.

USEPA. 2009. *National Lakes Assessment: A collaborative Survey of the Nation's Lakes.* EPA 841-R-09-001, Washington, DC: United States Environmental Protection Agency Offiec of Water and Office of Research and Development, 2009.

Valley, Ray, and Steven A. Heiskary. 2012. Short-term declines in curly-leaf pondweed in Minnesota: Potential influences of snowfall. *Lake and Reservoir Management* 28, no. 4 (2012): 338-345.

Vestergaard, O., and K. Sand-Jensen. 2000. Alkalinity and trophic state regulate aquatic plant distribution in Danish Lakes. *Aquatic Botany*, 2000: 67:85-107.

Watras, C.J., et al. 2013. Decadal oscillation of lakes and aquifers in the upper Great Lakes region of North America: Hydroclimate implications. *Geophysical Research Letters* 41, no. 2 (2013): pp. 456-462.

WDNR. 2017. Fish data summarized by the Bureau of Fisheries Management. *Wisconsin Department of Natural Resources Bureau of Fisheries Management.* 2017. http://infotrek.er.usgs.gov/wdnr_public (accessed January 2018).

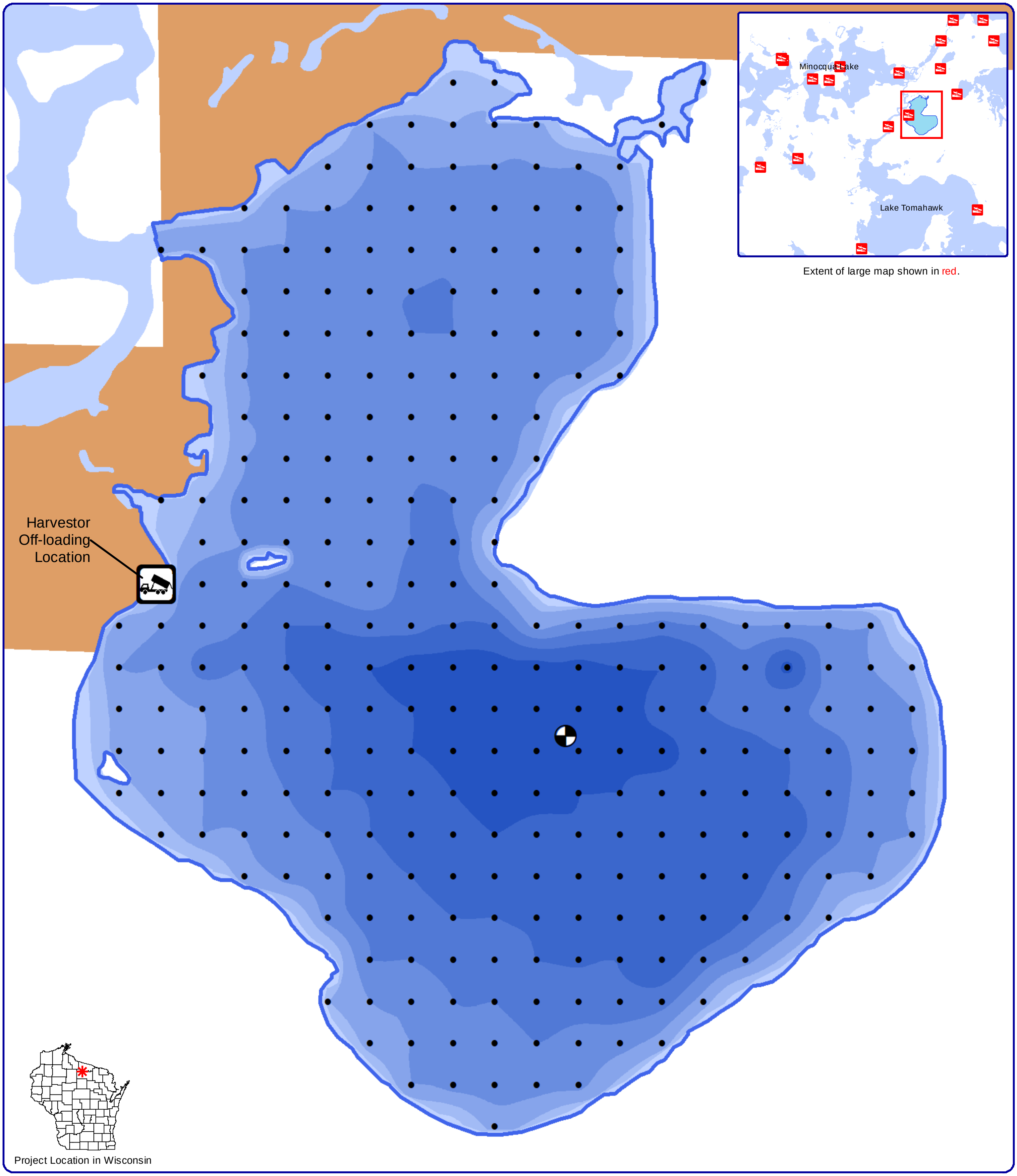
WDNR. 2019. *Total Maximum Daily Loads for Total Phosphorus in the Wisconsin River Basin.* Final U.S. EPA-Approved Report, Madison: WI Department of Natural Resources, 2019.

WDNR. 2018. *Wisconsin 2018 Consolidated Assessment and Listing Methodology (WisCALM).* Bureau of Water Quality Program Guidance, Wisconsin Department of Natural Resources, 2018.

Wills, T. C., M. T. Bremigan, and D. B. Haynes. 2004. Variable Effects of Habitat Enhancement Structures across Species Habitats in Michigan Reservoirs. *American Fisheries Society*, 2004: 133:399-411.

Woodford, J.E., and M.W. Meyer. 2003. Impact of Lakeshore Development on Green Frog Abundance. *Biological Conservation*, 2003: 110: 277-284.

Wu, J., S. Cheng, W. Liang, F. He, and Z. Wu. 2009. Effects of sediment anoxia and light on turion germination and early growth of Potamogeton crispus. *Hydrobiologia* 628 (2009): 111-119.



N
W E
S

550
Feet

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roadsm Hydro, and Lands: WDNR
Bathymetry: Onterra 2013 PI Survey
Map Date: July 14, 2020

Legend

Mid Lake ~224.9 acres
Ortho-corrected Definition

Point-Intercept Survey Location
55-meter spacing, 293 total points

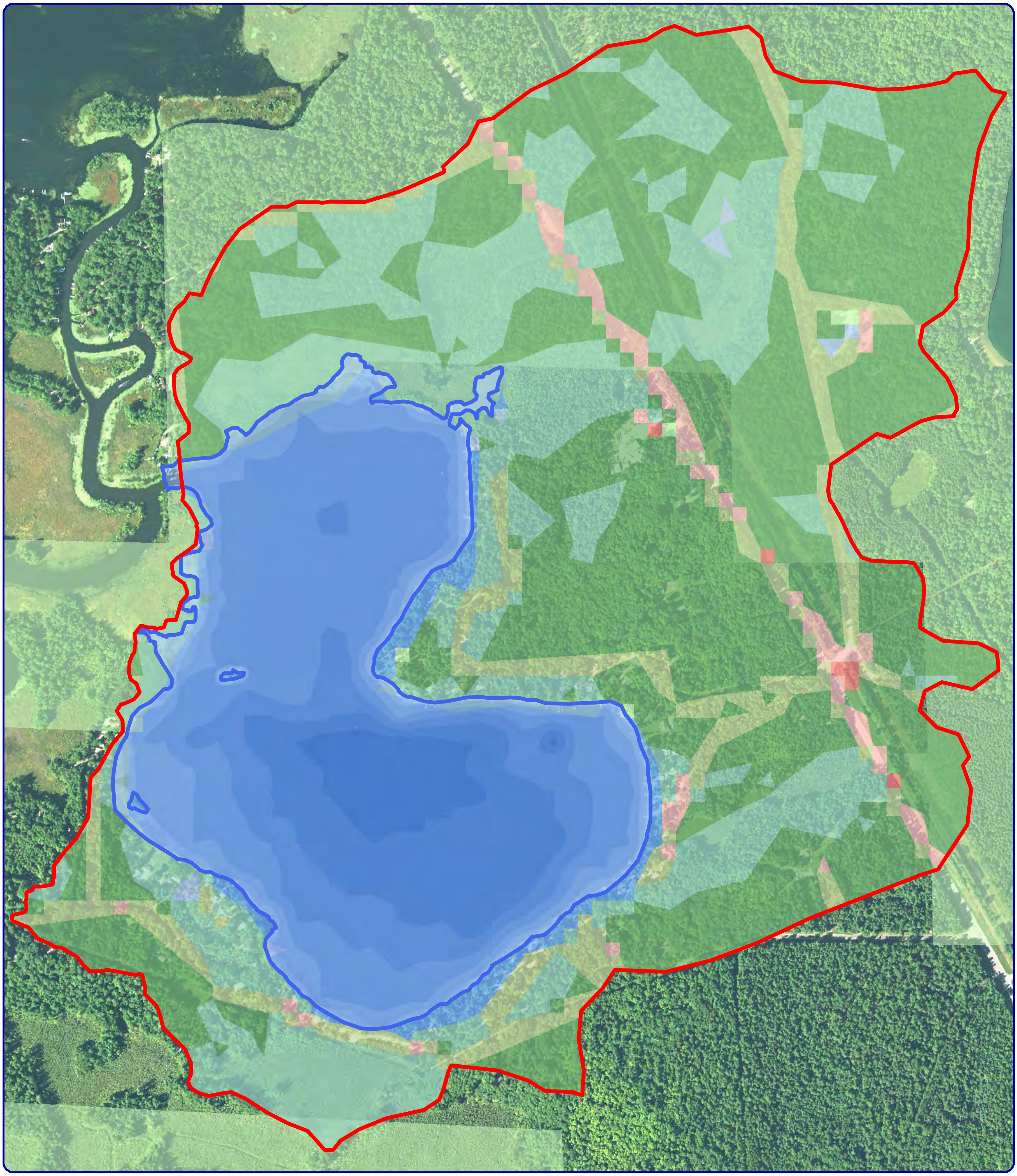
Water Quality
Sample Location

Land Ownership

Federal *(none shown)*
State
County *(none shown)*

Map 1
Mid Lake
Oneida County, Wisconsin

Project Location & Lake Boundaries

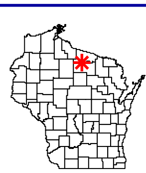


N
W E
S

1,400
Feet

Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Hydro: WDNR
Bathymetry: WDNR/Onterra, 2019
Orthophotography: NAIP 2017
Land Cover: NLCD, 2016
Watershed Boundaries: Onterra, 2019
Map Date: December 30, 2019 JMB
File Name: Mid_Watershed_2019



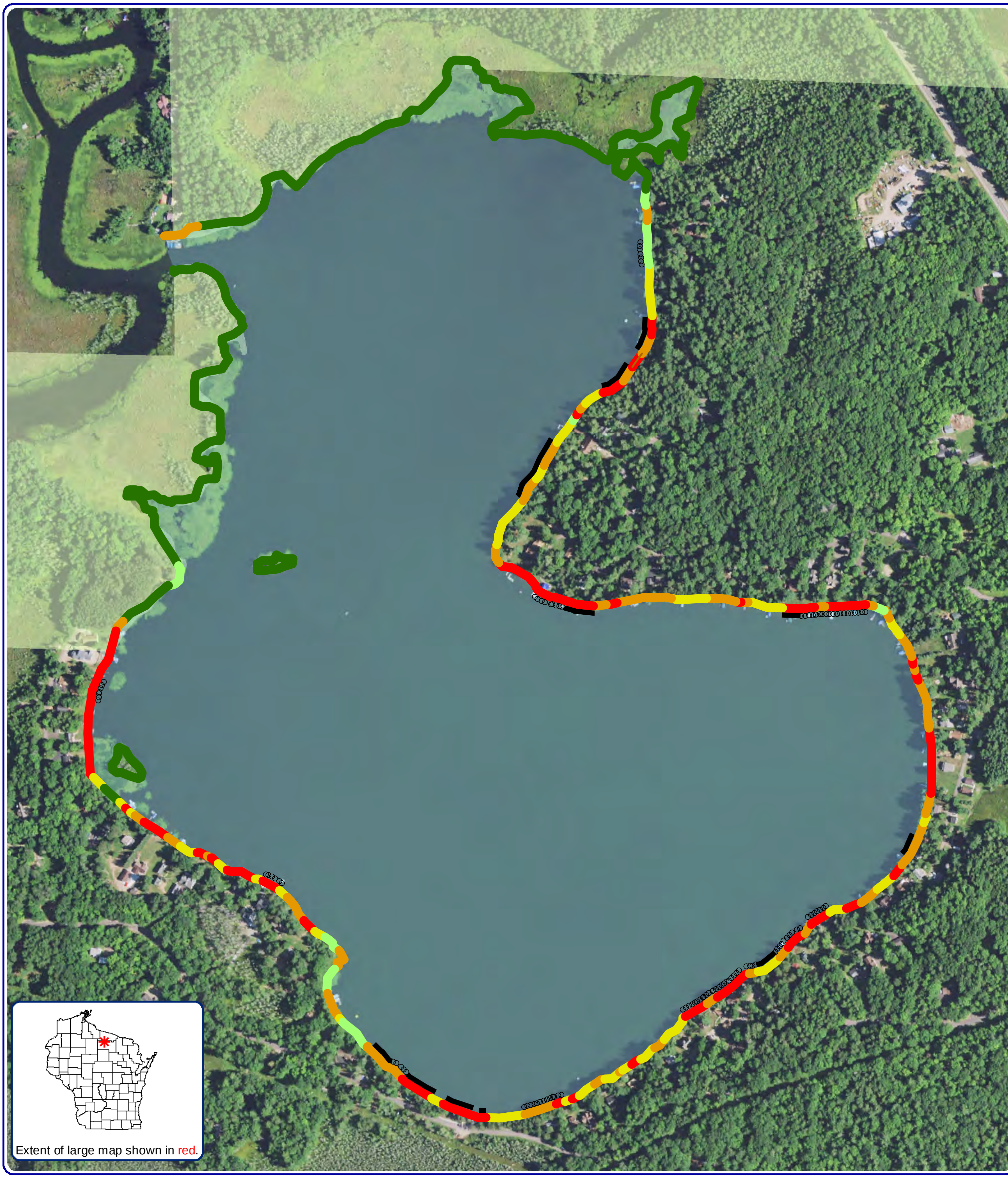
Extent of large map shown in red.

Legend

- Forest
- Forested Wetlands
- Pasture/Grass
- Open Water
- Wetland
- Row Crop Agriculture
- Rural Open Space
- Rural Residential
- Urban - High Density
- Urban - Medium Density
- Mid Lake
- Watershed Boundary

Map 2
Mid Lake
Oneida County, Wisconsin

Watershed Boundaries & Land Cover Types



560

Feet

Legend

Survey Date: October 23, 2019

- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Seawall

- Masonary/Wood Seawall
- Rip-Rap/Stone
- DNR Managed Land

Onterra, LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: November 22, 2019 AMS
Filename: Mid_SCA_2019.mxd

Map 3
Mid Lake
Oneida County, Wisconsin
Shoreland Condition Assessment

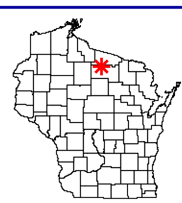
N W E S

520

Feet

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
CWH Survey: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: November 27, 2019 AMS
Filename: Mid_CWH_2019.mxd



Extent of large map shown in red.

Legend

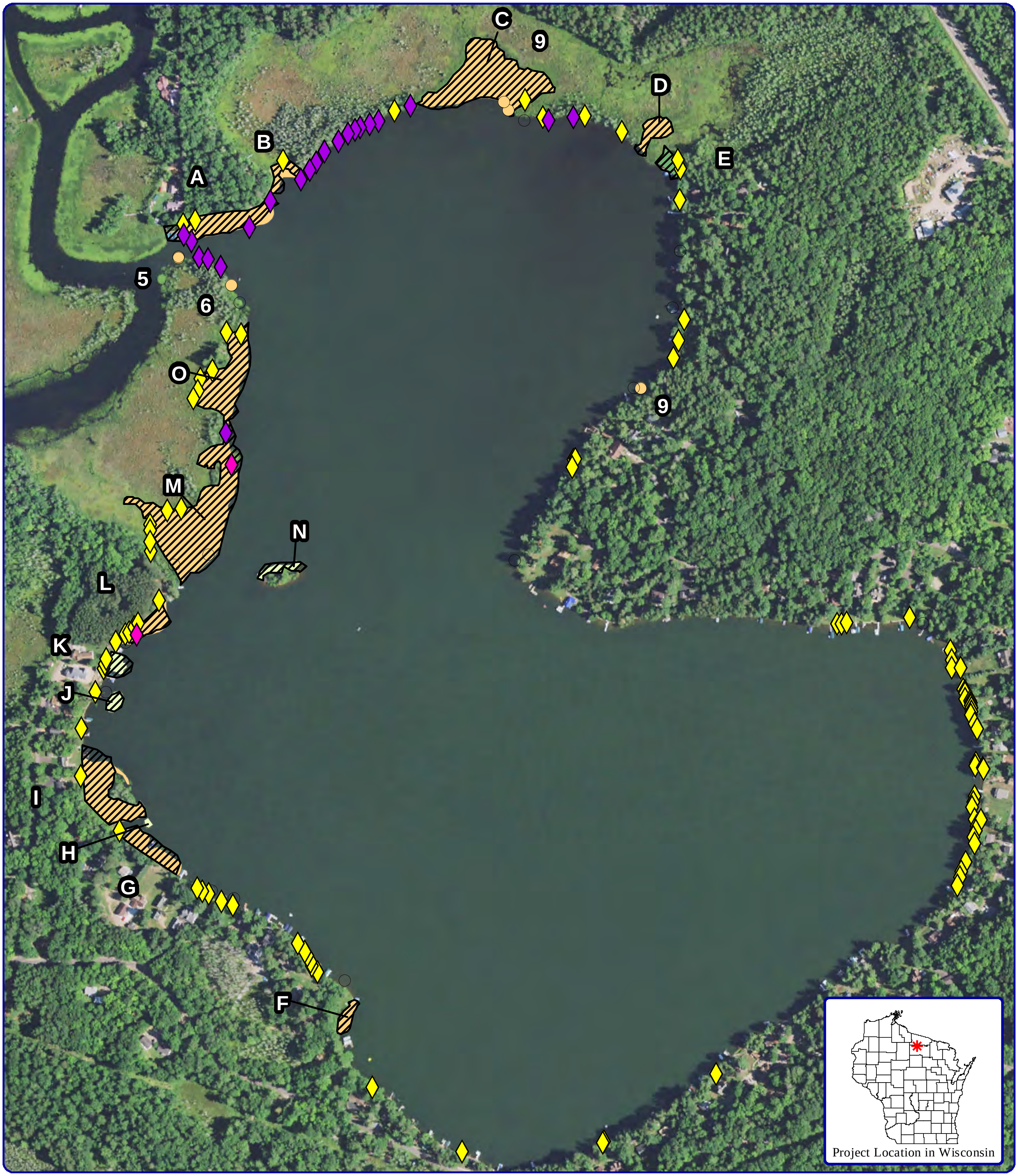
Survey Date: October 23, 2019

2-8 Inch Pieces	**8+ Inch Pieces**
No Branches	No Branches
Minimal Branches	Minimal Branches
Moderate Branches	Moderate Branches
Full Canopy	Full Canopy

Map 4

Mid Lake
Oneida County, Wisconsin

Coarse Woody Habitat



N
W E
S

525

Feet

Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: December 11, 2019 AMS
Filename: Mid_Comm_2019.mxd

Legend

Survey Date: August 15, 2019

Small Plant Community
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- 2008 Community

Large Plant Community
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- 2008 Community

Exotic Plant Community
- Flowering rush
- Purple loosestrife
- Pale-yellow iris

Map 5

Mid Lake

Oneida County, Wisconsin

2019 Aquatic Plant Communities

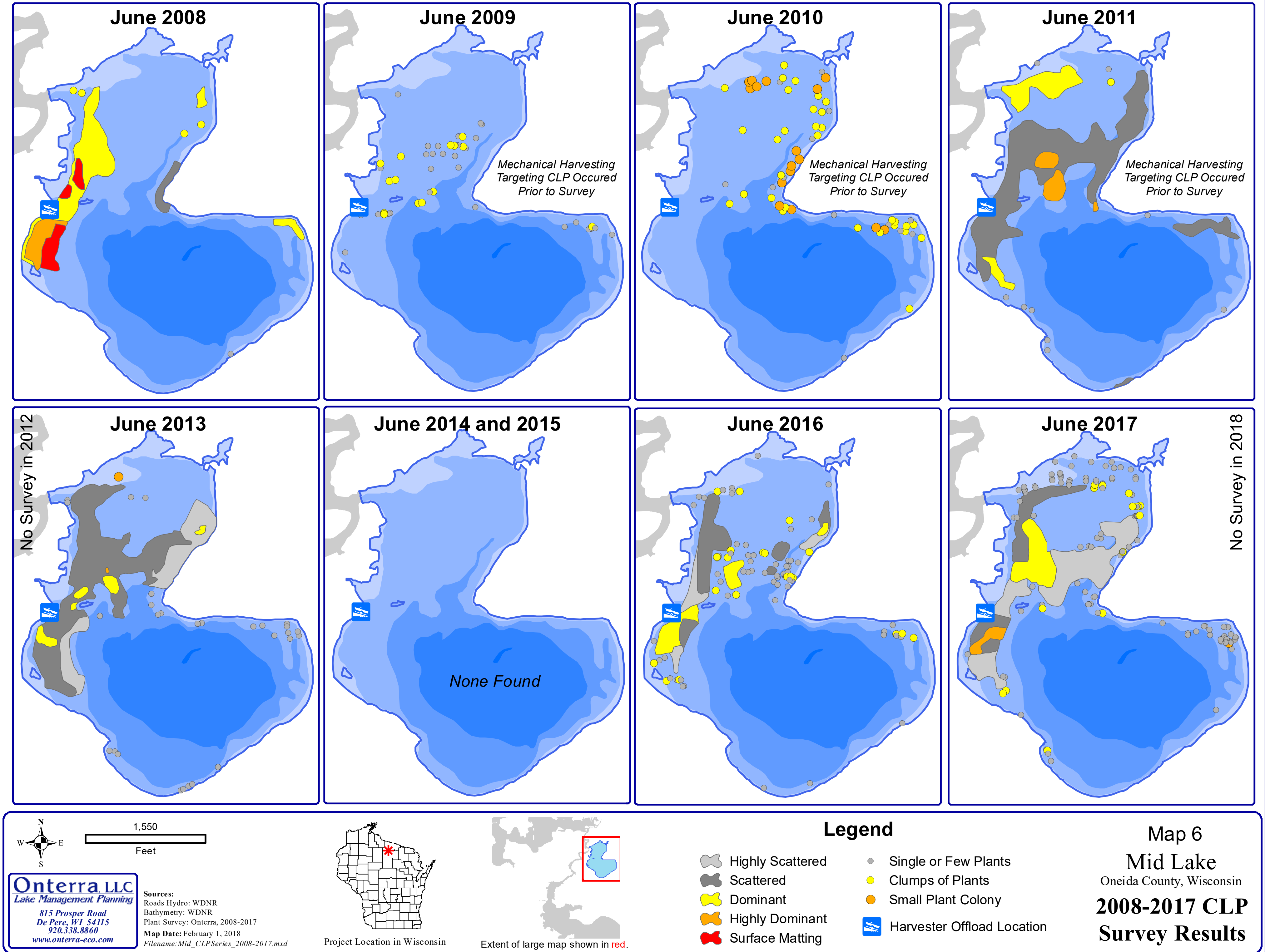
Mid Lake 2019 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Mid Lake- Map 5

Large Plant Community (Polygons)									
Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
A	**Cattail sp.**	**Purple loosestrife**	**Pickerelweed**						0.15
Floating-leaf/Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
B	**Spatterdock**	**Watershield**	**Pickerelweed**	**Purple loosestrife**	White water lily	American bur-reed			1.02
C	**Spatterdock**	**Pickerelweed**	**Cattail sp.**	**White water lily**	Soft rush				2.38
D	**Spatterdock**	**White water lily**	**Pickerelweed**						0.32
E	**Pickerelweed**	**Water willow**	**White water lily**	**Spatterdock**	Soft rush	Cyperus sedge	Softstem bulrush		0.87
F	**Spatterdock**	**Pickerelweed**	**White water lily**						0.18
G	**Pickerelweed**	**Spatterdock**	**Purple loosestrife**						0.25
H	**White water lily**	**Water willow**	**Cattail sp.**	**Pickerelweed**	Purple loosestrife				1.93
I	**Pickerelweed**	**Water willow**	**Purple loosestrife**	**Spatterdock**	White water lily	Cyperus sedge			0.21
J	**Pickerelweed**	**Spatterdock**	**White water lily**						0.75

Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
1	**Purple Loosestrife**							
2	**Flowering rush**							
Floating-Leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
3	**Spatterdock**	**White water lily**						
4	**Spatterdock**	**White water lily**	**Watershield**					
Floating-Leaf/Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
5	**Spatterdock**	**White water lily**	**Purple loosestrife**	**Cattail sp.**				
6	**White water lily**	**Spatterdock**	**Purple loosestrife**					
7	**Spatterdock**	**Pickerelweed**						
8	**Watershield**	**Spatterdock**	**Cattail sp.**	**Wool-grass**	Softstem bulrush	Soft rush	Grass-leaved arrowhead	
9	**Pickerelweed**	**Watershield**	**Softstem bulrush**					

Species are listed in order of dominance within the community; Scientifc names can be found in the species list in Table 3.4-2

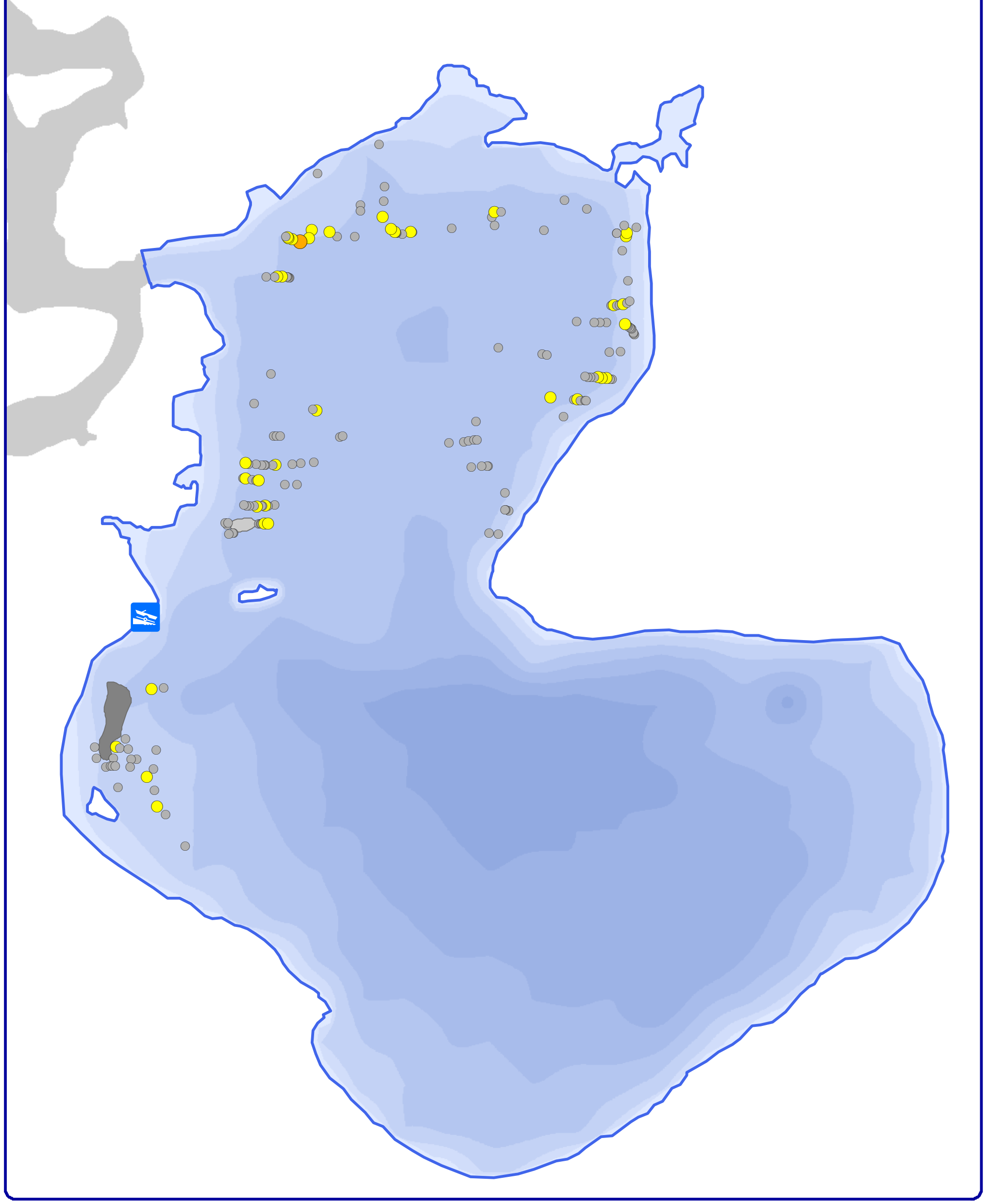


Onterra, LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

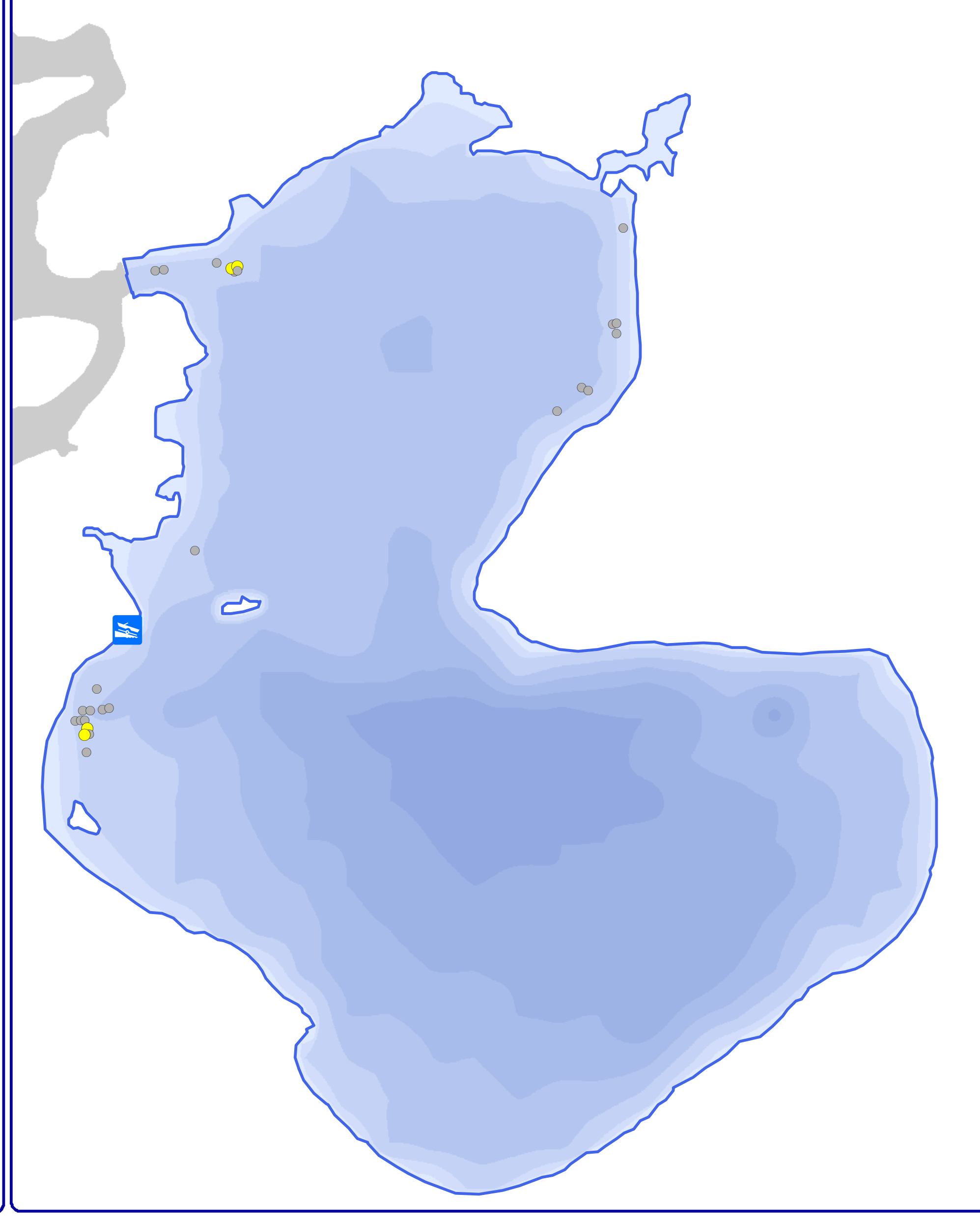
Sources:
Roads Hydro: WDNR
Bathymetry: WDNR
Plant Survey: Onterra, 2008-2017
Map Date: February 1, 2018
Filename:Mid_CLPSeries_2008-2017.mxd

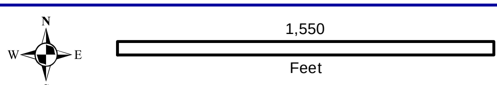
Map 6
Mid Lake
Oneida County, Wisconsin
2008-2017 CLP Survey Results

June 2019



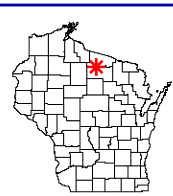
June 2020



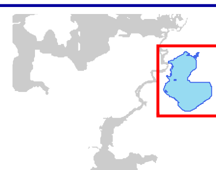


Onterra, LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads Hydro: WDNR
Bathymetry: WDNR
Plant Survey: Onterra, 2019-2020
Map Date: July 14, 2020
Filename:Mid_CLPSeries_2008-2017.mxd



Project Location in Wisconsin

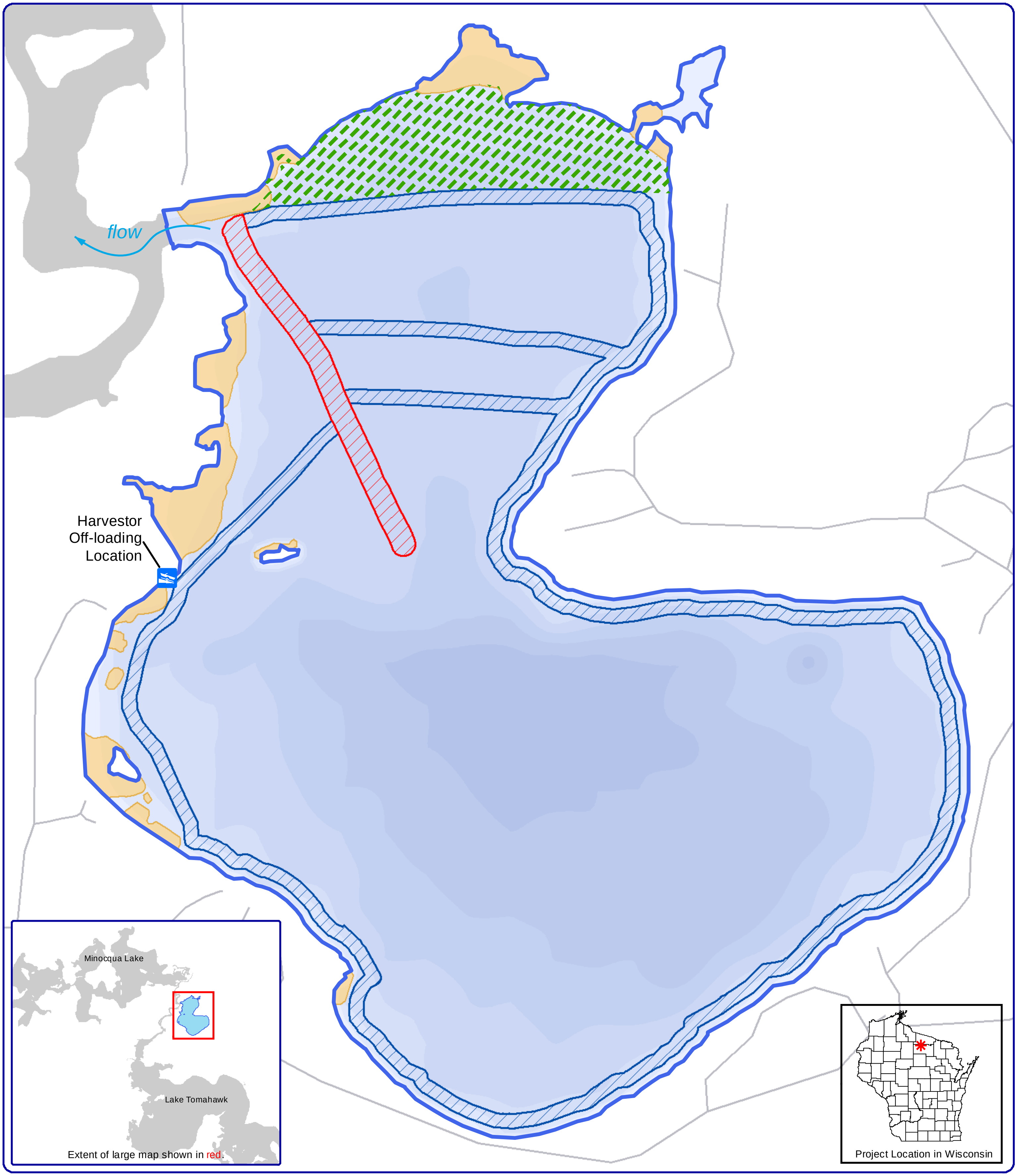


Extent of large map shown in red.

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Harvester Offload Location

Map 7
Mid Lake
Oneida County, Wisconsin
2019-2020 CLP Survey Results



N
W E
S

550
Feet

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Aquatic Plant Survey: Onterra, 2020
Bathymetry: Onterra 2013 PI Survey
Map Date: June 26, 2020 - EJH

Legend

- 100-ft Mechanical Harvesting Lane
- 60-ft Mechanical Harvesting Lane
- Open Water Conservation Area
- Floating-leaf & Emergent Native Plant Community (2019)

Map 8
Mid Lake
Oneida County, Wisconsin

Mechanical Harvest Plan