Kettle Moraine Lake

Fond du Lac County, Wisconsin

Comprehensive Management Plan

February 2019

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Acknowledgements

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

Kettle Moraine Lake Planning Committee

David Katt – Chair	Cindy Katt
Mark Meske	Tom Thompson
Jeff May	Karen Duffy

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1.0 INTRODUCTION

According to the 1968 recording sonar WDNR Lake Survey Map, Kettle Moraine Lake is 227 acres. The WDNR website lists the lake as 209 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in summer of 2017. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 214 acres. Kettle Moraine Lake, Fond du Lac County, is a deep seepage lake with a maximum depth of 29 feet and a mean depth of 8 feet. This mesotrophic lake has a small watershed when compared to the size of the lake. Kettle Moraine Lake contains 28 native plant species, of which coontail is the most common plant. Five exotic plant species are known to exist in Kettle Moraine Lake.

Field Survey Notes

Kettle Moraine Lake's clear water supports a variety of recreational activities. On some days, the beach at the Tiki Bar is hopping! Our crews enjoy working on KML, as the lake contains a number of cool plants that aren't all that common in this part of the state. The lake is always bigger than we think, probably because we can see the entire lake at one time. This has resulted in us working some rather long days on KML.

Photograph 1.0-1. Kettle Moraine Lake, Fond du Lac County.

Lake at a Glance - Kettle Moraine Lake

Morphology	
Acreage	214
Maximum Depth (ft)	29
Mean Depth (ft)	8
Shoreline Complexity	2.1
Vegetation	
Number of Native Species	28
Threatened/Special Concern Species	-
Exotic Plant Species	Pale yellow iris, Yellow garden loosestrife, Purple loosestrife, Eurasian watermilfoil, Curly-leaf pondweed
Simpson's Diversity	0.85
Average Conservatism	5.8
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	9.1
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	1:1

Kettle Moraine Lake is located in the Town of Osceola in Fond du Lac County, WI. In 1995 Eurasian water milfoil (EWM) was first documented within the lake. In 2004, curly-leaf pondweed (CLP) was first vouchered in the lake by the WDNR; however, accounts of the plant go back as far as 1999. Zebra mussels have also been documented within the lake. KML is known to contain the NHI species Blanding's turtle.

The Kettle Moraine Lake Association (KMLA) and its members have been active in the lake's management beyond that of facilitating the herbicide treatments. Past efforts have included the stocking of milfoil weevils and in 2004, the association sponsored the completion of a management plan for the lake. Also, during that same year, the group introduced 1000 large-leaf pondweed plants to the lake in an effort to enhance the native plant population's competition against exotics. In 2004 the KMLA sponsored the completion of a management plan for the lake (SPL-055-03, ACEI-004-05). The KMLA obtained an AIS-EPC grant in 2012 (ACEI-126-13) which has sponsored AIS management activities on the lake.

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.

Kick-off Meeting

On June 17, 2017, a project kick-off meeting was held at the Osceola Town Hall to introduce the project to the general public. The approximately 40 attendees observed a presentation given by Eddie Heath, an aquatic ecologist with Onterra. Mr. Heath's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting

On September 19, 2018, Eddie Heath of Onterra met with six members of the KMLA Planning Committee for nearly four hours. The results of the surveys were presented to the committee. The meeting also discussed the stakeholder survey results and began developing management goals and actions for Kettle Moraine Lake management plan. The presentation materials from this meeting are included in Appendix A.

Planning Committee Consultation with WDNR

On October 23, 2018, a meeting was held between the KMLA (David Katt), Onterra (Eddie Heath), and WDNR (Mary Gansberg) with the purpose of gaining WDNR feedback on the perspective management goals and actions prior to submittal of the draft Comprehensive Management Plan.

Management Plan Review and Adoption Process

On September 25, 2018, a draft outline of the Implementation Plan was provided to the Planning Committee for review. Additional comments were received and a revised draft was created. This draft outline was provided to WDNR on October 12, 2018. A subsequent meeting between KMLA, Onterra, and WDNR (Mary Gansberg) occurred on October 23, 2018. The Implementation Plan Section (5.0) was created based on the comments received.

On November 20, 2018, an official first draft of the KMLA's Comprehensive Management Plan was supplied to the WDNR, Fond du Lac County, Town of Osceola, and KMLA's Planning Committee for review.

The WDNR provided comments to the draft Comprehensive Management Plan on January 4, 2019 (45 days later). The comments and how they were integrated into this document are included as

Appendix F. The WDNR indicated approval of all management goals and actions, but denied approval of the pelletized fluridone strategy. Subsequent discussions occurred between the KMLA and WDNR. The second draft was officially sent for review on February 18, 2019.

Stakeholder Survey

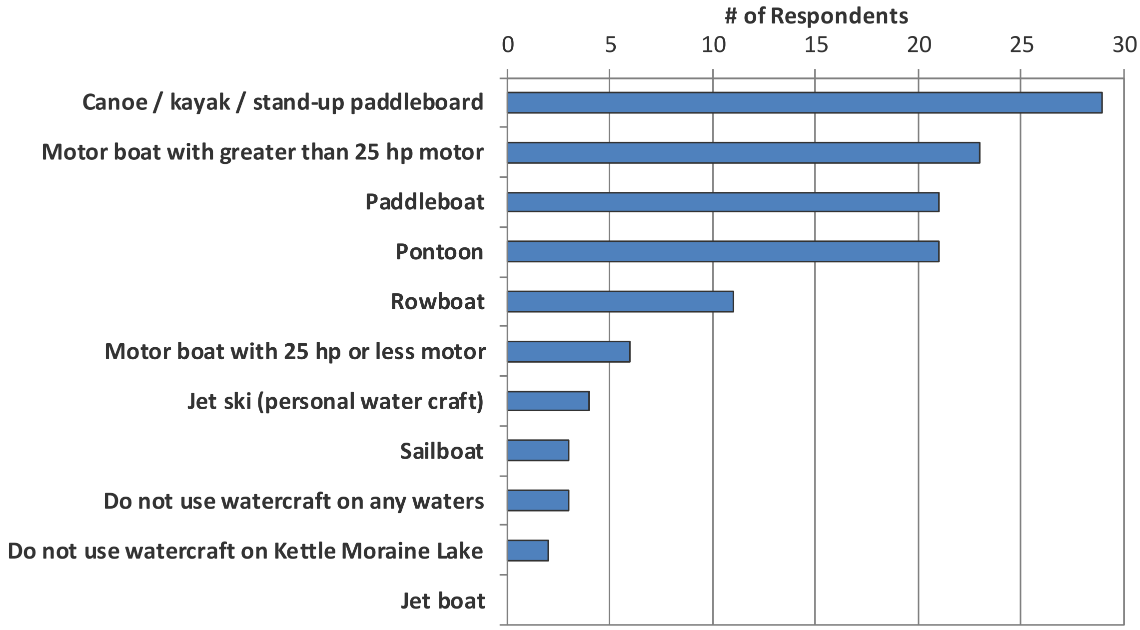
As a part of this project, a stakeholder survey was distributed to riparian property owners and KMLA members around Kettle Moraine Lake. The survey was designed by Onterra staff and the KMLA planning committee and reviewed by a WDNR social scientist. During November 2017, the nine-page, 37-question survey 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 KMLA volunteer for analysis. Forty-six 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 that use and care for Kettle Moraine Lake. The majority of stakeholder respondents (30%) are year-round residents, while 28% live on the lake during the summer months only, 28% visit on weekends throughout the year, 2% are resort properties, and 2% are rental properties. 57% of stakeholder respondents have owned their property for over 15 years, and 30% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a canoe, kayak, or stand-up paddleboard on Kettle Moraine Lake (Question 14). Larger motor boats, paddleboats, and pontoons were also popular options. On a relatively small lake such as Kettle Moraine Lake, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 17, several of the top recreational activities on the lake involve boat use. Unsafe watercraft practices and Excessive watercraft traffic were listed as factors potentially impacting Kettle Moraine Lake in a negative manner (Question 23), and they were ranked 3rd and 6th, respectively, on a list of stakeholder's top concerns regarding the lake (Question 24).

A concern of stakeholders noted throughout the stakeholder survey (see Questions 23-24 and survey comments – Appendix B) was the Canada goose populations in Kettle Moraine Lake, watercraft traffic, and aquatic invasive species.

Question 14: What types of watercraft do you currently use on Kettle Moraine Lake?



Question 17: Please rank up to three activities that are important reasons for owning your property on Kettle Moraine Lake.

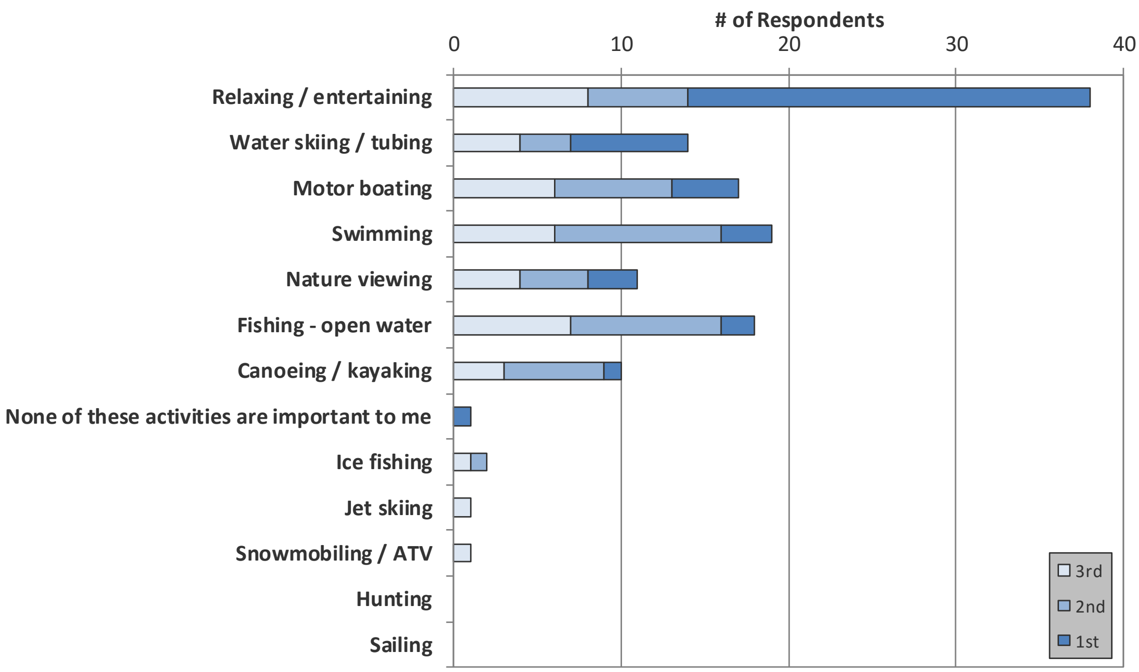
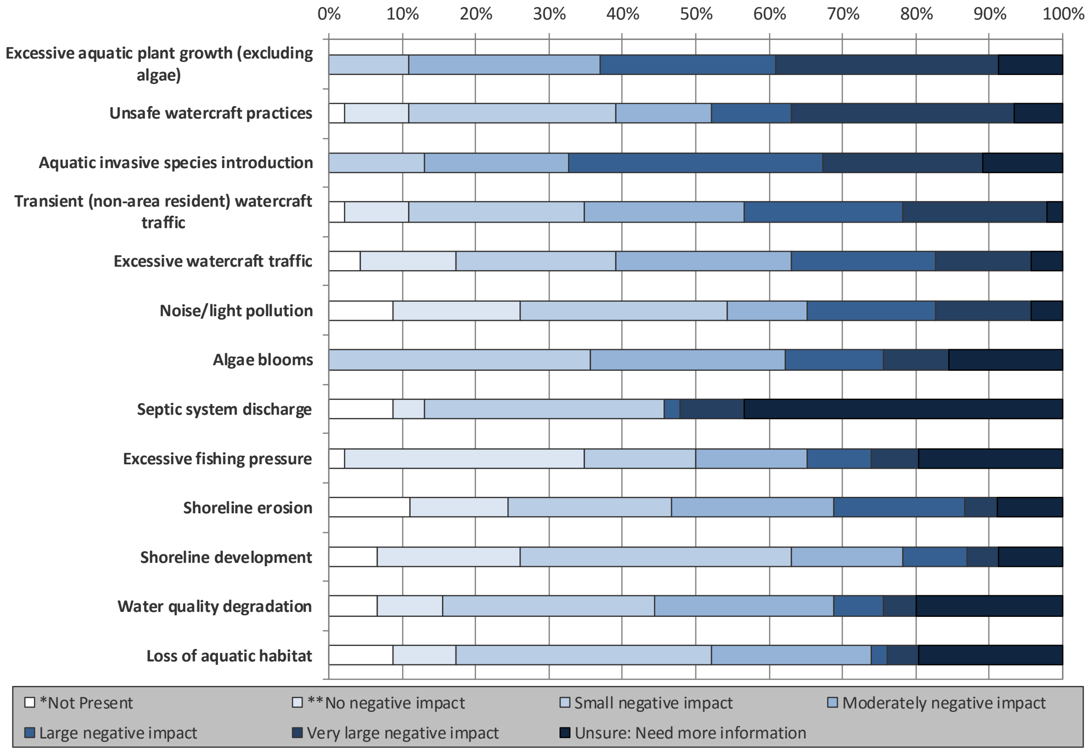


Figure 2.0-1. Select survey responses from the Kettle Moraine Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 23: To what level do you believe these factors may be negatively impacting Kettle Moraine Lake?



Question 24: Please rank your top three concerns regarding Kettle Moraine Lake.

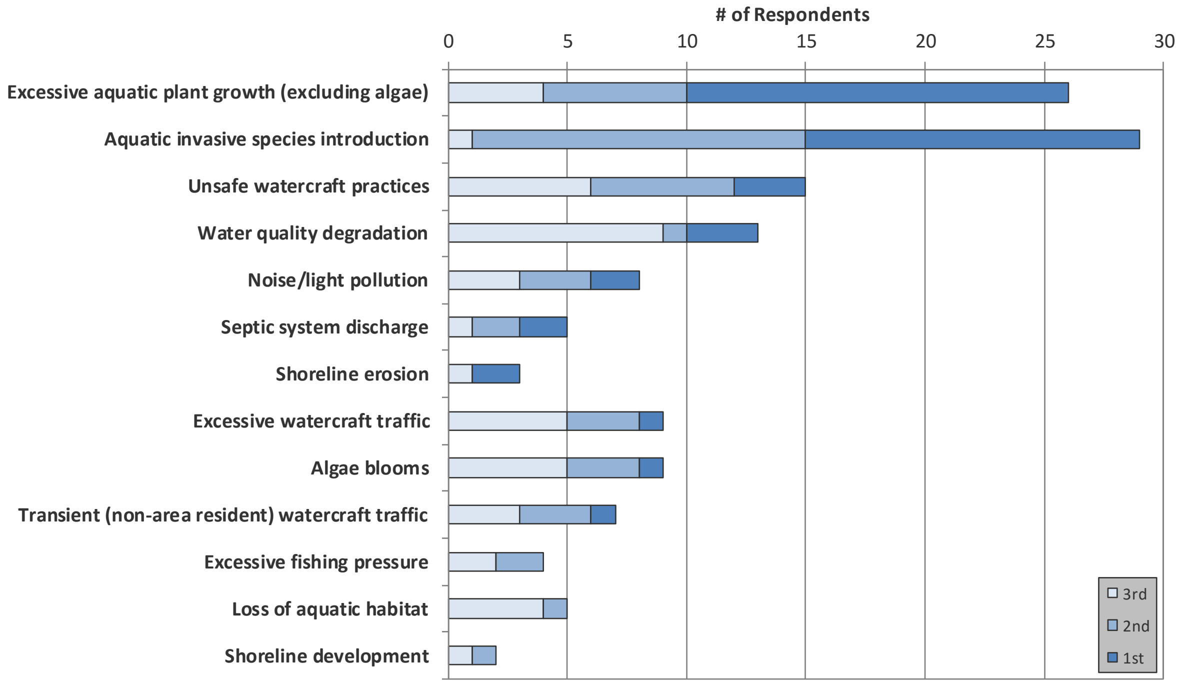


Figure 2.0-2. Select survey responses from the Kettle Moraine Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, 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 analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

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 Kettle Moraine 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 Kettle Moraine Lake's water quality analysis:

Phosphorus is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.

Chlorophyll-*a* is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.

Secchi disk transparency is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

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 more clear 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 epiliminion is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The hypolimnion is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The metalimnion, often called the thermocline, is the middle layer containing the steepest temperature gradient.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, 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 process 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 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 2013A) 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 Kettle Moraine 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.

Because of its depth, small watershed and hydrology, Kettle Moraine Lake is classified as a deep, stratified seepage lake (category 7 on Figure 3.1-1). It is believed that Kettle Moraine Lake does not have any significant surface water outflow such as a river or stream. Water may move through the wetland complex on the north end of the lake but the lake likely functions as a seepage lake.

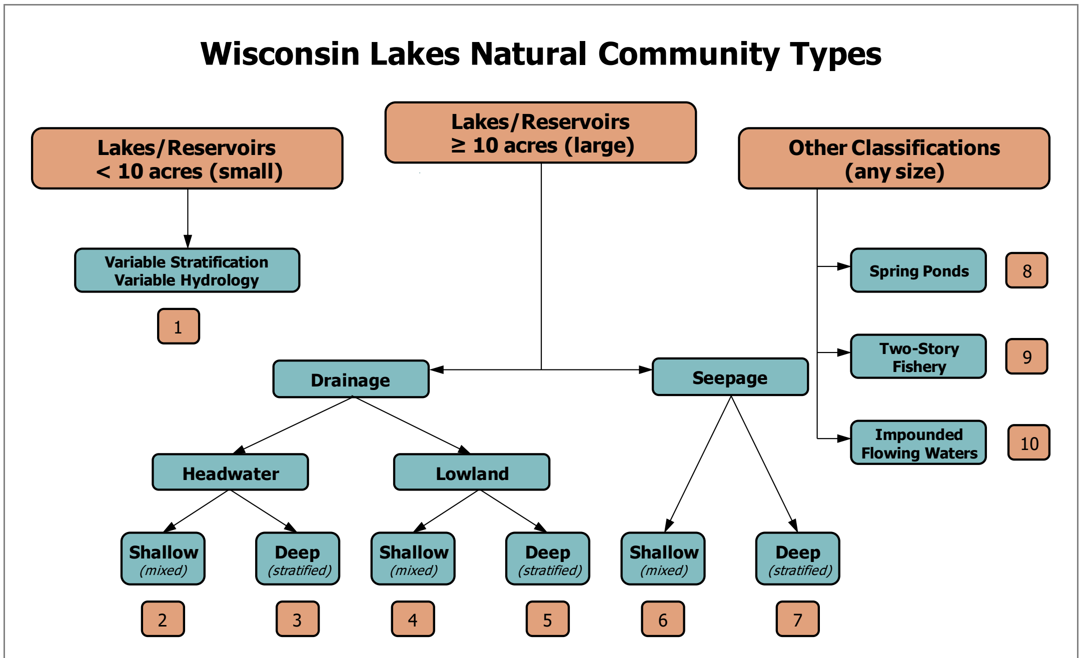


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. Kettle Moraine Lake is within the Southeastern Wisconsin Till Plains (SWTP) ecoregion.

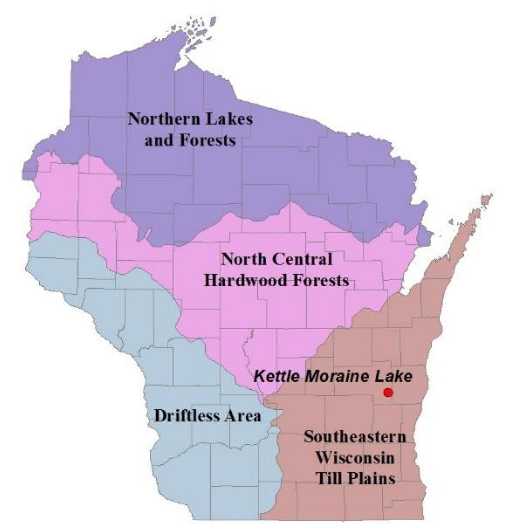


Figure 3.1-2. Location of Kettle Moraine Lake within the ecoregions of Wisconsin. After Nichols 1999.

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 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 Kettle Moraine Lake is displayed in Figures 3.1-3 - 3.1-11. 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.

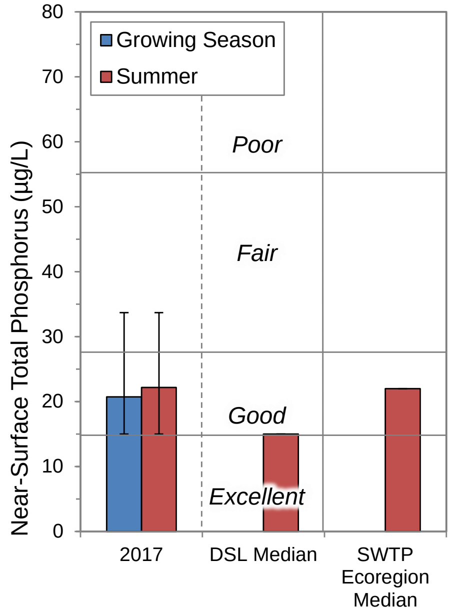
Kettle Moraine Lake Water Quality Analysis

Historical total phosphorus and chlorophyll-*a* data are not available from Kettle Moraine Lake, only Secchi disk transparency historical data are available. Therefore, the studies completed in 2017 represent the first assessment of the lake's water quality. This lack of historical data makes long-term trends impossible, but an understanding of the lake's current state can be discerned from the 2017 water quality data collection. The data collected in 2017 can be compared against median values for lakes within the SWTP ecoregion and other deep, stratified seepage lakes throughout Wisconsin.

Total Phosphorus

Total phosphorus concentrations were measured five times over the course of the 2017 growing season. Summer total phosphorus concentrations in 2017 ranged from 15 µg/L to 34 µg/L (Figure 3.1-3). The weighted summer average total phosphorus concentration in 2017 was 22 µg/L and falls within the *good* category for Wisconsin's deep stratified seepage lakes and indicates Kettle Moraine Lake's total phosphorus concentrations are slightly higher than the median value for deep stratified seepage lakes in the state and are relatively similar to the median value for all lake types within the SWTP ecoregion.

To determine if internal nutrient loading (discussed in the primer section) is a significant source of phosphorus in Kettle Moraine Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom and near-surface total phosphorus concentrations are displayed in Figure 3.1-4. As illustrated, in April of 2017 the near-bottom total phosphorus concentration is similar to the concentration measured near the surface, but in May through August of 2017 the near-bottom concentrations are higher than the near-surface concentrations and increase throughout the summer. The higher concentrations of phosphorus near the bottom occurred when Kettle Moraine Lake was stratified and the bottom layer of water (hypolimnion) was anoxic. The higher concentrations near the bottom are an indication that phosphorus is being released from bottom sediments into the overlying water during periods of anoxia. Overall, while this process may be contributing some phosphorus to Kettle Moraine Lake's water column, the impacts of internal loading are not significant because of the small volume of water that is anoxic.



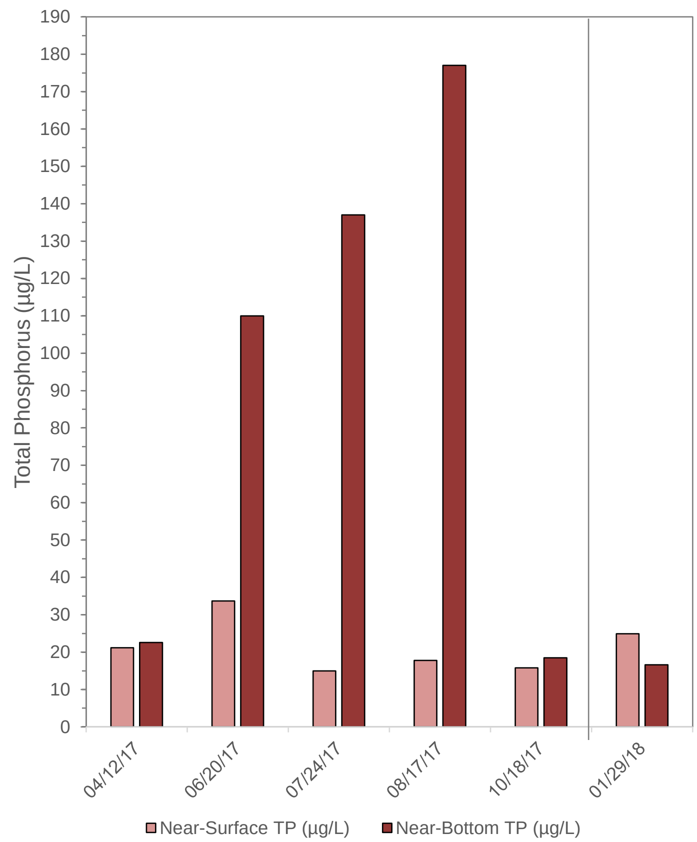


Figure 3.1-3. Kettle Moraine Lake, state-wide deep stratified seepage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Figure 3.1-4. Kettle Moraine Lake near-surface and near-bottom total phosphorus concentrations.

Chlorophyll-*a*

Chlorophyll-*a* concentrations were measured five times over the course of the 2017 growing season. Summer chlorophyll-*a* concentrations in 2017 ranged from 3 µg/L to 4 µg/L (Figure 3.1-5). The weighted summer average chlorophyll-*a* concentration in 2017 was 3.4 µg/L and falls just within the *excellent* category for Wisconsin's deep seepage lakes and indicates Kettle Moraine Lake's chlorophyll-*a* concentrations are slightly lower than the median values for both deep stratified seepage lakes in the state and all lake types within the SWTP ecoregion.

As discussed in the primer section, chlorophyll-*a* is a measure of free-floating algal biomass within a lake and is usually positively correlated with total phosphorus concentrations. Using predictive equations developed by Carlson (1977), average chlorophyll-*a* values can be estimated using the average growing season surface phosphorus value. Using the average growing season mean total phosphorus concentration of 21 µg/L, it is expected that Kettle Moraine Lake would have a growing season mean chlorophyll-a concentration of approximately 7 µg/L, nearly double the measured growing season mean chlorophyll-*a* concentration of 3.7 µg/L. This lower ratio of chlorophyll-*a* to total phosphorus indicates that another factor other than phosphorus was limiting the growth of phytoplankton in Kettle Moraine Lake in 2017.

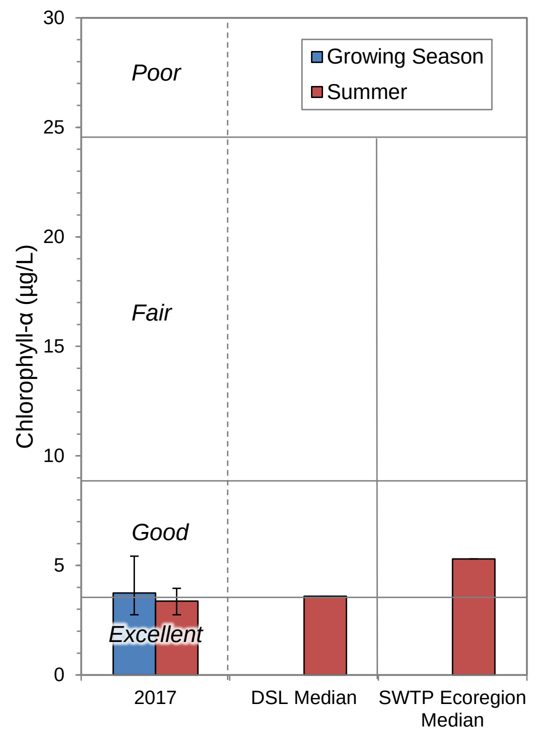


Figure 3.1-5. Kettle Moraine Lake, state-wide deep stratified seepage lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed in the Zebra Mussels in Kettle Moraine Lake Section below, zebra mussels were discovered in the lake in 2010. Zebra mussels are very efficient filter feeders, and water that has been filtered is almost entirely devoid of suspended particles (Karatayev et al. 1997). However, adult zebra mussels have not been noted by Onterra ecologists during surveys on the lake and studies have shown that zebra mussels usually do not have detectable effects on the lake's ecosystem until their population rapidly expands about five to 10 years after their introduction (Karatayev et al. 1997). This is an indication that zebra mussels are not likely the primary limitation on phytoplankton growth in the lake.

Macrophyte communities in a lake can also have an impact on phytoplankton growth. Non-rooted vegetation, such as coontail (*Ceratophyllum demersum*), get their nutrients directly from the water column and coontail was found to limit phytoplankton production through direct competition for inorganic nitrogen, shading or light competition, and/or allelopathy (Mjelde and Faafeng 1997). In 2017, coontail was the most common submerged aquatic plant found in Kettle Moraine Lake with a littoral frequency of occurrence of 63%. Coontail has only been noted by Onterra ecologists to be surface-matting in localized areas and was most abundant between 6 and 14 feet of water; an indication that coontail is not likely limiting phytoplankton growth through light limitation. Instead coontail is likely limiting phytoplankton growth through nutrient uptake. Production in Kettle Moraine Lake is primarily tied up in macrophyte production, helping to maintain a clear water state *in lieu* of a turbid state dominated by phytoplankton.

Water Clarity

Water clarity was measured using a Secchi disk in Kettle Moraine Lake in 2017 and historical Secchi disk transparency data is available from 2006 and 2007 and 2009-2016 (Figure 3.1-6). Average summer Secchi disk depth ranged from 6.3 feet in 2012 to 9.1 feet in 2017. The weighted average summer Secchi disk depth is 7.6 feet, which falls into the *good* category for Secchi disk depth in Wisconsin's deep stratified seepage lakes. The weighted average summer Secchi disk depth is shallower than the median value for deep stratified seepage lakes in Wisconsin but exceeds the median value for all lake types in the SWTP ecoregion. The chlorophyll-*a* values place the lake in the excellent category and phosphorus concentrations place the lake on the border between excellent and good. Since the Secchi disk depth places the lake well into the good category, this is further evidence that the water clarity is not significantly impacted by zebra mussels.

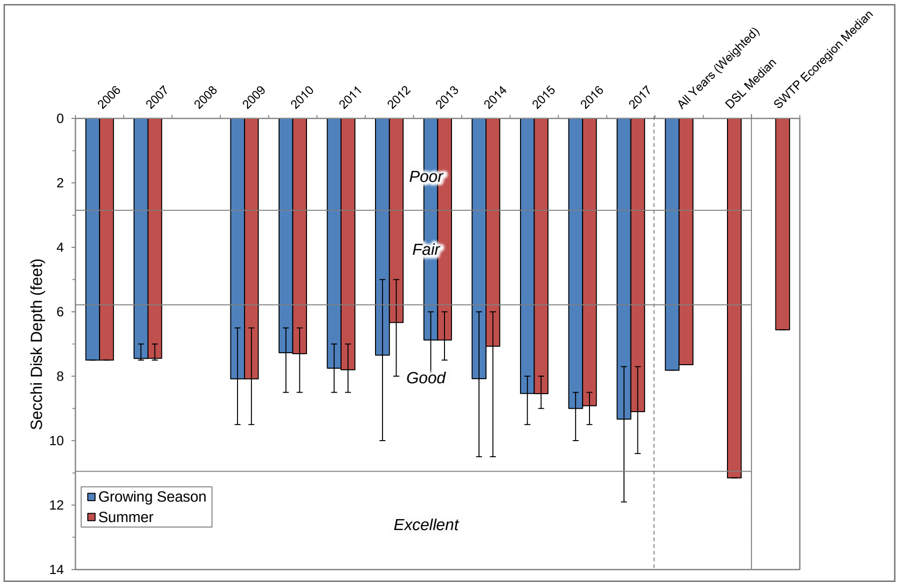


Figure 3.1-6. Kettle Moraine Lake, state-wide deep stratified seepage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Water clarity is not only influenced by particulates such as phytoplankton and suspended sediments, but it is also influenced by dissolved compounds and elements within the water. *True color* is a measure of the amount of light absorbed by materials dissolved within the water once all of the suspended material has been filtered out. Lakes with watersheds which drain large areas of wetlands and/or coniferous forests typically have higher amounts of dissolved organic materials which originate from decomposing plant material. At higher concentrations, these compounds give the water a tea-like appearance and reduce water clarity. True color values measured from Kettle Moraine Lake in 2017 averaged 15 SU (standard units), indicating the lake's water is *slightly colored* and that the lake's water clarity is not influenced by dissolved components in the water (Figure 3.1-7).

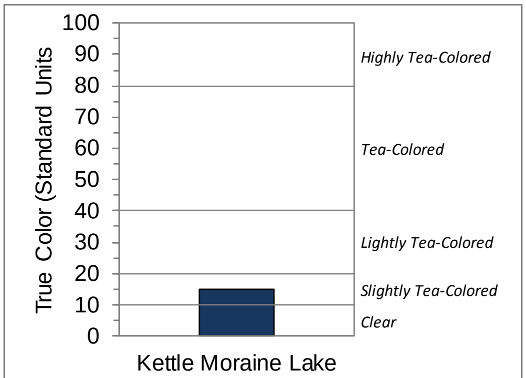


Figure 3.1-7. Kettle Moraine Lake true color value.

Zebra Mussels in Kettle Moraine Lake

Zebra mussels (*Dreissena polymorpha;* Photograph 3.1-1), first documented in Kettle Moraine Lake in 2010, are native to the Caspian, Black, and Azov Seas, and were introduced to the Great Lakes through the ballast water of trans-Atlantic shipping vessels in the mid- to late 1980s (Karatayev et al. 1997; Reed-Andersen et al. 2000). Since their introduction to the Great Lakes, zebra mussels have at present spread to 168 habitable inland waterbodies in Wisconsin (WDNR 2014). Like other invasive species, zebra mussels can drastically alter aquatic ecosystems and generate negative economic impacts by interfering with recreation, navigation, and industrial operations (Mellina et al. 1995; Reed-Andersen et al. 2000).

Photograph 3.1-1. Non-native zebra mussels (*Dreissena polymorpha*) attached to a native plain pocketbook mussel (*Lampsilis cardium*). Photo credit: Onterra, LLC.

Zebra mussels require certain habitat requirements to establish and maintain a population. These requirements primarily include pH, calcium concentration, and suitable substrates (Ramcharan et al. 1992; Mellina et al. 1995). The commonly accepted pH range for zebra mussels is 7.0 to 9.0. Calcium concentrations of >12 mg/L are considered suitable for zebra mussels; however, waterbodies with calcium concentrations of >28 mg/L are considered to be highly susceptible to their establishment if they are introduced.

The pH and calcium concentration within a lake largely depends on the geology of the lake's surficial and ground watersheds. In 2017, samples collected from near Kettle Moraine Lake's surface had a pH value of 9.1 and a calcium concentration of 24.4 mg/L, indicating the environment within Kettle Moraine Lake is suitable for supporting a zebra mussel population. Aquatic plants can provide habitat for zebra mussels (Reed-Andersen et al. 2000), and the 2017 point-intercept survey indicated that 95% of Kettle Moraine Lake's littoral zone is vegetated.

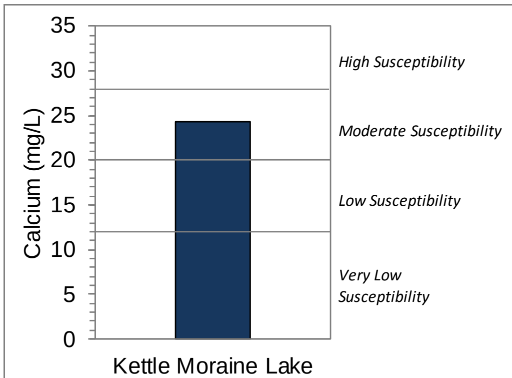


Figure 3.1-11. Kettle Moraine Lake average growing season calcium concentration and zebra mussel susceptibility. Samples collected from near-surface.

Numerous studies have shown that following the establishment of zebra mussels, many lakes experience increased water clarity as a result of decreased suspended material within the water from the filtering of zebra mussels (MacIsaac 1996; Karatayev et al. 1997; Reed-Andersen et al. 2000; Zhu et al. 2006). Zebra mussels are very efficient filter feeders, and water that has been filtered is almost entirely devoid of suspended particles (Karatayev et al. 1997). Even unwanted particles (e.g. clay particles) that pass through the zebra mussel are deposited to the sediment as pseudofeces (Karatayev et al. 1997). However; studies have shown that zebra mussels usually do not have detectable effects on the lake's ecosystem until their population rapidly expands about five to 10 years after their introduction (Karatayev et al. 1997). At present, there are no methods for controlling a lake-wide population of zebra mussels.

Limiting Plant Nutrient of Kettle Moraine Lake

Using midsummer nitrogen and phosphorus concentrations from Kettle Moraine Lake, a nitrogen:phosphorus ratio of 45:1 was calculated. This finding indicates that Kettle Moraine 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.

Kettle Moraine Lake Trophic State

Figure 3.1-8 displays the TSI values for Kettle Moraine Lake. The TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical Secchi disk transparency data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by factors other than phytoplankton such as dissolved organic compounds. The proximity of the calculated TSI values for these three parameters is an indication of the degree of correlation.

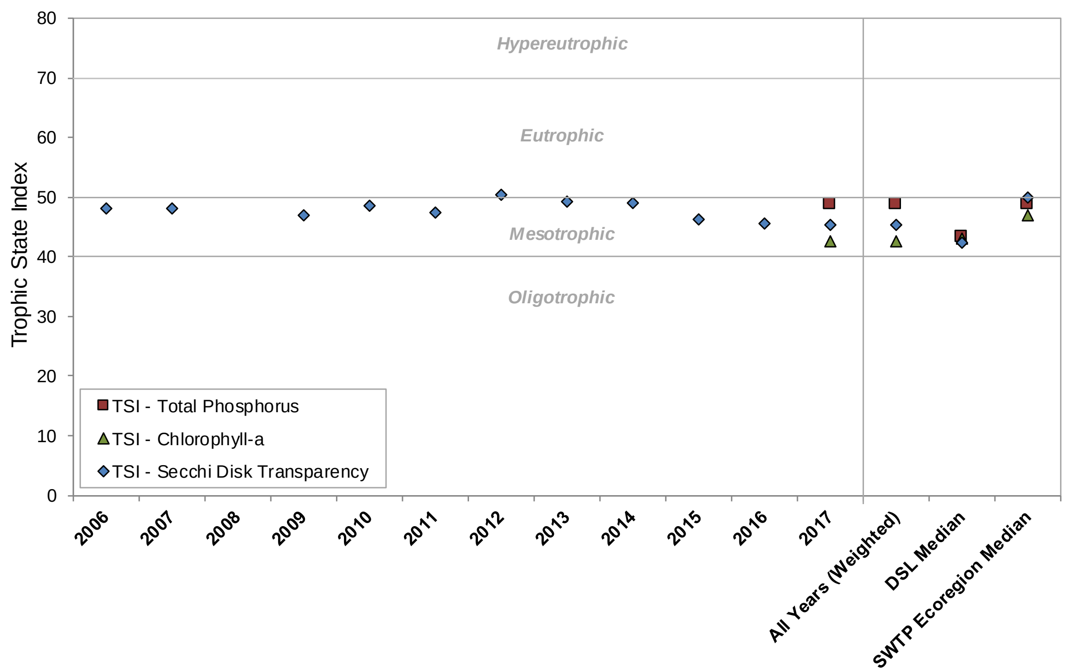


Figure 3.1-8. Kettle Moraine Lake, state-wide deep seepage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

All three TSI values indicate Kettle Moraine Lake is in a mesotrophic state (Figure 3.1-8). Kettle Moraine Lake is slightly more productive when compared to other deep stratified seepage lakes in the state and has similar productivity to other lakes within the SWTP ecoregion. The 2017 total phosphorus TSI value is higher than the chlorophyll-*a* TSI value, indicating that a factor other than total phosphorus is influencing phytoplankton production in Kettle Moraine Lake. As discussed previously, phytoplankton production in Kettle Moraine Lake is likely restricted by the macrophyte community in the lake.

Dissolved Oxygen and Temperature in Kettle Moraine Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Kettle Moraine Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-9. Kettle Moraine Lake is *dimictic*, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, once in spring and once in fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Kettle Moraine Lake's deep nature, wind and water movement are not sufficient during the summer to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen.

In fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice, while oxygen gradually declines once again towards the bottom of the lake. The data indicates that there was sufficient oxygen throughout the entire water column under the ice to support the fishery during winter sampling in February 2018 (Figure 3.1-9). Winter aeration systems serve to ensure that Kettle Moraine Lake remains sufficiently oxygenated during the winter months.

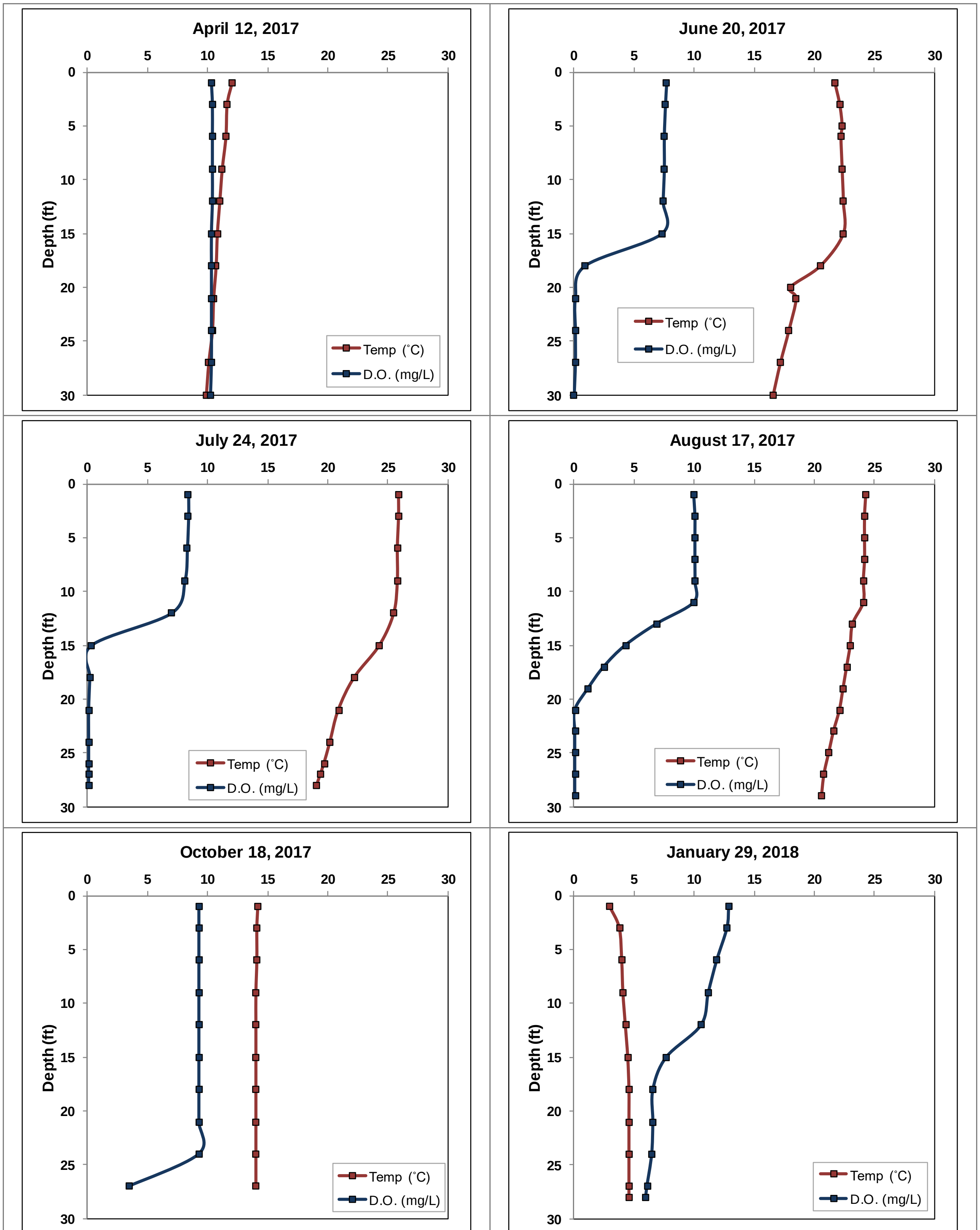


Figure 3.1-9. Kettle Moraine Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Kettle Moraine 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 Kettle Moraine Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl and productive softwater lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985).

The pH of the water in Kettle Moraine Lake was found to be alkaline with a value of 9.1 (Figure 3.1-10, top frame). While the lake's pH falls outside the normal range for most lakes in Wisconsin, this higher pH may be, in large part, due to the large macrophyte community in the lake. During photosynthesis, acidic carbon dioxide is removed from the water which causes the pH to rise.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Kettle Moraine Lake was measured at 104 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain (Figure 3.1-10, bottom frame).

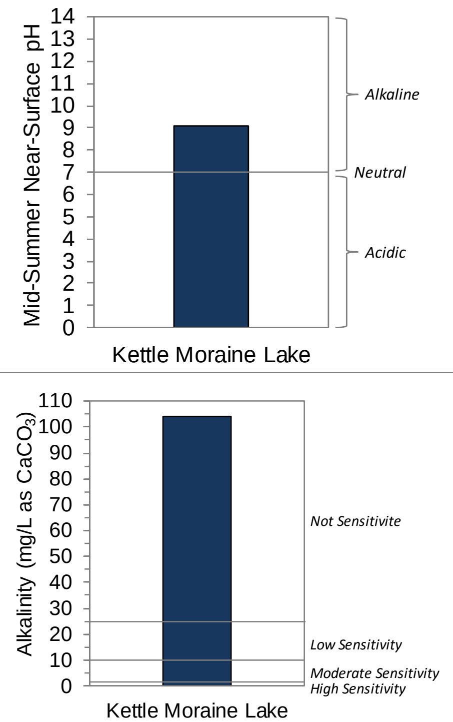


Figure 3.1-10. Kettle Moraine Lake mid-summer near-surface pH value (top frame) and average growing season total alkalinity and sensitivity to acid rain (bottom frame). Samples collected from the near-surface

Stakeholder Survey Responses to Kettle Moraine 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. Of the 104 surveys distributed, 48 (46%) were returned. Without a response rate of 60% or higher, the responses to the following questions regarding water quality cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the respondents' perceptions of water quality in Kettle Moraine Lake but cannot be stated with statistical confidence.

Figure 3.1-11 displays the responses of Kettle Moraine Lake stakeholders to questions regarding water quality and how it has changed over their years visiting Kettle Moraine Lake. When asked how they would describe the current water quality of Kettle Moraine Lake, 60% of respondents indicated *good*, 23% indicated *fair*, 11% indicated *excellent*, 4% indicated *poor*, and 2% indicated that they were *unsure*.

When asked how they believe the current water quality has changed since they first visited the lake, 34% of respondents indicated it has *somewhat improved*, 26% indicated it has *somewhat degraded*, 17% indicated it has *remained the same*, 15% indicated it has *greatly improved*, 6% indicated they were *unsure*, and 2% indicated it has *severely degraded* (Figure 3.1-12). Unfortunately, historical water quality data are not available for total phosphorus and chlorophyll-*a*, so it cannot be said if water quality in terms of nutrients and phytoplankton abundance have changed over time in Kettle Moraine Lake.

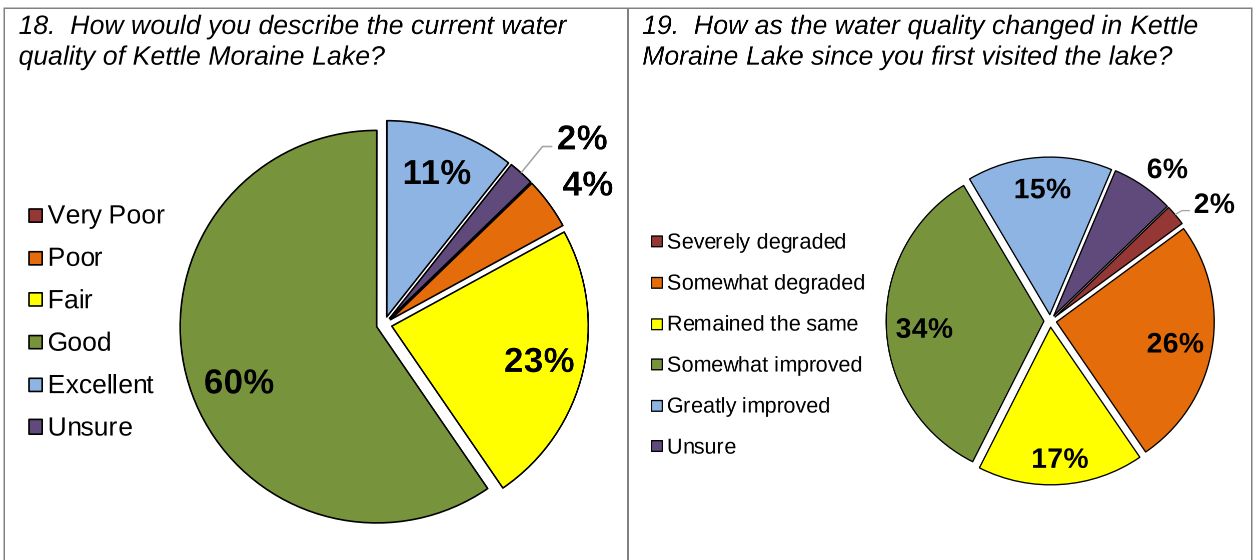


Figure 3.1-11. Kettle Moraine Lake stakeholder survey responses to questions regarding perceptions of lake water quality.

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.

Kettle Moraine Lake Watershed Assessment

Kettle Moraine Lake's watershed encompasses an area of approximately 441 acres, yielding a watershed to lake area ratio of 1:1 (Map 2). In other words, approximately one acre of land drains to every one acre of Kettle Moraine Lake. Approximately 49% of the Kettle Moraine Lake's watershed is composed of the lake's surface, 24% of pasture/grass, 16% wetlands, 5% forest, 4% rural residential areas, and 2% row crop agriculture (Figure 3.2-1, left frame). According to WiLMS modeling, the lake's water is replaced approximately once every 8 years (residence time) or 0.1 times per year (flushing rate); however, the residence time is likely shorter than estimated as Kettle Moraine Lake is primarily fed by groundwater and WiLMS largely uses surface runoff to estimate residence time.

As discussed previously, the land cover within watersheds with watershed to lake area ratios of 10-15:1 or less has a greater influence on the water quality of a lake. Using the land cover described above, WiLMS was utilized to estimate annual potential phosphorus load from Kettle Moraine Lake's watershed. It was estimated that approximately 111 pounds of phosphorus are delivered to the lake from its watershed on an annual basis (Figure 3.2-1, right frame). Phosphorus loading from septic systems was also estimated using data obtained from the 2018 stakeholder survey of riparian property owners. Of the estimated 111 pounds of phosphorus being delivered annually to Kettle Moraine Lake 51% is estimated to originate from direct atmospheric deposition into the lake, 26% from pasture/grass, 7% from septic systems, 7% from wetlands, 7% from row crop agriculture, 2% from forest, and 2% from rural residential areas.

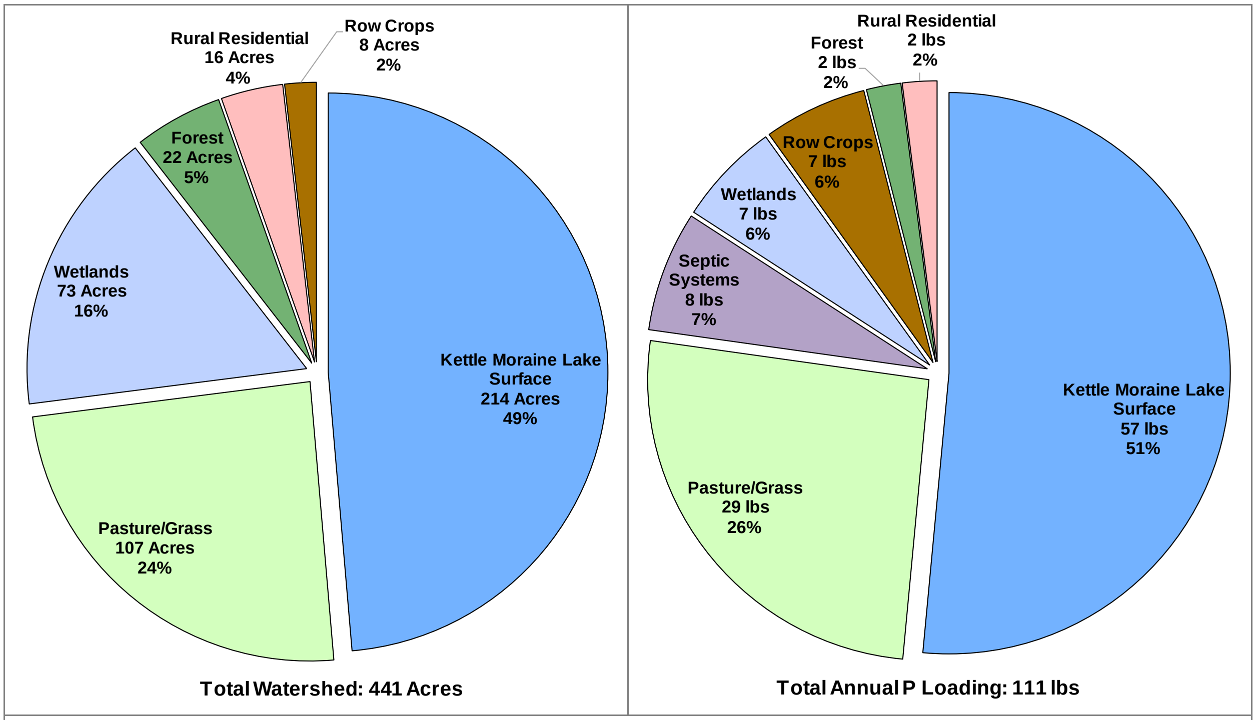


Figure 3.2-1. Kettle Moraine Lake watershed land cover types in acres and phosphorus loading in pounds. Watershed land cover type based upon National Land Cover Database (NLCD – Fry et. al 2011). Phosphorus loading based upon Wisconsin Lake Modeling Suite (WiLMS).

Using predictive equations, WiLMS estimates that based on the potential annual phosphorus load, Kettle Moraine Lake should most likely have a growing season mean (GSM) total phosphorus concentration of approximately 30 µg/L. This predicted concentration is approximately 9 µg/L higher than the measured GSM total phosphorus concentration of 21 µg/L. This indicates the model overpredicted the amount of phosphorus entering the lake on an annual basis. The most likely reason for the poor model performance is the underestimation of the lake's flushing rate. Since WiLMS best predicts surface water runoff and can underpredict the contribution from groundwater, the model is not as accurate for seepage lakes like Kettle Moraine Lake. If a more reasonable hydraulic residence time of 2-3 years is used, the predicted GSM total phosphorus is close to the measured concentration of 21 µg/L.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

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. Passed in February of 2010, the final 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. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

- <u>Vegetation Removal</u>: 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).

- <u>Impervious surface standards</u>: 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.

- <u>Nonconforming structures</u>: 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 with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
    - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

- <u>Mitigation requirements</u>: 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.

<u>Wisconsin Act 31</u>

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 et al. 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.

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

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.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area, as well as spawning habitat (Hanchin et al 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 (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.

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do nott allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owners should contact the county's regulations/zoning department for all minimum requirements. The single site used for the estimate indicated above has the following characteristics:

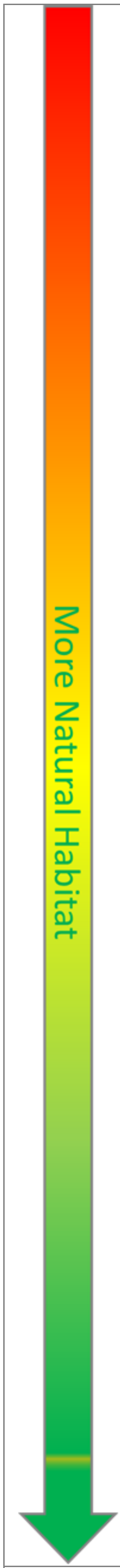
- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq ft and 2 shrubs/100 sq ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5' x 35' areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70' of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

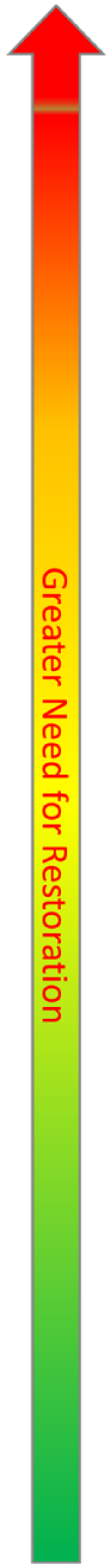
Advantages	*Disadvantages*
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake from developed properties. • Reduces bottom sediment re-suspension and shoreland erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • Once native plants are established, they require less water, maintenance, no fertilizer; provide wildlife food and habitat, and natural aesthetics compared to ornamental (non-native) varieties. • Many educational and volunteer opportunities are available with each project.	• Property owners need to be educated on the benefits of native plant restoration before they are willing to participate. • Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in. • Monitoring and maintenance are required to assure that newly planted areas will thrive. • Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Kettle Moraine Lake Shoreland Zone Condition

Shoreland Development

Kettle Moraine 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 3.3-1 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.





	**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 3.3-1. Shoreland assessment category descriptions.

On Kettle Moraine Lake, the development stage of the entire shoreland was surveyed during fall of 2017, 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 3.3-2.

Kettle Moraine Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.5 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-4). 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, 1.3 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Kettle Moraine 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.

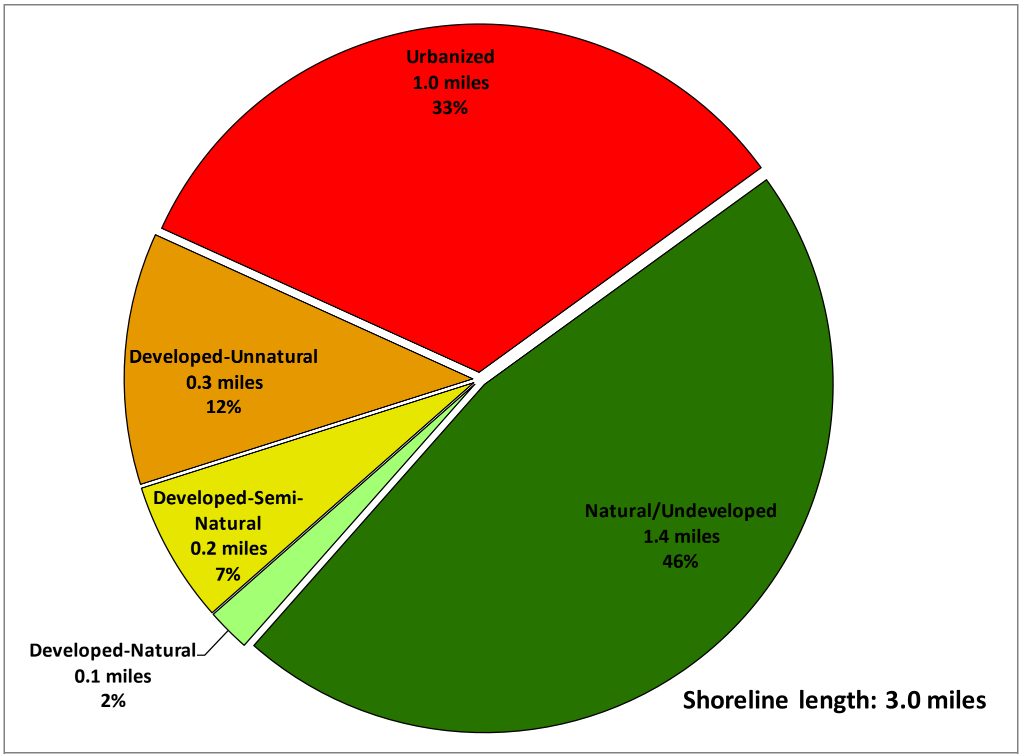


Figure 3.3-2. Kettle Moraine Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Map3.

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, Kettle Moraine 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, and cluster 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, 16 total pieces of coarse woody habitat were observed along 3 miles of shoreline (Map 4), which gives Kettle Moraine Lake a coarse woody habitat to shoreline mile ratio of 5:1 (Figure 3.3-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Of the 16 total pieces of coarse woody habitat observed during the survey, 11 pieces were 2-8 inches in diameters, 5 were 8 inches in diameter or greater, and no clusters of pieces of coarse woody habitat were found.

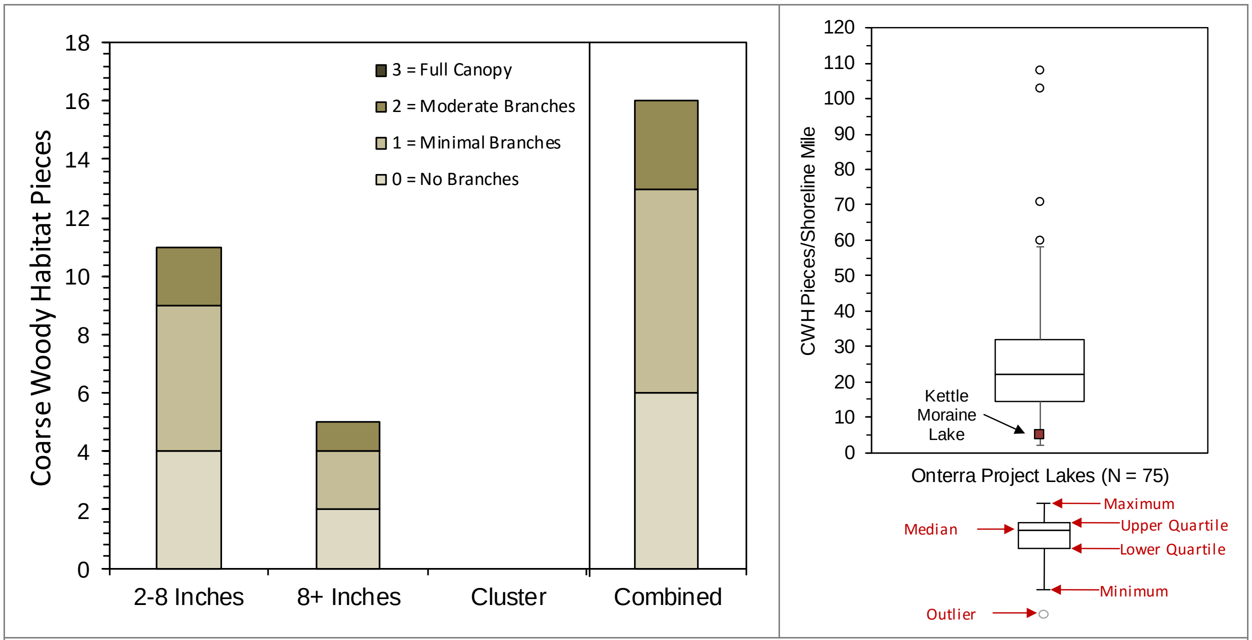


Figure 3.3-3. Kettle Moraine Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of Kettle Moraine Lake coarse woody habitat can be found on Map 4.

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 Kettle Moraine 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 75 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 Kettle Moraine Lake fell well below the 25th percentile of these 75 lakes (Figure 3.3-3).

3.4 Aquatic Plants

Introduction

Photograph 3.4-1. Example of emergent and floating-leaf communities.

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

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*). In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the periphyton attached to them as their primary food source. The plants also provide cover for feeder fish and zooplankton, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent 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.

Aspecific 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 Kettle Moraine 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 Kettle Moraine 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

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. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

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

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

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

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

Bottom Screens

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

Water Level Drawdown

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

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

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

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

Photograph 3.4-4. Granular herbicide application.

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. Table 3.4-1 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:

1. Contact herbicides act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

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

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.

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.

The use of any aquatic herbicide poses environmental risks to non-target plants and aquatic organisms. The majority of available toxicity data has been conducted as part of the EPA product registration process. These laboratory studies are attempted to mimic field settings, but can underestimate or overestimate the actual risk (Faribrother and Kapuska 1996). Federal and state pesticide regulations and strict application guidelines are in place to minimize impacts to non-target organisms based on the organismal studies. The use of aquatic herbicides includes regulatory oversight and must comply with the following list:

- Labeled and registered with U.S. EPA's office of Pesticide Programs;
- Registered for sale and use by the Department of Agriculture, Trade, and Consumer Protection (DATCP);
- Permitted by the Wisconsin Department of Natural Resources (WDNR); and
- Applied by a DATCP-certified and licensed applicator

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. • Herbicide selection and application timing can provide a degree of selectivity towards the target plant. • Some herbicides can be used effectively in spot treatments. • 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 emergents 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 were completed on Kettle Moraine Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed in Kettle Moraine Lake. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in 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 survey completed on Kettle Moraine 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 Kettle Moraine Lake to be compared to other lakes within the region and state.

$$\text{FQI} = \text{Average Coefficient of Conservatism} * \sqrt{\text{Number of Native Species}}$$

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. However, in a recent study of 1,100 Minnesota lakes, researchers concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan et al. 2018). 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 Kettle Moraine Lake is compared to data collected by Onterra and the WDNR Science Services on 77 lakes withn the Southeast Wisconsin Till Plain ecoregion and on 392 lakes throughout Wisconsin.

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 Kettle Moraine 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. In some situations, Eurasian watermilfoil integrates itself into the native plant community without causing wide-scale ecological impacts nor impacts to human uses of the lake.

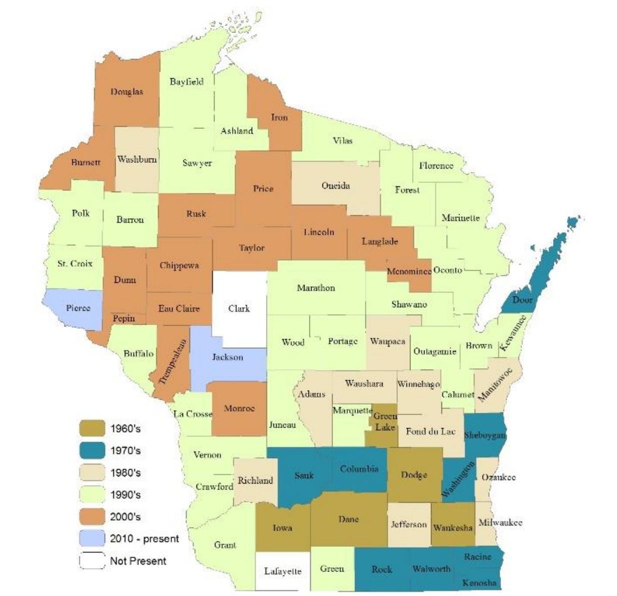


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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. But also like Eurasian watermilfoil, the impacts of curly-leaf pondweed in a lake may be minimal, especially in northern and northeastern Wisconsin.

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.

Aquatic Plant Survey Results

A total of 60 species of plants have been located from Kettle Moraine Lake or the immediate shoreline during aquatic plant surveys completed between 2007 and 2018. Please note that many of these species are only sparsely located and/or marginal wetland species with coontail, southern naiad, common waterweed, and recently Eurasian watermilfoil comprising the majority of aquatic plant abundance. Please note that in some years, multiple point-intercept surveys were conducted for varying purposes, and the population data reflected here is from the latest summer survey of each year.

During the aquatic plant surveys completed on Kettle Moraine Lake in 2018, a total of 33 species of plants were located, five of which are considered non-native, invasive species: Eurasian watermilfoil (EWM), curly-leaf pondweed (CLP), pale yellow iris, yellow garden loosestrife, and purple loosestrife (Table 3.4-2). The populations of these non-native plants in Kettle Moraine Lake are discussed in detail in the subsequent Non-Native Aquatic Plants Subsection. Table 3.4-1 also includes the list of aquatic plant species which have been documented during annual surveys completed since 2007. A comparison of the 2018 aquatic plant survey data to these historical datasets is discussed later in this section.

Table 3.4-2. Aquatic plant species located on Kettle Moraine Lake during 2007-2018 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Emergent	*Decodon verticillatus*	Water-willow	7	I		I	X	I	I			I		I	
	Eleocharis erythropoda	Bald spikerush	3											I	
	Eleocharis palustris	Creeping spikerush	6			I									
	Iris psuedacorus	Pale yellow iris	Exotic					I						I	
	Iris sp.	Iris sp.	N/A					I							
	Lysimachia vulgaris	Yellow garden loosestrife	Exotic						I					I	
	Lythrum salicaria	Purple loosestrife	Exotic							I				I	
	Mimulus ringens	Monkey-flower	6											I	
	Poaceae sp.	Grass sp.	N/A			X									
	Pontederia cordata	Pickerelweed	9	I	I	I	X	X	X	I	I	X		I	
	Sagittaria latifolia	Common arrowhead	3											I	
	Sagittaria sp.	Arrowhead sp.	N/A	I			I								
	Schoenoplectus acutus	Hardstem bulrush	5			I	X			I					
	Schoenoplectus pungens	Three-square rush	5	I			I	I						I	
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I						I			I	
	Sparganium eurycarpum	Common bur-reed	5				I							I	
	Typha spp.	Cattail spp.	1	I	I	I		I						I	
	Zizania spp.	Wild rice sp.	8							I					
FL	*Brasenia schreberi*	Watershield	7	X	X	X	X	X	X	X	X	X	X	X	X
	Nuphar variegata	Spatterdock	6	X	X	X	X	X	I	X	X	I	X	X	X
	Nymphaea odorata	White water lily	6	X	X	X	X	X	X	X	X	X	X	X	X
	Persicaria amphibia	Water smartweed	5							X					
	Sparganium sp.	Bur-reed sp.	N/A		I	X									
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X	X	X	X	X	X	X	X	X	X	X
	Chara spp.	Muskgrasses	7	X	X	X		X	X	X	X	X	X	X	X
	Elodea canadensis	Common waterweed	3	X					X	X	X	X	X	X	X
	Elodea nutallii	Slender waterweed	7	X											
	Elodea spp.	Waterweed sp.	N/A		X	X	X	X							
	Heteranthera dubia	Water stargrass	6		X	X	X	X	X	X		X	X	X	X
	Myriophyllum sibiricum	Northern watermilfoil	7			X	X								
	Myriophyllum sp.	Milfoil sp.	N/A				X								
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X	X	X	X	I	X	X	I	I	X	X	X
	Najas flexilis	Slender naiad	6	X	X	X	X			X		X	X	X	
	Najas guadalupensis	Southern naiad	7			X	X	X	X	X	X	X	X	X	X
	Nitella spp.	Stoneworts	7		X	X	X						X		X
	Nitella tenuissima	Compact stonewort	N/A											I	
	Potamogeton amplifolius	Large-leaf pondweed	7	X		X			X	X	X	X			X
	Potamogeton crispus	Curly-leaf pondweed	Exotic	X	X	X	X		X	X	I	I	I	X	X
	Potamogeton friesii	Frie's pondweed	8		X										
	Potamogeton gramineus	Variable-leaf pondweed	7		X	X	X	X		X	X	X	X	X	X
	Potamogeton hybrid 1	Pondweed hybrid 1	N/A										I		I
	Potamogeton illinoensis	Illinois pondweed	6	X	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton illinoensis X *P. natans*	Illinois X floating-leaf pondweed	N/A											I	
	Potamogeton natans	Floating-leaf pondweed	5	I	I		X					I		I	
	Potamogeton nodosus	Long-leaf pondweed	5	X		X							X	X	
	Potamogeton praelongus	White-stem pondweed	8			X		X	X		X	X			X
	Potamogeton robbinsii	Fern-leaf pondweed	8						I						
	Potamogeton X *scoliophyllus*	Large-leaf X Illinois pondweed	N/A	X		X		X						X	
	Ranunculus aquatilis	White water crowfoot	8	X	X	X	X								
	Stuckenia pectinata	Sago pondweed	3	X	X	X	X	X	X	X	X	X	X	X	X
	Utricularia gibba	Creeping bladderwort	9		X	X	X	X		X	X	X	X	X	X
	Utricularia minor	Small bladderwort	10			X	X								
	Utricularia vulgaris	Common bladderwort	9	X	X	X	X	I	I	I	X	X	X		
	Vallisneria americana	Wild celery	6	X	X	X	X	X	X	X	X	X	X	X	X
S/E	*Schoenoplectus subterminalis*	Water bulrush	9			X	X								
	Eleocharis acicularis	Needle spikerush	5												X
FF	*Lemna minor*	Lesser duckweed	5	X	X	X	X	I							
	Lemna trisulca	Forked duckweed	6			X									
	Spirodela polyrhiza	Greater duckweed	5	X	X	X	X	I							
	Wolffia columbiana	Common watermeal	5			I	X								

FL = Floating Leaf; S/E = Submergent and Emergent; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species

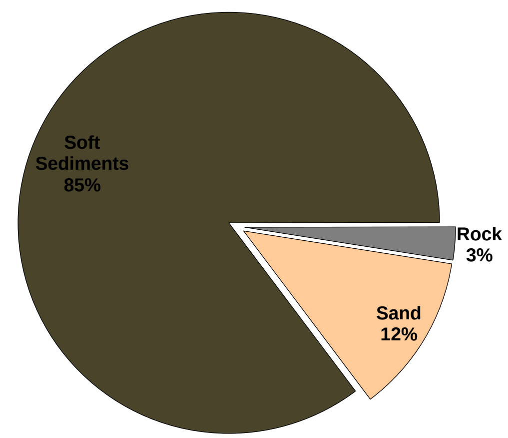


Figure 3.4-2. Kettle Moraine Lake proportion of substrate types within littoral areas. Created using data from September 2018 whole-lake point-intercept survey. N=236

The sediment within littoral areas of Kettle Moraine Lake is very conducive for supporting lush aquatic plant growth. Data from the point-intercept survey indicate that approximately 85% of the sampling locations located under approximately 15 feet (the length of the survey rake pole) and within the littoral zone, contained soft sediments (muck), 12% contained sand, and 3% contained rock (Map 5, Figure 3.4-2).

Later in this section, the aquatic plant management activities that have occurred on Kettle Moraine Lake will be discussed. While directed towards controlling invasive species, management with herbicides can also have impacts on non-target native plant species. On many of the subsequent figures, a blue background indicates the years when herbicide treatments likely had lake-wide impacts and the green background indicates years the impacts from the herbicide treatment were likely localized to the application area.

Kettle Moraine Lake's littoral zone is almost entirely vegetated, with approximately 91% of the point-intercept sampling locations that fell within the maximum depth of aquatic plant growth (16 feet) containing aquatic vegetation (Figure 3.4-3). Aquatic plant rake fullness data collected in 2018 indicates that 11% of the 246 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 18% had a TRF rating of 2, and 61% had a TRF rating of 3 (Figure 3.4-3). The large proportion of TRF ratings of 3 is an indication that aquatic plant biomass in Kettle Moraine Lake is high.

It is likely that this increased herbicide use in 2011-2014 resulted in the measured decline in the proportion of TRF ratings of 2 and 3, a surrogate for aquatic plant biomass. The reduced herbicide use in 2015 and 2016 and lack of an herbicide application in 2017 may have led to the recovery in aquatic plant biomass in these years.

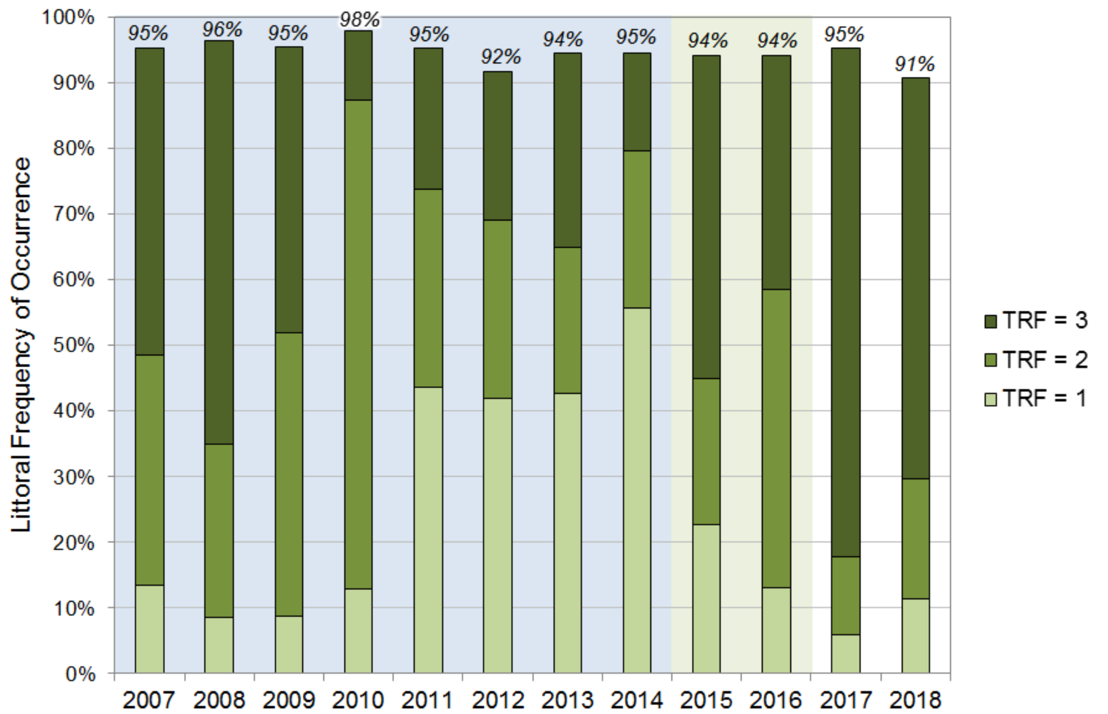


Figure 3.4-3. Kettle Moraine Lake 2007-2018 aquatic plant total rake fullness (TRF) ratings within the littoral zone. Created using data from 2007 - 2018 whole-lake point-intercept surveys. The blue background indicates years with herbicide treatments which likely had lake-wide impacts and the green background indicates years with herbicide spot treatments where impacts were likely localized to the application area.

Map 6 illustrates the distribution of aquatic plant growth in Kettle Moraine Lake and shows that aquatic vegetation occupies approximately 98% of the lake's surface area, with only 3 acres of the lake being too deep to support plants. Despite a maximum depth of 29 feet, Kettle Moraine Lake is overall relatively shallow with a mean depth of 8 feet. As discussed in the water quality section, the water clarity in Kettle Moraine Lake is high which allows sunlight to penetrate deeper into the water column and support aquatic plant growth throughout most of the lake.

Of the 60 aquatic plant species that have been located during historic point intercept surveys, 18 species were physically encountered on the rake during the point-intercept survey in 2018. Additional species that are observed during the survey but are not physically sampled on the survey rake are listed as *incidental* species. An incidentally-located species means the plant was not directly sampled on the rake during the point-intercept survey, but was observed in the lake by Onterra ecologists and was recorded/collected. The majority of incidentally-located plants typically include emergent species growing along the lake's margins and submersed species that are relatively rare within the lake's plant community. Of the 18 native species encountered on the rake in 2018, coontail, southern naiad, common waterweed, and muskgrasses were the four-most frequently encountered (Figure 3.4-4).

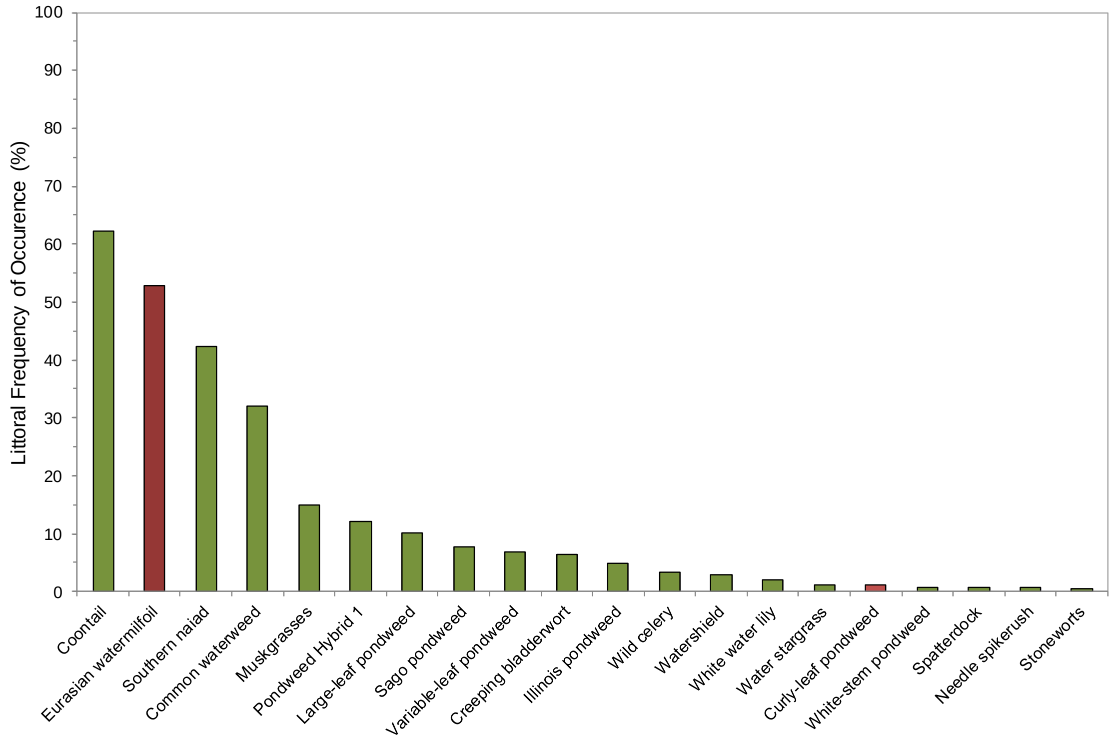


Figure 3.4-4. Kettle Moraine Lake 2018 aquatic plant littoral frequency of occurrence. Exotic species indicated with red. Created using data from September 2018 whole-lake point-intercept survey.

Coontail, arguably the most common aquatic plant in Wisconsin, was the most frequently encountered aquatic plant in Kettle Moraine Lake in 2018 with a littoral frequency of occurrence of 62% (Figure 3.4-4). 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 all of its nutrients directly from the water (Gross et al. 2013). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in productive waterbodies with higher nutrients and lower water clarity. Given its low-light tolerance, coontail was most abundant in deeper waters of Kettle Moraine Lake's littoral zone from 8 to 16 feet of water. While coontail has the capacity to form dense beds which mat on the surface coontail was not observed matting on the surface in Kettle Moraine Lake. Coontail provides many benefits to the aquatic community. Its dense whorls for leaves provide excellent structural habitat for aquatic invertebrates and fish, especially in winter as this plant remains green under the ice. In addition, it competes for nutrients that would otherwise be available for free-floating algae and helps maintain Kettle Moraine Lake's clear-water state.

Southern naiad was the second-most frequently encountered aquatic plant in Kettle Moraine Lake in 2018 with a littoral frequency of occurrence of approximately 42% (Figure 3.4-4). Southern naiad is similar to slender naiad, and they are often difficult to separate. While southern naiad is native to North America, recent observations indicate that some populations of this plant have been expanding and behaving invasively, particularly in northern Wisconsin lakes. It is not known if this behavior represents recent introductions of these plants to waterbodies where it was not found naturally, or if certain environmental conditions are favoring the expansion of southern naiad. In

Kettle Moraine Lake the littoral occurrence of southern naiad has fluctuated from year to year but has not increased in its occurrence over this period. In 2018, southern naiad was most abundant in moderate depths of the littoral zone between 4 and 11 feet of water.

Common waterweed, the third-most frequently-encountered aquatic plant with a littoral frequency of occurrence of 32% (Figure 3.4-4), is an aquatic plant species with a wide distribution across North America, and like coontail obtains the majority of its nutrients directly from the water. While common waterweed can be found growing in many of Wisconsin's waterbodies, excessive growth of common waterweed is often observed in waterbodies with higher nutrients. Like coontail, it can tolerate the low light conditions found in eutrophic systems better than many other aquatic plant species. For these reasons, common waterweed has competitive advantages over other aquatic plant species that favor its growth in productive systems. In Kettle Moraine Lake, common waterweed was most abundant in shallower areas of the littoral zone, primarily between 3 and 12 feet of water.

In 2018, muskgrasses, the fourth-most encountered aquatic plant) had a littoral frequency of occurrence of approximately 15% (Figure 3.4-4). Muskgrasses are a genus of macroalgae represented by seven species in Wisconsin (Photograph 3.4-5). Muskgrasses are typically common in hardwater lakes like Kettle Moraine Lake. These macroalgae have been found to more competitive against vascular plants (e.g. pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002; Wetzel 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002). In Kettle Moraine Lake, muskgrasses were most abundant in shallower areas of the littoral zone from 2 to 6 feet.

Photograph 3.4-5. The aquatic macroalgae muskgrasses (*Chara* spp.). Photo credit Onterra.

The quality of Kettle Moraine Lake's plant community is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in near-shore areas around the lake. The 2017 community map indicates that approximately 35.1 acres (16.4%) of the 214 acre-lake contain these types of plant communities (Table 3.4-3 and Map 7). Twelve native floating-leaf and emergent species were located on Kettle Moraine Lake in 2017, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

Because 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 valuable understanding of the dynamics of these communities within Kettle Moraine Lake. This is important because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands 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 shorelands.

Table 3.4-3. Kettle Moraine Lake acres of plant community types. Created from July 2017 community mapping survey.

Plant Community	Acres
Emergent	1.8
Floating-leaf	33.3
Total	**35.1**

Aquatic plant point-intercept datasets from Kettle Moraine Lake are available annually since 2007, and the methodology and sampling locations were the same as the survey completed in 2018. These datasets can be statistically compared to determine if any significant changes in the overall occurrence of vegetation or individual species abundance have occurred over the time period.

Figure 3.4-3 displays the littoral occurrence of aquatic vegetation in Kettle Moraine Lake and total rake fullness ratings from 2007-2018. The littoral frequency of occurrence of aquatic vegetation ranged from 92% in 2012 to 98% in 2010; however, changes in littoral occurrence between these years were not statistically different (Chi-square $\alpha = 0.05$). While the littoral occurrence of aquatic vegetation has not changed from 2007-2017, changes in TRF ratings suggests the biomass of aquatic plants in Kettle Moraine Lake has fluctuated over this time period. From 2007 to 2010, an average of 85% of littoral sampling locations contained a TRF rating of 2 or 3. From 2011-2013, the average proportion of TRF ratings of 2 and 3 declined to 51% and declined further to 39% in 2014. From 2015-2017, the average proportion of TRF ratings of 2 and 3 increased to 81%.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, water levels, changes in clarity, herbivory, competition, and disease among other factors. Certain native aquatic plants can also decline following the implementation of herbicide applications to control non-native aquatic plants

In addition to examining changes in the overall occurrence of vegetation in Kettle Moraine Lake from 2007 to 2018, changes in the occurrence of individual plant species were also investigated. Submersed aquatic plant species which had a littoral occurrence of at least 5% in one of the 12 surveys were included in this analysis. Floating-leaf species (i.e. white water lily and watershield) were omitted from this analysis, as sampling intensity in these areas can influence their abundance metrics. Some species within Kettle Moraine Lake have similar morphological characteristics and cannot always be easily be identified in the field and were combined for this analysis. For this analysis, common/slender waterweed refers to the combined occurrences of both *Elodea canadensis* and *E. nuttallii*, slender/southern naiad refers to the combined occurrences of *Najas* *flexilis* and *N. guadalupensis,* and large pondweed spp. refers to the collective occurrences of *Potamogeton amplifolius*, *P. illinoensis*, *P. gramineus* and a hybrid *Potamogeton* species that is believed to be a cross between *P. amplifolius* and *P. illinoensis* (*P.* × *scoliophyllus*).

Linear regression analysis is a relatively basic way for lake ecologists a way to discover if statistically valid trends (increases or decreases) are occurring. Linear regression analysis generates an equation or line of best fit (regression line) that minimizes the distance between the data points. A statistical measure of how close the measured data are to the regression line is called the r-squared statistic (r^2) and ranges from 0 to 1 (0% to 100%). An r^2 value of 0 indicates that the model does not explain any of the variability in the data (0% of the data), while an r^2 value of 1 indicates that the model explains all of the variability in the data (100% of the data).

In addition to r^2, linear regression analysis also generates a *p*-value, which indicates if time is a significant predictor of change in a water quality parameter (i.e. is a trend occurring). A low *p*-value (≤ 0.05) indicates that a statistically valid change in a water quality parameter has occurred over time, while a larger *p*-value (> 0.05) indicates that a statistically valid change has not occurred.

Of the 8 native species/lumped species that were analyzed for simple linear analysis, five did not exhibit a statistically trend over time (Figure 3.4-5). The littoral occurrences of coontail, muskgrasses, slender/southern naiad, water celery, and creeping bladderwort have fluctuated between years over this time period, but trends in their occurrence over time are not statistically significant (simple linear regression p-value > 0.05).

Muskgrasses, a group of macro-algae, are almost universally resilient to most herbicide treatments. As an algae, herbicides are not moved through (translocated) the tissue as the "plant" is made up of colonies of cells. The populations of muskgrasses has fluctuated over time on Kettle Moraine Lake, reducing sharply in 2018 for unknown reasons. Naiad species also declined sharply in 2018, but this species grouping has exhibited this magnitude of annual change in other years.

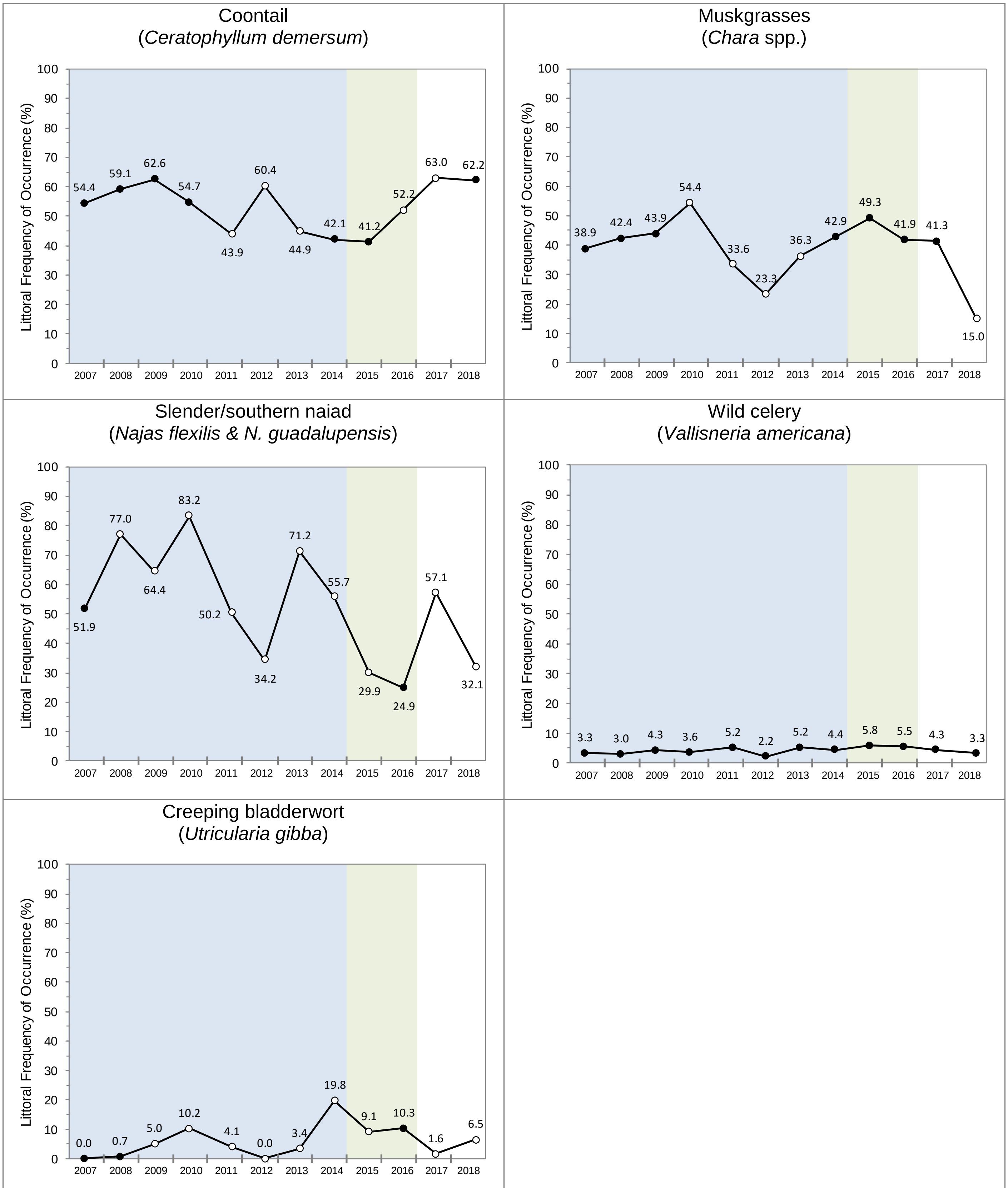


Figure 3.4-5. Littoral frequency of occurrence of select native aquatic plant species in Kettle Moraine Lake from 2007-2018. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Of the 8 native species/lumped species that were analyzed for simple linear analysis, two species groupings exhibited a statistically valid increasing trend, and two exhibited a statistically valid decreasing trend (Figure 3.4-6).

Large pondweed species and sago pondweed species have exhibited statistically valid increases from 2007-2018. In 2004, the KMLA facilitated the introduction of 1,000 large-leaf pondweed plants into the lake. During recent surveys, a hybrid of large-leaf pondweed and Illinois pondweed has been confirmed. It is possible that the plants added to the lake were in fact of a hybrid or horticultural variety that may have improved function and have allowed the species in increase at a time of relatively intense herbicide management. Sago pondweed is a disturbance tolerant species and Onterra's experience is that some lakes have had increases in this species surrounding herbicide management activities.

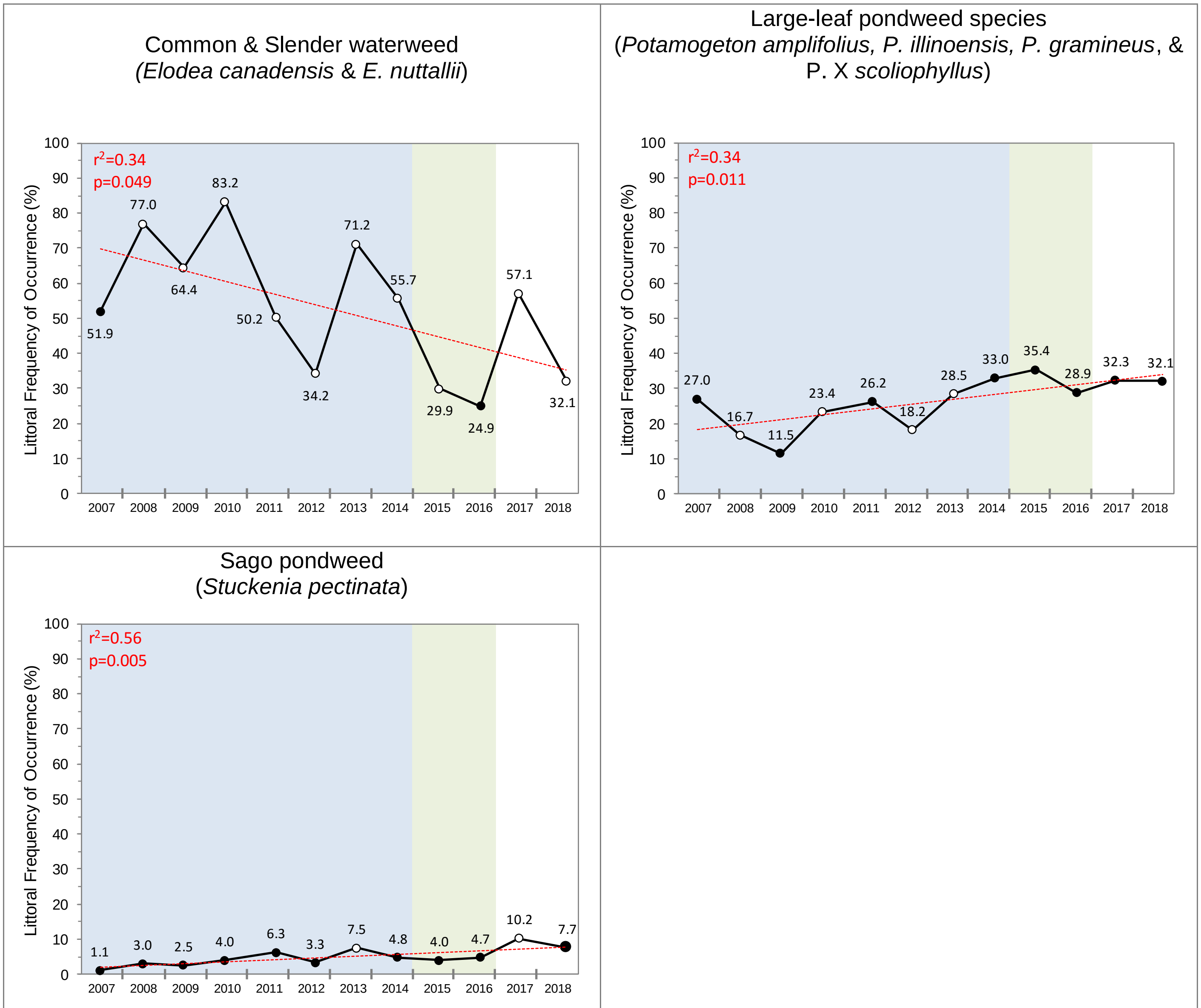


Figure 3.4-6. Littoral frequency of occurrence of select native aquatic plant species in Kettle Moraine Lake from 2007-2018. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Linear regression model shown in red with labeled r^2 and p-values.

Waterweed populations have fluctuated widely on Kettle Moraine during this period. This plant is known to be at nuisance levels in some years. While a statistically valid decreasing population trend is observed, the large amount of variation in the data makes it difficult to determine the practical significance of this metric. For instance, the fourth highest waterweed population was recorded during the second-to-last year in the trend analysis (2017).

The calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while 28 native aquatic plant species were located in Kettle Moraine Lake during the 2017 surveys, 16 were encountered on the rake during the point-intercept survey. The native aquatic plant species located on the rake during the point-intercept surveys from 2007 to 2018 and their conservatism values were used to calculate the FQI for each year. Native plant species richness has ranged between 13 and 29 with an average of 18 species (Figure 3.4-7). The average native plant species richness falls above the median values for other lakes within the SWTP ecoregion and below the median value for lakes throughout Wisconsin.

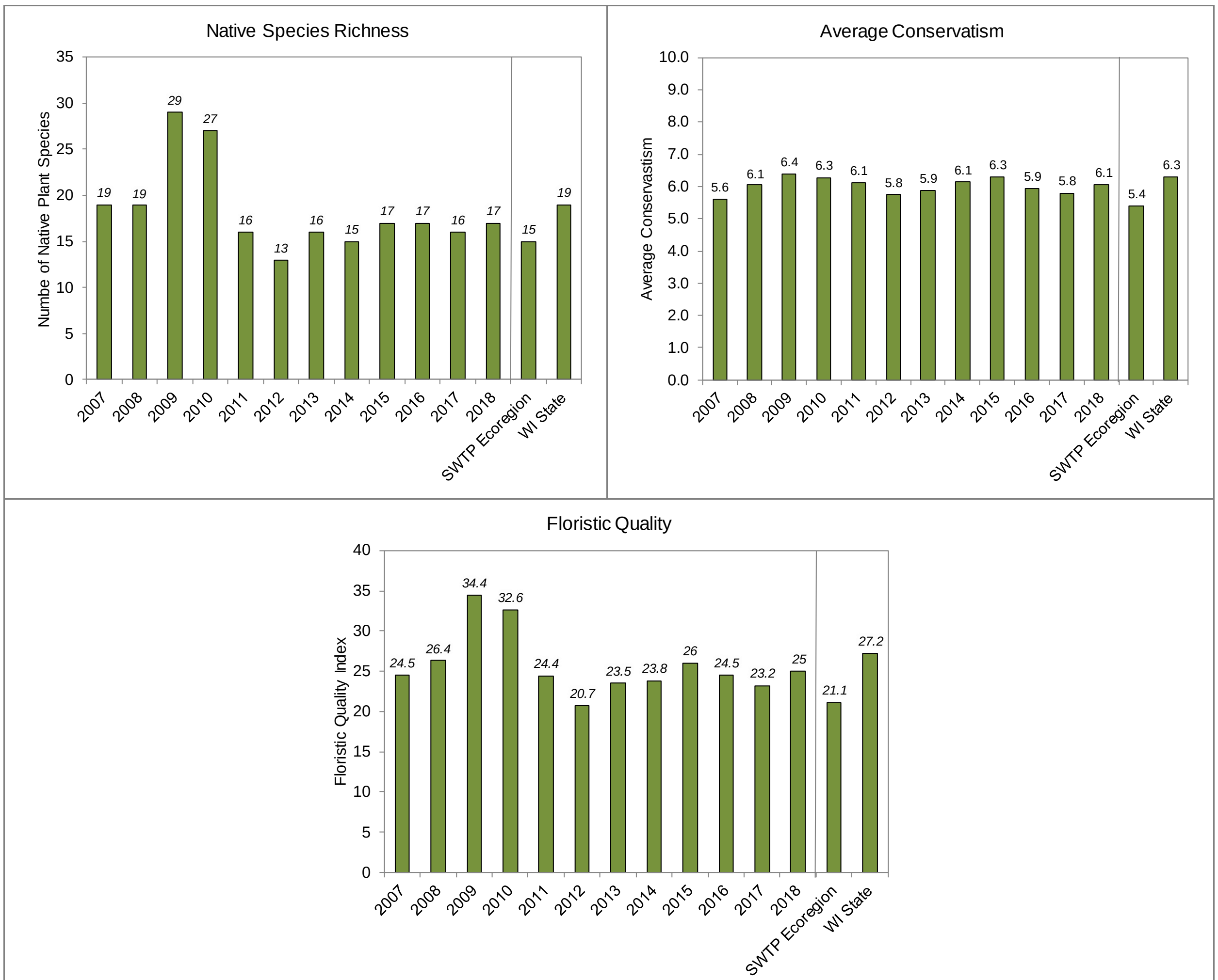


Figure 3.4-7. Kettle Moraine Lake Floristic Quality Assessment. Created using data from 2007-2018 whole-lake point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data. Analysis follows Nichols 1999.

Average species conservatism ranged between 5.6 to 6.4 between the 2007-2018 surveys with an average of 6.0, falling above the median value for lakes in the SWTP region (5.4) but below the median for lakes within the state (6.3) (Figure 3.4-7). Using Kettle Moraine Lake's annual species richness and average conservatism to calculate the annual FQI yielded values ranging between 20.7 and 34.4 with an average of 25.8 (Figure 3.4-7). The average FQI value for Kettle Moraine Lake's aquatic plant community falls above the median for lakes within the SWTP ecoregion (21.1) but below the median for lakes throughout Wisconsin (27.2).

When compared to other lakes in the SWTP ecoregion, Kettle Moraine Lake has a higher number of native aquatic plant species and a higher number of conservative species, or species that are sensitive to environmental degradation. However, when compared to lakes statewide, Kettle Moraine Lake has a lower number of native species and fewer species with higher conservatism values. Overall, the FQI analysis indicates that the native plant community of Kettle Moraine Lake is of higher quality when compared to regional lakes but lower quality when compared to lakes throughout the state. Plant species which tend to flourish in higher nutrient conditions are dominant in Kettle Moraine Lake (e.g. coontail and common waterweed).

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 Kettle Moraine Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 77 lakes within the SWTP Ecoregion (Figure 3.4-8). Using the data collected from the 2007-2018 whole-lake point-intercept surveys, Kettle Moraine Lake's aquatic plant species diversity ranged between 0.81 and 0.87 with an average of 0.85. Aquatic plant species diversity was 0.86 in 2018. The average species diversity value of 0.85 falls above the median value for lakes within the SWTP ecoregion, indicating high species diversity for this region.

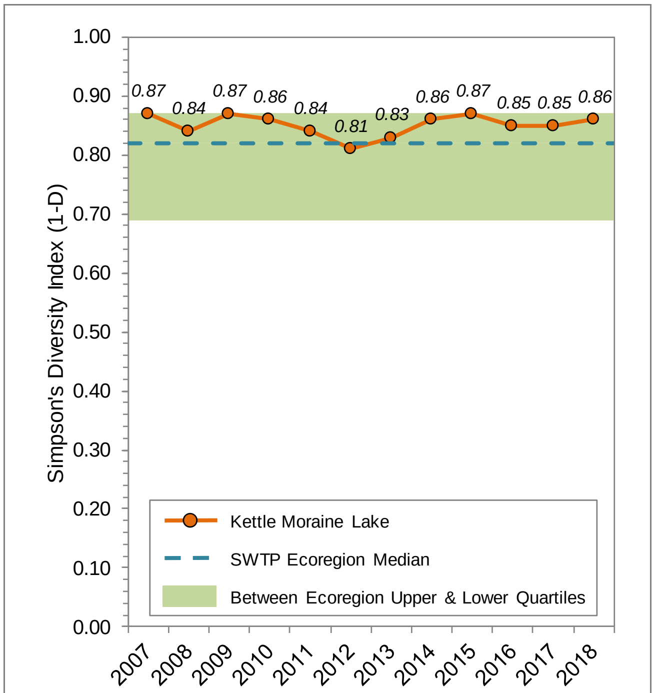


Figure 3.4-8. Kettle Moraine Lake 2007-2018 Simpson's Diversity Index. Created using data from 2007-2018 whole lake-lake point intercept surveys.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while coontail was found at 62% of the sampling locations in Kettle Moraine Lake in 2018, its relative frequency of occurrence was approximately 23%. Explained another way, if 100 plants were randomly sampled from Kettle Moraine Lake, 23 of them would be coontail.

Looking at relative frequency of occurrence (Figure 3.4-9), Kettle Moraine Lake's aquatic plant community is not dominated by just one or two species which would yield lower species diversity.

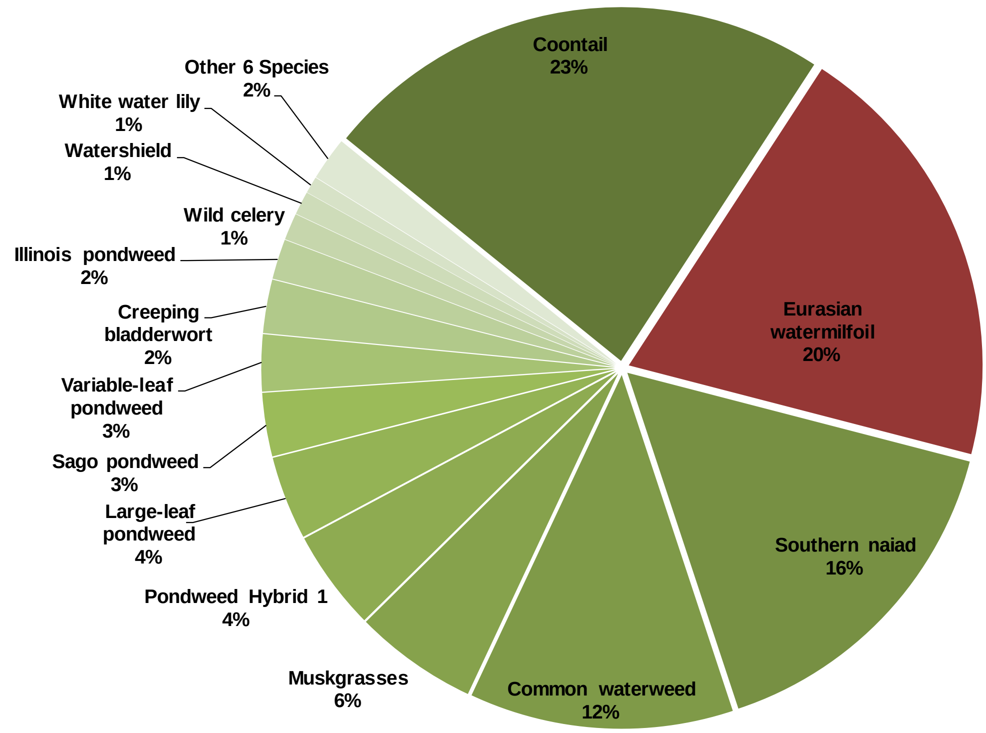


Figure 3.4-9. 2018 relative frequency of occurrence of aquatic plants in Kettle Moraine Lake. Created using data from 2018 point-intercept survey.

Non-native Plants in Kettle Moraine Lake

Curly-leaf pondweed and Eurasian watermilfoil

Curly-leaf pondweed (CLP – Photograph 3.4-6) was officially documented in Kettle Moraine Lake in 2004. The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Not all of the turions produced each year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Normally a control strategy for an established CLP population includes multiple years of controlling the same area to deplete the existing turion bank within the sediment.

Early season herbicide treatments, particularly low-concentration whole-lake 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 2 years of the control program, but continued reductions were observed following all five years of the project.

The occurrence of CLP has remained quite stable in Kettle Moraine Lake over the course of the monitoring from 2007 to 2018 with the majority of surveys showing a littoral frequency of occurrence below 2% (Figure 3.4-10). As discussed earlier, CLP naturally senesces in early summer and therefore, early summer point-intercept surveys were conducted on Kettle Moraine Lake to properly track the changes in curly-leaf pondweed populations. Figure 3.4-9 displays the data from the June surveys from 2008-2015 and the late-summer point intercept surveys from 2016 through 2018. Since the 2016-2018 surveys were conducted later in the growing season, the littoral occurrence of the CLP population is likely underestimated in these years as much of the population had senesced by the time of the surveys. Additional details regarding a management strategy for CLP in 2019 and beyond is discussed in the *Implementation Plan* Section.

Onterra ecologists have also monitored the CLP population in recent years through qualitative mapping surveys that are conducted during the early summer when CLP is expected to be near its peak-growth stage in the growing season. Recent early summer surveys completed in 2017 & 2018 show the CLP population to be fairly widespread throughout the littoral areas of Kettle Moraine Lake. Much of the CLP population consists of relatively low-density colonies while a few more dense colonies have also been observed in some areas of the lake (Map 8). Of the CLP population that was mapped with area-based methodologies in the 2018 survey, approximately 30.3 acres consisted of lower density colonies consisting of highly scattered or scattered plants, whereas an additional 3.9 acres consisted of higher density colonies described as dominant or highly dominant.

Curly-leaf pondweed (*Potamogeton crispus*)

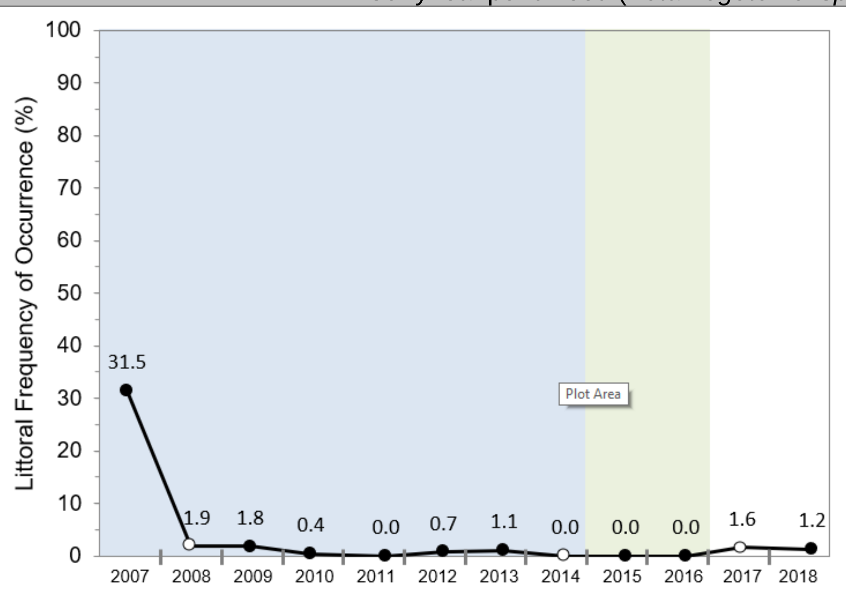


Figure 3.4-10. Littoral frequency of occurrence of curly-leaf pondweed in Kettle Moraine Lake from 2007-2018. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Created using data from 2007-2015 June surveys and 2016-2018 late-summer whole-lake point-intercept surveys. The blue background indicates years with herbicide treatments which likely had lake-wide impacts and the green background indicates years with herbicide spot treatments where impacts were likely localized to the application area.

Photograph 3.4-6. Curly-leaf pondweed, a non-native, invasive aquatic plant. Photo credit Onterra.

Eurasian watermilfoil (EWM – Photograph 3.4-7) was first documented in Kettle Moraine Lake in 1995. Typically, EWM reaches its peak growth in mid- to late-summer. In addition to the quantitative monitoring through annual point-intercept surveys, Onterra ecologists have also monitored the EWM population in recent years through qualitative mapping surveys that are conducted during the mid-to-late summer when EWM is expected to be near its peak-growth stage in the growing season. The results of the late-summer EWM mappings surveys from 2015-2018 are displayed on Map 9. A noticeable increase in the EWM population is evident between 2016-2018. During the most recent mapping survey completed in the late-summer of 2018, EWM was found to be widespread throughout most of the littoral areas of the lake. Approximately 101.7 acres of EWM were mapped in 2018 of which 42.8 acres consisted of dense colonized populations described as either dominant, highly dominant or surface matted plants. An additional 58.9 acres of lower density colonies consisting of highly scattered or scattered plants were also mapped in 2018.

The littoral occurrence of EWM from 2007-2016 ranged from zero to 5.9% until in 2017 when the population increased to 18.9% (Figure 3.4-11). The EWM population increased in littoral occurrence in 2018 to 52.8%, which is the highest littoral frequency of occurrence observed over the twelve-year period. Additional details regarding a management strategy for EWM in 2019 and beyond is included in the *Implementation Plan* section.

Eurasian watermilfoil (*Myriophyllum spicatum*)

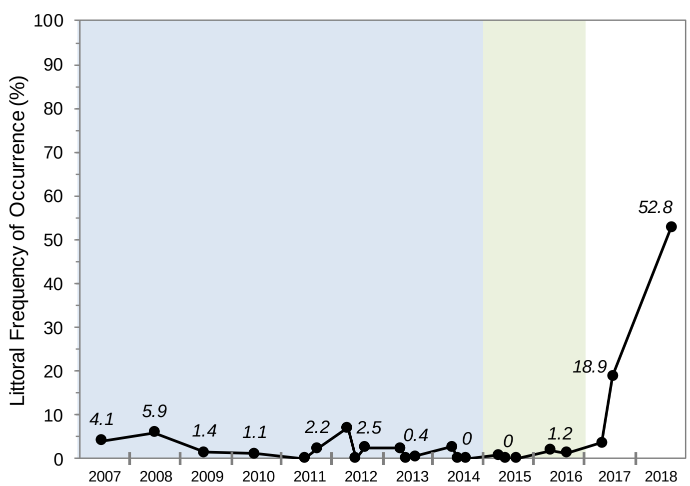


Figure 3.4-11. Littoral frequency of occurrence of Eurasian watermilfoil in Kettle Moraine Lake from 2007-2018. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Created using data from 2007-2018 whole-lake point-intercept surveys. The blue background indicates years with herbicide treatments which likely had lake-wide impacts and the green background indicates years with herbicide spot treatments where impacts were likely localized to the application area. Up to 3 point-intercept surveys were conducted in some years, with the labeled value referring to the late-summer survey.

Photograph 3.4-7. Eurasian watermilfoil a non-native, invasive aquatic plant. Photo credit Onterra.

Kettle Moraine Lake Aquatic Invasive Species (AIS) Active Management History

Records indicate that the application of herbicides to control aquatic plants and/or algae has occurred on an annual basis since 1991 in Kettle Moraine Lake. Treatment records detailing which herbicides were used and at what dosage are incomplete from 1991-2006; however, a complete record of treatments is available from 2006-2016 (Figure 3.4-12). Over this 10-year period, a combination of 2,4-D, endothall, and/or diquat have been applied to Kettle Moraine Lake in an effort to control non-native aquatic plants. The annual amount of herbicide in pounds of active ingredient ranged from 79 pounds in 2015 to 4,279 pounds in 2014 with an average of 1,937 pounds per year. No herbicide treatments occurred in 2017 or 2018.

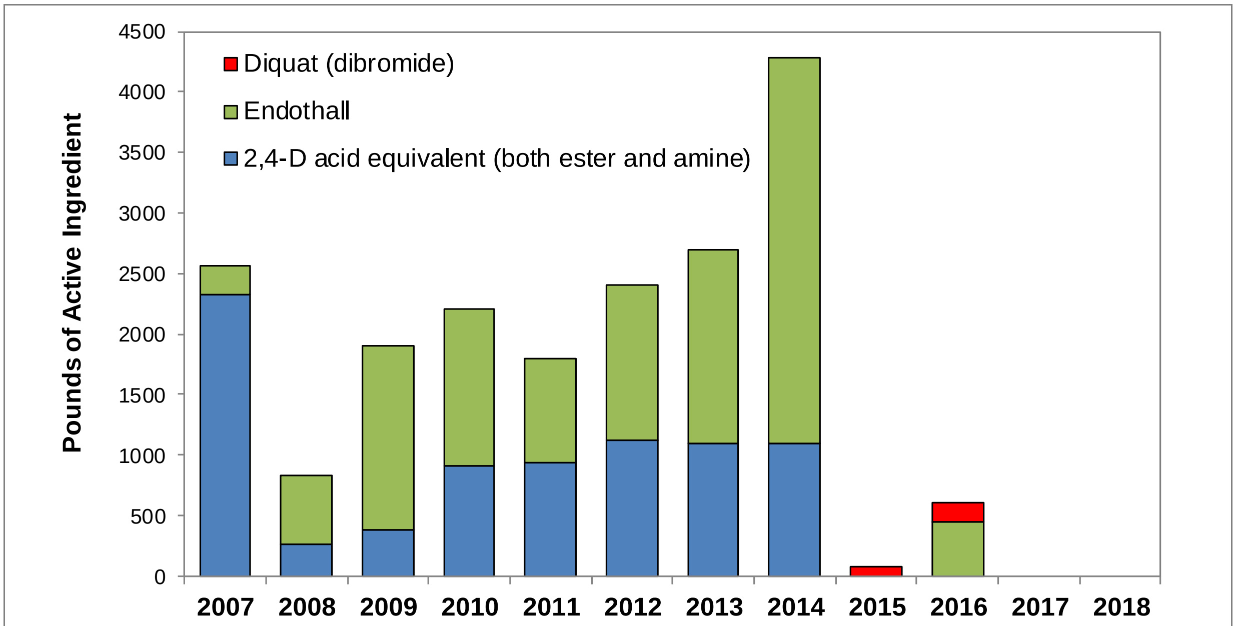


Figure 3.4-12. Kettle Moraine Lake herbicide treatment history from 2007-2018.

As discussed previously, it is known that the combined application of 2,4-D and endothall have synergistic effects in terms of aquatic plant control. It is believed that the variability in native aquatic plant abundance observed from 2007-2016, is the result of recurring applications of these herbicides. The changes in total biomass, especially the changes in percentage of total rake fullness ratings on 2 or 3 (Figure 3.4-3), shows that the whole-lake herbicides are having an effect on plants within Kettle Moraine Lake. The herbicide treatments have maintained smaller populations of CLP and EWM without affecting the native plant population too drastically, since the beginning of the native plant monitoring.

Management from 2007 to 2013 consisted of applying 2,4-D to areas with EWM and endothall to areas with CLP. It was observed that the treatment would seem to achieve good CLP control each year, but the EWM population would rebound from the treatment later that season. This suggests that the herbicide use pattern was insufficient to completely kill the EWM and was only providing seasonal control.

In 2014, the KMLA adopted a large-scale (aka whole-lake) herbicide dosing strategy. From an ecological perspective, large-scale treatments are those where the herbicide may be applied to specific sites where the target AIS species is present, but when the herbicide dissipates from where it was applied and reaches equilibrium within the entire mixing volume of water of the lake, it is at a concentration that is sufficient to cause mortality to the target plant within that entire treated volume (Nault et al. 2012). A recent article by Nault et al. 2018 investigated 28 large-scale herbicide treatments in Wisconsin and found that "herbicide dissipation from the treatment sites into surrounding untreated waters was rapid (within 1 day) and lakewide low-concentration equilibriums were reached within the first few days after application." Herbicide exposure time in large-scale treatments is primarily dictated by herbicide degradation. Herbicides degrade differently, but typically take weeks to degrade in large-scale treatment scenarios.

The simultaneous exposure to endothall and 2,4-D has been shown to provide increased control of invasive milfoil in outdoor growth chamber studies (Madsen et. al 2010). A handful of EWM and hybrid EWM (HWM) treatments in Wisconsin utilizing this strategy have been conducted to date with promising results of control and selectivity towards native plants. A large-scale 2,4-D/endothall use-pattern was embraced in 2014 where the goal was to achieve a lake-wide concentration of 2,4-D at 0.25 ppm acid equivalent (ae) and endothall at 0.75 ppm active ingredient (ai). An updated bathymetric (depth contour) modeling study was conducted in the spring prior to the treatment, revealing higher water levels and a greater herbicide mixing volume. Herbicide concentration monitoring occurred at different locations and time period following the application. The results indicated that a lake-wide equilibrium concentration was achieved by 2 days after treatment and target concentrations were approximately reached. Formal monitoring concluded a highly efficacious treatment with minimal AIS being located during the growing season following the treatment.

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. As a part of the ongoing EWM management project, the KMLA have been educated on the difference between spot-treatments and large-scale (whole-lake or basin-wide) treatments. Ongoing studies are indicating that in small spot treatments (working definition is less than 5 acres) the herbicide dissipates too rapidly to cause EWM mortality if systemic herbicides like 2,4-D are used (Nault et al. 2015). Even in some cases where larger treatment areas can be constructed, their narrow shape or exposed location within a lake may result in insufficient herbicide concentrations and exposure times for long-term control. Ongoing field trials are assessing the efficacy (AIS control) and selectivity (collateral native plant impacts) of herbicides that may be effective with shorter contact and exposure time (CET) requirements such as diquat or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.).

EWM survivorship from the 2014 treatment was largely contained in one area of the lake. During the spring of 2015, this location was targeted with a diquat, an herbicide with a short CET requirement often used in small or exposed spot treatment scenarios. Unfortunately, the 2015 control strategy did not meet control objectives as the EWM within this site rebounded by the end of the growing season. Following incomplete control of EWM in the 2015 treatment area targeted with diquat, a more aggressive approach with a slightly different herbicide control strategy was recommended for 2016. A spot treatment was proposed to target EWM with a combination herbicide consisting of diquat and endothall using the commercially available Aquastrike® herbicide. The addition of the endothall component is theorized to have increased systemic activity on EWM to result in complete control. Some EWM survivorship was documented during the late-summer following the 2016 spot treatment, but at a much-lowered level.

The overall AIS population on Kettle Moraine Lake observed in 2016 was arguably the lowest it had been in over a decade. For the first time since coordinated active management began in 2007, herbicide control strategies were not proposed for Kettle Moraine Lake in 2017. Another justification for forgoing herbicide treatment in 2017 was to allow for aquatic plant studies that were being conducted as a part of a Comprehensive Lake Management Planning project to be completed in absence of large-scale AIS control activities. The KMLA did not want to abandon management and simply wait for AIS populations to reach levels that are again applicable for herbicide control. The KMLA piloted a professional-based hand-harvesting program in 2017 to evaluate what role this management technique may have in its integrated approach moving forward. The focus of these efforts was directed towards EWM, as hand-removal of CLP has additional challenges that may be better undertaken once the program is established.

The AIS monitoring studies completed in 2017 on Kettle Moraine Lake found both the CLP and EWM populations had expanded significantly since 2016. Professional hand-harvesting proved effective during 2017, however the benefits were confined to the rather small areas where removal efforts took place. The EWM population within Kettle Moraine was too great for hand-harvesting to have a meaningful impact on the lake-wide population. By the late-summer 2017, the EWM population had increased to its highest levels since the point-intercept survey had been used to monitor the plant population of Kettle Moraine Lake.

No active AIS management (herbicide or hand-harvesting) occurred on Kettle Moraine Lake in 2018 as the KMLA moved through the lake management planning project. The EWM and CLP populations were monitored in 2018 through qualitative and quantitative survey methods for which the results have been integrated into this document. As discussed above, CLP populations were present in the lake but largely in low densities.

In 2018, the EWM population increased to almost 53%. Nault et al. 2016 investigated point-intercept data from almost 400 Wisconsin Lakes that had EWM populations. Within this dataset, 94.7% of lakes contained EWM populations less than 50%. This indicates that Kettle Moraine Lake's 2018 EWM population is roughly within the top 5% of Wisconsin lakes that have EWM populations.

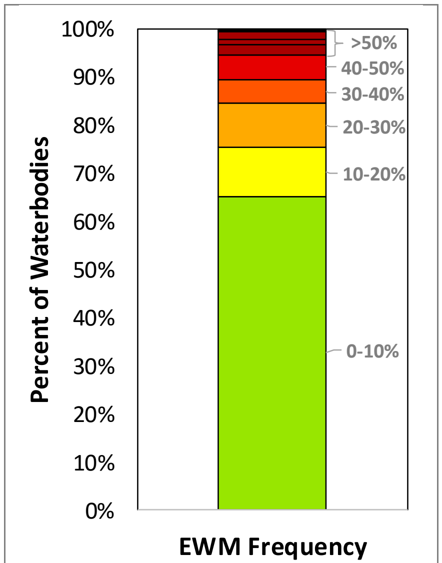


Figure 3.4-13. EWM littoral frequency of occurrence in 397 WI lakes with EWM populations. Data provided by and used with permission from WDNR.

Stakeholder Survey Responses to Aquatic Vegetation in Kettle Moraine Lake

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. The return rate of the survey was 46%. In instances where stakeholder survey response rates are 60% or above, the results can be interpreted as being a statistical representation of the population. While the survey response rate may not be sufficient to be a statistical representation of the population, the KMLA believe the sentiments of the stakeholder respondents is sufficient to provide a generalized indication of riparian preferences and concerns. Said another way, these are the best quantitative data the KMLA has to help understand stakeholder's opinions and will couple the results with other communications to determine which management actions to pursue moving forward.

Figures 3.4-14 and 3.4-15 display the responses of members of Kettle Moraine Lake stakeholders to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed. When asked how often aquatic plant growth, during the open water season, negatively impacts the enjoyment of Kettle Moraine Lake, the majority of stakeholder survey respondents (50%) indicated *sometimes*, 30% indicated *often*, 15% indicated *rarely*, and 5% indicated *always* (Figure 3.4-14). When asked if they believe aquatic plant control is needed on Kettle Moraine Lake, 61% of respondents indicated *definitely yes*, 30% indicate *probably yes*, and 9% indicated *unsure* (Figure 3.4-15). No respondents indicated *probably no* or *definitely no*.

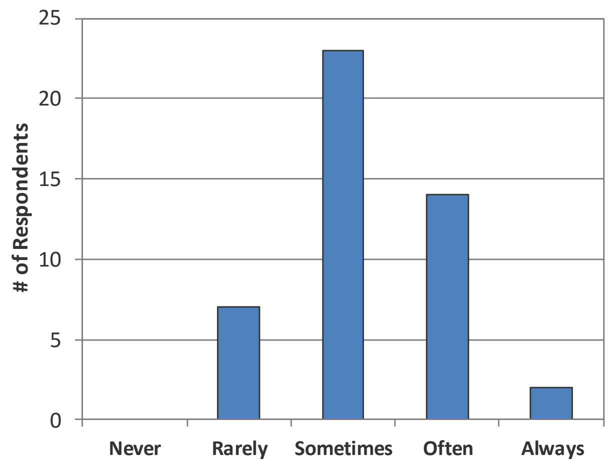


Figure 3.4-14. Stakeholder survey response Question #25. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Kettle Moraine Lake?

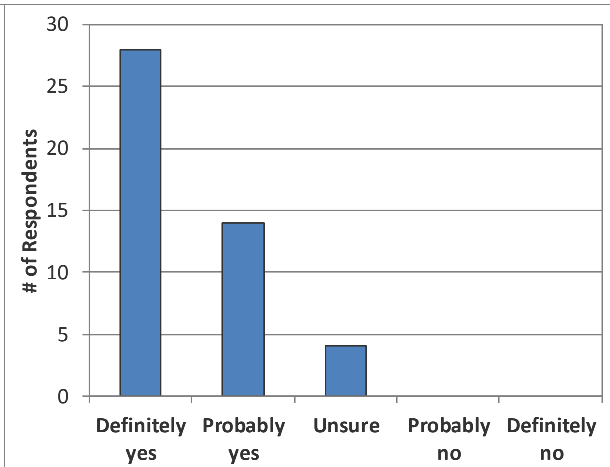


Figure 3.4-15. Stakeholder survey response Question #26. Do you believe aquatic plant control is needed on Kettle Moraine Lake?

The presence of AIS within Kettle Moraine Lake is well-known knowledge of the stakeholders so while aquatic plants only sometimes impact user's enjoyment of the lake, stakeholders believe that control of AIS is needed. The planning committee wanted to understand the stakeholders' perceptions on the use of various active management techniques (Figure 3.4-16). 74% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of using herbicides on Kettle Moraine Lake, whereas 6% were unsupportive (pooled *not supportive* and *moderately un-supportive* responses). 9% of respondents were *neutral* and 11% where *unsure: need more information.*

73% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of conducting hand-harvesting with divers, whereas 7% were unsupportive (*moderately un-supportive* responses as no respondents were *not supportive*).

46% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of mechanical harvesting, with 37% being unsure (22%) or neutral (15%).

No stakeholder survey respondents were supportive of not managing the aquatic plants (*highly supportive* and *moderately supportive*).

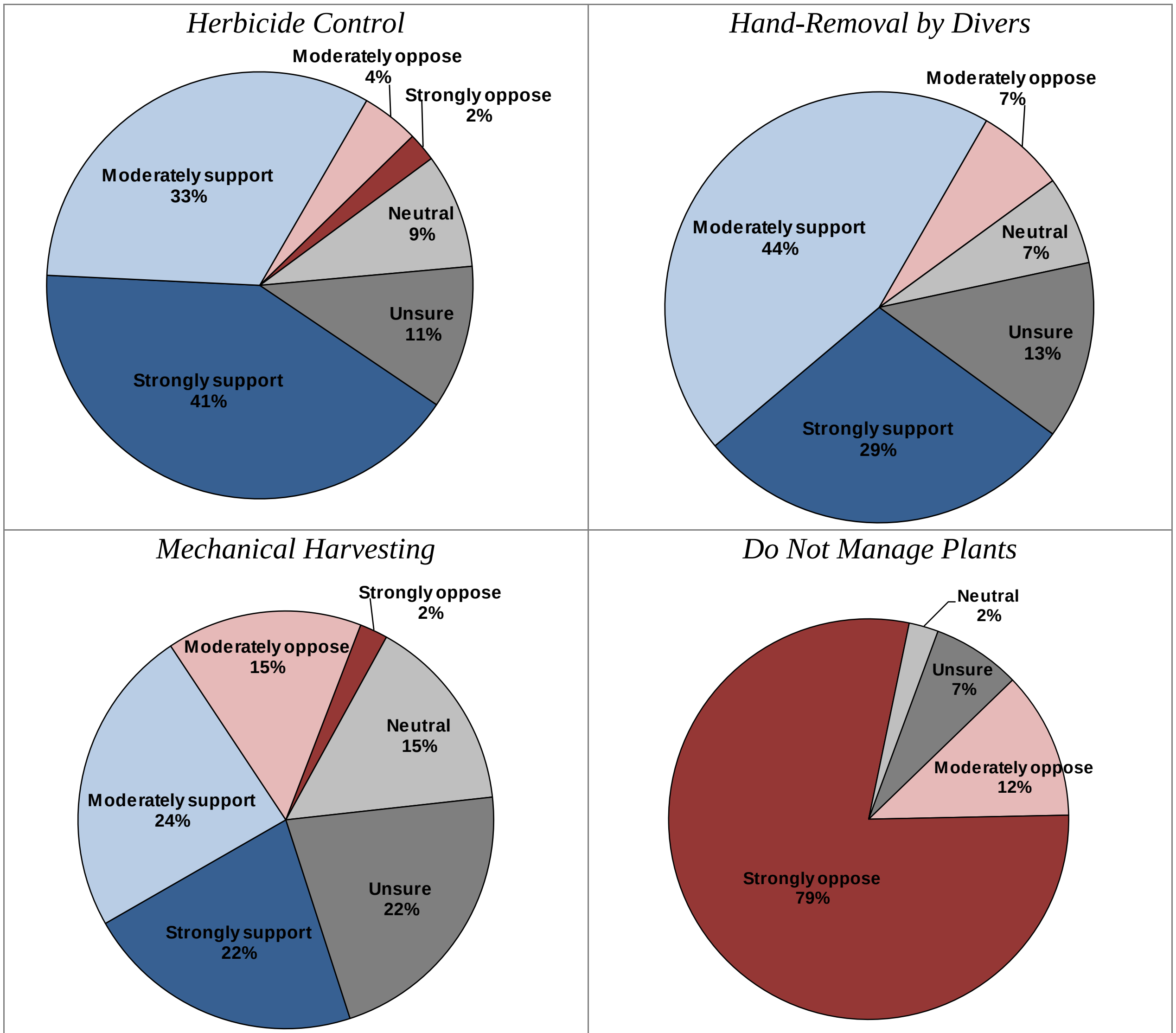


Figure 3.4-16. Select survey responses from the KMLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Over 86% of respondents were aware that aquatic herbicides were being applied to Kettle Moraine Lake to manage AIS, whereas approximately 11% were not aware (Appendix B, question #28). Approximately 87% of respondents indicated that they *completely supportive* or *moderately supportive* of the past use of herbicides to treat AIS in previous years. 3 respondents (6.5%) indicated they were *unsure*/*neutral* and 3 respondents indicated they *moderately opposed* or *completely opposed* to past use of herbicides for AIS management (Figure 3.4-17).

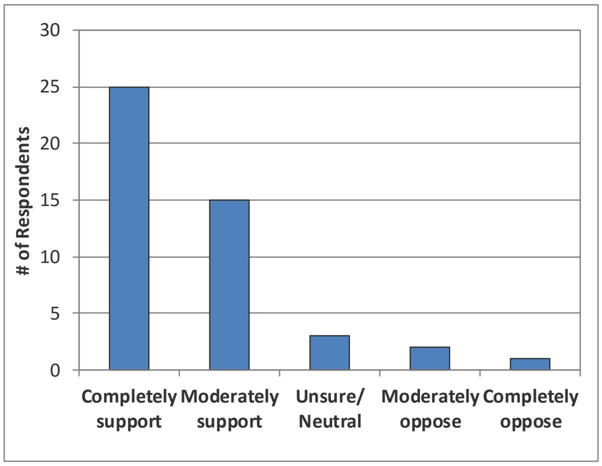


Figure 3.4-17. Stakeholder survey response Question #29. How do you feel about the past use of herbicides to treat AIS in previous years?

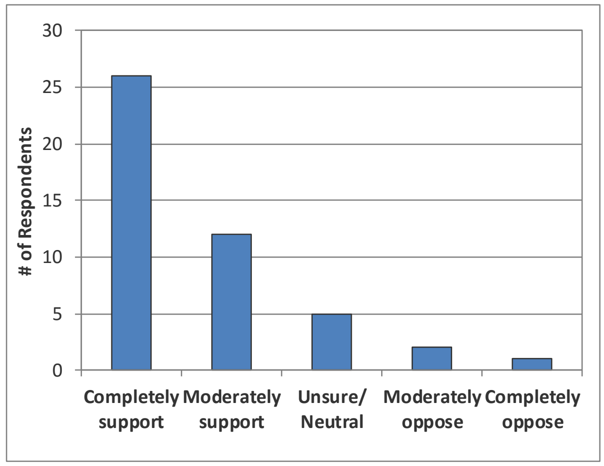


Figure 3.4-18. Stakeholder survey response Question #30. What is your level of support or opposition for future aquatic herbicide use to target AIS in Kettle Moraine Lake?

When asked what their level of support or opposition for future aquatic herbicide use to manage AIS in Kettle Moraine Lake, the majority of respondents, 83%, indicated they *completely support* or *moderately support* future use, 11% indicated they were *unsure/neutral*, 6.5% indicated they *moderately oppose* or *completely oppose* the future use of aquatic herbicides (Figure 3.4-18). All three respondents that indicated they either *moderately oppose* or *completely oppose* the future use of aquatic herbicides indicated their opposition is due to the potential impacts to human health and that the future impacts are unknown (Question 31, Appendix B).

Future AIS Management

During the strategic Planning Committee meetings, Onterra outlined three broad potential EWM population goals for consideration including a recommended action plan to help reach each of the goals (Figure 3.4-19). Each management goal was discussed and considered for applicability. The following paragraphs provide brief overview of these extensive conversations.

1. **No Coordinated Active Management**
   (Let Nature Take its Course)
   - Focus on education of manual removal by property owners
2. **Minimize navigation and recreation impediment**
   (Nuisance Control)
   - Accomplished through professional hand-harvesting of areas or lanes
   - Hand-harvesting may not be able to accomplish this goal and herbicides or a mechanical harvester may be required
3. **Reduce EWM Population on a lake-wide level**
   (Lake-Wide Population Management)
   - Would likely rely on herbicide treatment strategies (risk assessment)
   - Will not "eradicate" EWM
   - Set triggers (thresholds) of implementation and tolerance

Figure 3.4-19. Potential EWM Management Goals. Presented by Onterra at Planning Committee meetings.

Let Nature Take its Course: On some lakes, the EWM population plateaus or reduces without active management. Some lake groups decide to periodically monitor the EWM population, typically through an annual or semi-annual point-intercept survey, but do not coordinate active management (e.g. hand-harvesting or herbicide treatments). Individual riparians could choose to hand-remove the EWM within their recreational footprint, but the lake group would not assist financially or by securing permits if necessary. In most instances, the lake group may select an EWM population threshold or "trigger" where they would revisit their management goal if the population reached that level.

The association discussed this management goal, but quickly dismissed it as a possibility for Kettle Moraine Lake. The extent of the EWM population in 2018 was such that association members were clear that they wanted to conduct some form of EWM management.

Nuisance Control: The concept of ecosystem services is that the natural world provides a multitude of services to humans, such as the production of food and water (provisioning), control of climate and disease (regulating), nutrient cycles and pollination (supporting), and spiritual and recreational benefits (cultural). Some lake groups acknowledge that the most pressing issues with their EWM population is the reduced recreation, navigation, and aesthetics compared to before EWM became established in their lake. Particularly on lakes with large EWM populations that may be impractical or unpopular to target on a lake-wide basis, the lake group would coordinate (secure permits and financially support the effort) a strategy to improve the navigability within the lake. This is typically accomplished by designing common-use navigation lanes through EWM colonies that would be managed through mechanical harvesting.

As discussed in the previous sub-section, numerous stakeholder respondents were unsure or had neutral opinion of mechanical harvesting. If decided to pursue this management action in the future, the KMLA would need to provide educate riparians about mechanical harvesting so they can have an opinion on the strategy.

On Kettle Moraine Lake, navigation and recreation impediments caused by EWM colonies have been documented. Mechanical harvesting of navigation lanes or clear-cutting particularly high-use areas is likely to reduce these impediments. The WDNR has expressed preference for the KMLA to consider non-herbicide management actions such as mechanical harvesting for Kettle Moraine Lake. The association's perspective on mechanical harvesting is outlined below. In summary, the KMLA acknowledges that a nuisance relief goal through mechanical harvesting may be applicable in the future. At this time, the association would like to address more than just the nuisance conditions caused by EWM by conducting population management strategies.

> The current cost for contract harvesting is approximately $2500 per day. The area that can be harvested in a day varies based on plant density, weather and distance to off-loading site. For KML estimates range between 0.75 and 1.25 acres per hour using a cutter capable of a 7 foot cut. Smaller units would require additional time to complete one acre. This works out to a cost of between $235 and $310 per acre.
>
> KML has an area of about 145 acres between 3 feet and 10 feet in depth. Based on the cutting plan below, about 100 acres would require cutting. At an average of 1 acre per hour it would take about 3 work weeks to complete one cutting. At an estimated cost $37,500 (15 days at

$2,500 per day). Regrowth of the EWM may require cutting 3 times during the summer for a total cost over $100,000.

One concern with harvesting on KML is finding an off-loading site. KMLA is working with the Town of Osceola to determine if one of the lake access sites under control of the town would work. This process could take some time possibly making harvesting in the summer of 2019 unrealistic. All sites owned by the town would require the addition of a gravel access to support the weight of the off-loaded material.

KMLA is also looking into the cost of purchasing equipment and maintaining a harvesting operation of our own. The lack of an off-loading site and the long-term commitment to a yearly expenditure that could easily exceed $60,000 may require the conversion from a non-profit lake association to a lake district. Moving to a lake district would create a stable and predictable income that could be used to fund the cost of the harvesting operation.

Lake-Wide Population Management: Some believe that there is an intrinsic responsibility to correct for changes in the environment that are caused by humans. For lakes with EWM populations, that may be to manage the EWM population at a reduced level with the perceived goal to allow the lake to function as it had prior to EWM establishment. Due to the inevitable collateral impacts from most forms of EWM management, lake managers and natural resource regulators question whether that is an achievable goal. The WDNR maintains a cost-share grant funding program for projects that aim to reduced established aquatic invasive species populations.

In early EWM populations, the entire population may be targeted through hand-harvesting or spot treatments. The stakeholder survey results largely indicated favorability for hand-harvesting. However, this is a scale-appropriate management action for small areas. On more advanced or established populations, lake-wide EWM population management be accomplished through large-scale control efforts such as water-level drawdowns or whole-lake herbicide treatment strategies. Large-scale management can reduce EWM populations for several years, but will not eradicate it from the lake. Subsequent smaller scale management (e.g. hand-harvesting or spot treatments) is typically employed to slow the rebound of the population until another large-scale effort may be considered again. Large-scale control efforts, especially using herbicide treatments, can be impactful of some native plant species as well as carry a risk of environmental toxicity. Some argue that the impacts of the control actions may have greater negative impacts to the ecology of the system than if the EWM population was not managed.

The KMLA believes the current EWM population in Kettle Moraine Lake warrants consideration for another large-scale treatment. The KMLA would like to consider all available herbicide use-patterns to seek increased longevity of EWM control and minimize the costs and environmental impacts/risks of frequent herbicide management.

While understood in terrestrial herbicide applications for years, tolerance evolution is an emerging topic amongst aquatic herbicide applicators, lake management planners, and researchers. Herbicide tolerance is when a population of a given species develops reduced susceptibility to an herbicide over time. This occurs in a population when some of the targeted plants have an innate tolerance to the herbicide and some do not. Following an herbicide treatment, the more tolerant strains will rebound whereas the more sensitive strains will be controlled. Thus, the plants that repopulate the lake will be those that are more tolerant to that herbicide resulting in a more tolerant population.

In general, hybrid watermilfoil (*M. spicatum* x *sibiricum*) typically has thicker stems, is a prolific flowerer, and grows much faster than pure-strain EWM (LaRue et al. 2012). These conditions may likely contribute to this plant being particularly less susceptible to chemical control strategies (Glomski and Netherland 2010, Poovey et al. 2007, Nault et al. 2018). In lakes that contain both EWM and hybrid watermilfoil (HWM), concern exists that the more-easily controlled EWM component of a lake's invasive milfoil population may be controlled by herbicide treatment, but the slightly less-susceptible HWM component will survive, rebound in a short period of time, and then comprise a larger proportion of the invasive milfoil population. If genetic variation in the target population exists, particularly the presence of hybrid watermilfoils, repetitive treatments with the same herbicide may cause a shift towards increased herbicide tolerance in the population. Rotating herbicide use-patterns can help avoid population-level herbicide tolerance evolution from occurring. Concern exists that the past use-history of 2,4-D on Kettle Moraine Lake may have resulted in a population of more-tolerant invasive watermilfoils to auxin hormone mimic herbicides, which also includes triclopyr. DNA analysis completed on milfoil samples collected in 2010, 2011, 2013 & 2014 from Kettle Moraine Lake all were confirmed to be pure-strain EWM. With much less genetic diversity being present within pure-strain EWM populations, it is unclear if herbicide tolerance shifts can occur in these populations.

Multiple herbicide use patterns were explored in the *2017 AIS Monitoring & Control Strategy Assessment Report – March 2018* including 2,4-D, triclopyr, endothall, herbicide combinations, and fluridone. The following two sub-sections will explore fluridone and triclopyr. The KMLA's alternatives analysis yielded a pelletized fluridone treatment as the best option for 2019. The WDNR indicated the risk of native plant impacts from this form of treatment are too great to permit at this time, but would consider rotation to whole-lake liquid triclopyr.

Fluridone Management Option

Fluridone is a systematic herbicide that disrupts photosynthetic pathways (carotenoid synthesis inhibitor). This herbicide requires long exposure times (>90 days) to cause mortality to watermilfoils. Herbicide concentrations within the lake are kept within target levels by periodically adding additional herbicide (bump treatments) over the course of the summer based upon herbicide concentration monitoring results.

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In Wisconsin, a four-lake pilot project was conducted in the late-1990s and early-2000s. Liquid fluridone treatments within this study had peak fluridone concentrations of 12.4-15.9 ppb on three of the lakes, whereas the fourth had a peak concentration of 5.7 ppb. These treatments provided reduced EWM populations for up to four years, but resulted in native plant impacts that exceeded "acceptable levels" (Wagner et al. 2007). A revised use-pattern for fluridone was adopted on other midwestern lakes, particularly in Michigan, that initially targeted 6 ppb with a bump treatment later in the summer to bring the concentration back up to 6 ppb (6-bump-6). These use-patterns produces relatively high herbicide pulses that taper off slowly as the herbicide degrades. Manufacturers of fluridone (SePRO) believe that the high herbicide pulses are the mechanism causing the native plant impacts. (Dr. Mark Heilman, personal comm.).

A somewhat newer use-pattern of fluridone uses a pelletized product that gradually reaches a peak concentration over time (extended release) and results in a lower, sustained lake-wide herbicide concentration. For many of these initial treatments, the target concentration (4 ppb) was based upon theoretical equilibrium when mixed with the entire epilimnion. Because of the extended release rate and herbicide degradation, the 4-ppb initial target is not expected to be achieved, rather a prolonged period of 1.5 to 2.5 ppb is observed. Within a few limited Wisconsin field-trials, this use-pattern of fluridone appears to provide a similar level of efficacy as the 6-bump-6 approach, but with a lower magnitude (but still notable) of native plant impacts (Heath et al. 2018a, Heath et al. 2018b).

Figure 3.4-20 shows the fluridone concentration monitoring data from the six pelletized fluridone projects in Wisconsin that have concluded monitoring. All pelletized fluridone treatments to date have targeted lakes that are believed to have invasive milfoil populations largely or entirely composed of HWM. These lakes have also had an herbicide use history where a whole-lake auxin herbicide failed to reach desired managed goals.

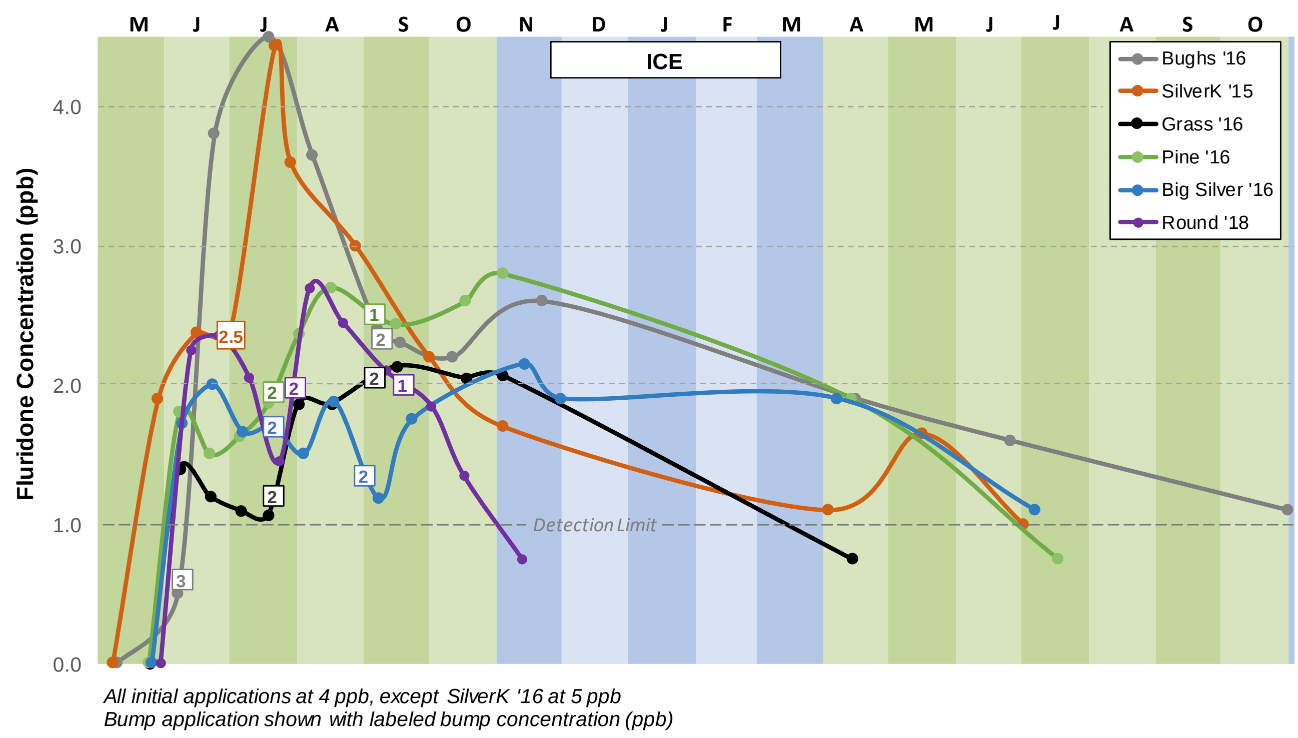


Figure 3.4-20. Fluridone Concentration Monitoring Results from five pelletized treatments in Wisconsin. Data shown are average surface concentrations, lines smoothed for ease of visualization. Initial application dates as follows: Bughs-5/10/2016, SilverK-5/8/2015, Grass-5/25/2-16, Pine-5/25/2016, Big Silver-5/26/2016, Round – 5/30/2018.

Silver Lake in Kenosha County was the first pelletized fluridone treatment in Wisconsin. The initial application rate was 5 ppb and a single 2.5 ppb bump occurred. The other four treatments had initial application rates of 4 ppb and two bump treatments ranging from 1-3 ppb.

The evolved goal of the pelletized fluridone use pattern is to maintain between 1.5 ppb and 3.0 ppb throughout the growing season, with detectable levels of the herbicide being observed within the lake going into ice-on. It is anticipated that herbicide degradation is minimal over the winter as fluridone is primarily broken down by sunlight, specifically UV-B (300-320 nm), but also by UV-A (320-380) spectrums. These wavelengths are absorbed by ice and snow, not allowing much penetration to fluridone in the lake during the winter. Fluridone was above detectable levels following ice-out on all lakes except Grass Lake.

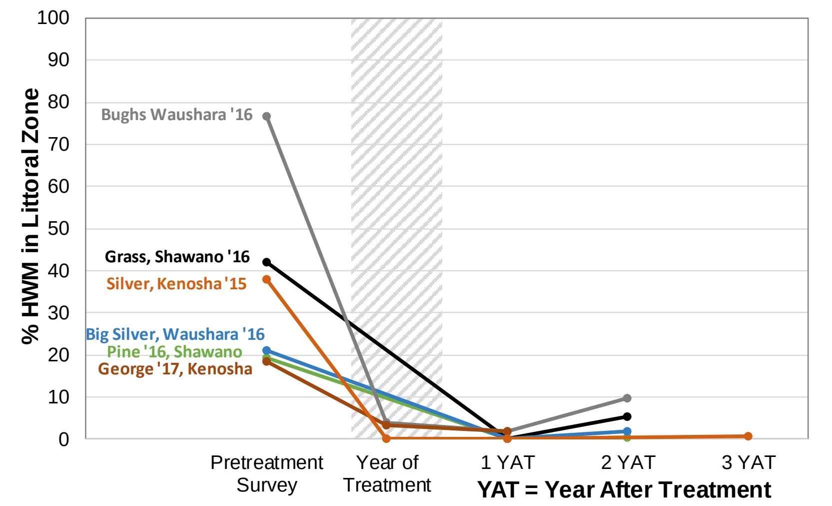


Figure 3.4-21. Littoral frequency of occurrence of HWM in lakes managed with whole-lake pelletized fluridone treatments.

Figure 3.4-21 shows the level of HWM control from the five pelletized fluridone treatments shown in Figure 3.4-20 as well as George Lake, which was treated in 2017. Please note that a point-intercept survey was not completed during the year of treatment on some lakes (Big Silver, Pine, and Grass), as the lakes were still in the process of being treated (i.e. had active herbicide concentrations). On most lakes, EWM die-off is noted in mid-summer but continues slowly over the course of the summer. During the year after treatment (YAT), all lakes contained HWM populations below 2% of the littoral zone. HWM rebound is largest on Bughs Lake, with all other lakes containing approximately 5% of less HWM at 2 YAT. Please note that Bughs Lake has a past history of fluridone treatment, whereas the others have not. Silver Lake in Kenosha County is the only lake that has progressed to 3 YAT, with 0.8% of the littoral zone containing HWM.

Many lake groups initiate a whole-lake herbicide strategy with the intention of implementing smaller-scale control measures (herbicide spot treatments, hand-removal) when EWM/HWM begins rebounding. This is referred to as Integrated Pest Management (IPM). The IPM strategy is best understood for Big Silver Lake, Grass Lake, and Pine Lake (all Onterra-monitored projects). To date, Pine Lake has had almost no HWM detected and has not conducted IPM. However, HWM rebound on Grass Lake has occurred faster than desired, potentially due to lower than target fluridone concentrations being achieved (1.64 ppb average year of treatment achieved concentration). This lake contained a targeted hand-harvesting program utilizing Diver Assisted Suction Harvesting (DASH) in 2018. Big Silver Lake conducted IPM in 2017 and 2018 to a high degree, implementing DASH and scuba surveillance monitoring for 6 days in 2017 and for 12 days in 2018. Big Silver has approved 20 days of DASH efforts and is considering a spot herbicide treatment in 2020 with the goal of maintaining the reduced EWM population that occurred following the 2016 pelletized fluridone treatment.

Collateral native plant impacts associate all whole-lake herbicide management activities. Investigating the potential impacts of the management strategy on a given lake in terms of sensitive species and potential magnitude of change is important when making management decisions. Table 3.4-4 outlines the species present within Kettle Moraine Lake and an analysis of each species' corresponding perceived susceptibility to fluridone. The "Liquid Case Studies" referenced are a large dataset of liquid fluridone field trials (many are 10+ ppb or 6-bump-6) compiled by the WDNR Science Services and made available in spreadsheet format. The pelletized case studies are those shown in Figure 3.4-15 and Figure 3.4-16 that targeted lower fluridone concentrations but may have had longer exposure times than the liquid case studies.

Table 3.4-4. Aquatic plant species list and potential sensitivity to differing fluridone use-patterns.

			Fluridone Sensitivity					
				Pelletized Case Studies				
Scientific Name	Common Name	2018 LFOO	Liquid Case Studies*	Pine	Grass	Big Silver	Bughs	Silverl
Ceratophyllum demersum	Coontail	*62.2*	↓ to X	X	X	↓	↓	↓
Myriophyllum spicatum	Eurasian watermilfoil	*52.8*	↓	↓	↓	↓	↓	↓
Najas guadalupensis	Southern naiad	*42.3*	↓ to X to ↑	↓	↓	↓	↓	↓
Elodea canadensis	Common waterweed	*32.1*	↓ to X	X	X	↓	↓	X
P. amplifolious, P. Illinoiensis, P. X scoliophyllus	Large-leaf Pondweeds & Hybrids	*32.1*	↓ to X to ↑	↓	X	↓	X	↓
Chara spp.	Muskgrasses	*15.0*	↓ to X to ↑	X	X	X	↑	X
Stuckenia pectinata	Sago pondweed	*7.7*	X to ↑	X	X	X	↑	↑
Potamogeton gramineus	Variable-leaf pondweed	*6.9*	↓ to X to ↑	X	X	↓	↑	↑
Utricularia gibba	Creeping bladderwort	*6.5*	X	-	-	-	-	-
Vallisneria americana	Wild celery	*3.3*	↓ to X	X	↓	X	X	↓
Brasenia schreberi	Watershield	*2.8*	X	-	X	-	-	X
Nymphaea odorata	White water lily	*2.0*	↓ to X	-	X	-	-	x
Heteranthera dubia	Water stargrass	*1.2*	X to ↑	-	-	↑	↑	↓
Potamogeton crispus	Curly-leaf pondweed	*1.2*	↓	-	-	-	↑	-
Potamogeton praelongus	White-stem pondweed	*0.8*	↓ to X	X	X	↓	↓	X
Nuphar variegata	Spatterdock	*0.8*	X	-	x	-	-	X
Eleocharis acicularis	Needle spikerush	*0.8*	-	-	-	-	-	-
Nitella spp.	Stoneworts	*0.4*	↓ to X to ↑	X	X	↓	-	↑

LFOO = littoral frequency of occurrence
* Fluridone sensitivity inferred from Wagner KI, WDNR Science Services, 2006, unpubl.

Analysis compares Pretreatment to 1 YAT:
↓↑ = statistically valid declines/increases observed. X = population remains statically unchanged. - = no data available.

Figure 3.4-22 investigates the population changes within the available pelletized case studies for the four historically most common species in Kettle Moraine Lake. The analysis presented suggests that some plant species, such as common waterweed and southern naiad are particularly sensitive to fluridone. Coontail populations on Bughs Lake and Big Silver Lake both reduced by about 40% when comparing the pretreatment point-intercept survey with the year after treatment survey. The populations of muskgrasses appears to be unimpacted by this use-pattern.

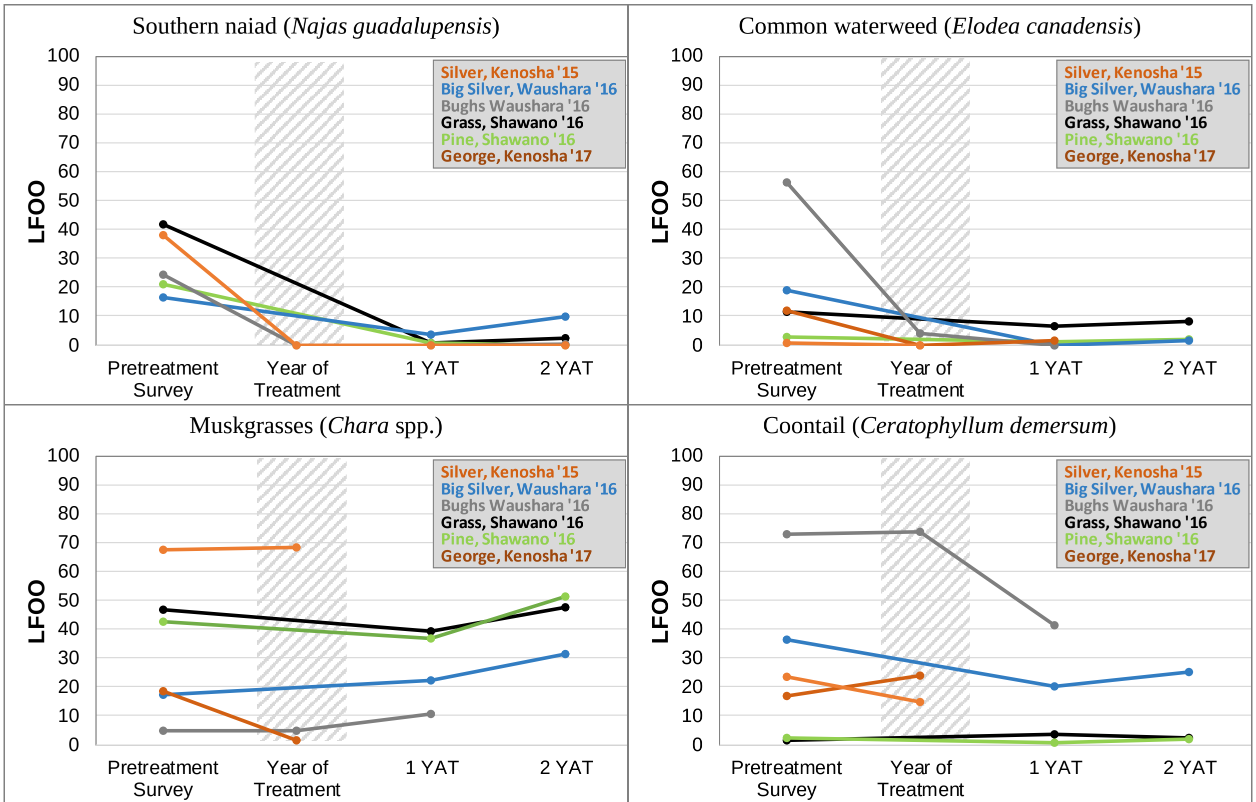


Figure 3.4-22. Littoral frequency of occurrence of select native plants in lakes managed with whole-lake pelletized fluridone treatments. YAT = Year after treatment.

It is important to consider that three of the most commonly found native aquatic plant species in Kettle Moraine Lake (coontail, southern naiad, and common waterweed) have shown to be particularly sensitive to fluridone treatments. It should also be noted that some of these same species have also likely contributed to past nuisance conditions observed on Kettle Moraine Lake.

The KMLA have expressed interest in further understanding the potential of a fluridone treatment for Kettle Moraine Lake, with the goal of getting increased longevity of EWM control compared to past strategies. Arguably the largest concern about a potential fluridone treatment on Kettle Moraine is the potential to impact the three most frequently encountered species within the lake (coontail, common waterweed, and southern naiad). While many lake users understand these to be the native plant species that can impact their recreation of the lake, this important biomass is important to the function of the Kettle Moraine Lake ecosystem.

Removing large amounts of this biomass could have negative ecological impacts greater than those the EWM population may potentially be causing. That being said, some lake managers have been supportive of fluridone control options as the plant biomass takes months to be impacted by the treatment so there is not a sudden loss of habitat for fisheries or plankton that could impact ecological function of the system. The slower die-off and subsequent decomposition of plant material is likely to minimize a resulting reduction of oxygen levels within the lake. In shallow lakes, a concern of shifting from a macrophyte-dominated state (i.e. clear water) to an algal-dominated state (i.e. turbid state) exists when total phosphorus concentrations are 100 µg/L or higher (Scheffer et al. 1993, Scheffer 1998). Kettle Moraine Lake had an average summer total phosphorus concentration of 22 µg/L in 2017, below thresholds that would drive further conversation about the potential of altering the stable state of the lake when large amounts of macrophyte biomass is removed. If the KMLA consider a future pelletized fluridone management strategy, consideration should be given to monitoring zooplankton every 2 weeks of the growing season during the *year before treatment*, *year of treatment*, and *year after treatment*. This may allow an understanding of population changes or shifts in community composition.

During a strategic planning meeting, the KMLA requested additional toxicological data about a potential fluridone treatment, which is included below for distribution to their constituents through this report. The use of any aquatic herbicide poses environmental risks to non-target plants and aquatic organisms. The majority of available toxicity data has been conducted as part of the EPA product registration process. These laboratory studies are attempted to mimic field settings but can underestimate or overestimate the actual risk (Fairbrother and Kapustka 1996). This is exemplified when laboratory tests focus on high concentrations and short exposure times where field application relies on long exposures of low concentrations.

Federal and state pesticide regulations and strict application guidelines are in place to minimize impacts to non-target organisms based on the organismal studies. Additional information is included within Appendix G including the WDNR's fluridone fact sheet and toxicological perspective from the herbicide manufacturer.

Triclopyr Management Option

The 2014 whole-lake combination 2,4-D and endothall treatment was the highest concentration of herbicides applied on Kettle Moraine Lake. The treatment approximately achieved target concentrations and resulted in 3 summers of reduced EWM populations, which falls slightly below expectations.

It has been hypothesized that the lack of longer-term control was due to the short exposure time that occurred in association with this treatment. Nault et al. 2018 indicated the 2,4-D half-life was shown to range from 4-76 days within the 28 lakes studies, with the "rate of herbicide degradation to be slower in lower-nutrient seepage lakes." Adding 17 additional Onterra-monitored projects to this dataset yields a median 2,4-D half-life of approximately 30.0 days (Figure 3.4-23). The 2014 whole-lake treatment on Kettle Moraine had a 2,4-D half life of 7 days, falling in the sixth percent of this database. During the 2014 whole-lake treatment, 2,4-D concentrations were below detection by 14 days after treatment.

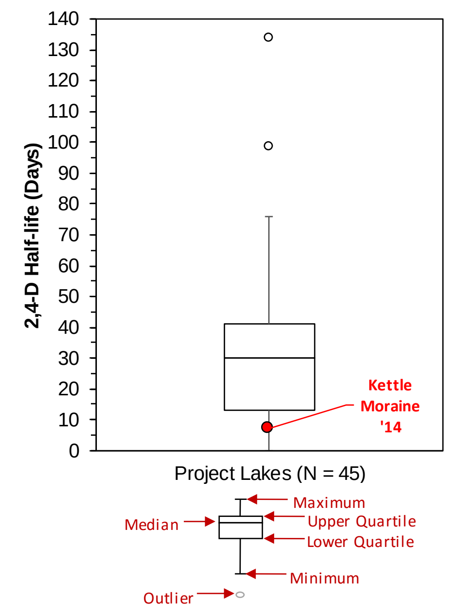


Figure 3.4-23. 2,4-D half-life of Kettle Moraine Lake compared with WDNR/Onterra database.

Triclopyr is an auxin mimic herbicide similar to 2,4-D. While it is a different molecule, it is conventionally accepted to impact aquatic plants similarly where dicot species are particularly sensitive and there is a range of sensitivity of monocots (some very sensitive and others tolerant). 2,4-D is broken down biologically (microbial digestion) whereas triclopyr breaks down photolytically (by exposure to sunlight, as discussed for fluridone). For Kettle Moraine Lake, this may result in a longer and more predictable exposure time compared with past experiences with 2,4-D. Said another way, if rapid herbicide degradation was the cause for the 2,4-D treatment being less effective than expectations, triclopyr is likely to persist longer and therefore could provide more efficacious results. That being said, the past whole-lake treatments have had only minor impacts on the native aquatic plant community of Kettle Moraine Lake. Longer exposure times of the auxin may result in increased impacts to particularly sensitive plants.

Triclopyr is been used in a relatively small number of Wisconsin spot-treatments, but almost exclusively in combination applications with 2,4-D (e.g. Renovate® MaxG). Triclpyr is commonly used in Minnesota, again primarily in spot-treatment scenarios (high concentration and short exposure time). Limited data exists for triclopyr in whole-lake treatment scenarios, with a few basin-wide treatments occurring in Lake Minnetonka, MN (Netherland and Jones 2015) and one conventional whole-lake granular triclopyr occurring in Wisconsin on Big Silver Lake, WI.

The whole-lake triclopyr treatment on Big Silver Lake targeted a difficult strain of hybrid water milfoil (HWM). A roughly 75% reduction of HWM was observed from the *year prior to treatment* compared to the *year of treatment*. Unfortunately, substantial HWM rebounded occurred as soon as the *year after treatment*. The native plant community of Big Silver Lake was minimally impacted by this treatment, with only northern watermilfoil and common waterweed having statistically valid declines following the treatment. Common waterweed populations reduced from approximately 35% to 28%.

SePRO, the manufacturer of liquid triclopyr, have indicated in writing that they believe a pelletized fluridone strategy is the most appropriate for Kettle Moraine, but supports a triclopyr strategy that has direct application of the product over dense EWM colonies to reach lake-wide concentration of 200 ppb ae (0.2 ppm).

Appendix E contains the WDNR's chemical fact sheet for triclopyr, which includes an overview of its toxicological properties.

Pale yellow iris

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. 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. Pale yellow iris was observed growing in shoreline areas mainly on the northeast shore but a few occurrences were found in other areas around the lake (Map 7). Control of pale-yellow iris on Kettle Moraine Lake will be discussed in the Implementation Plan Section.

Photograph 3.4-8. Pale-yellow iris in shoreland area. Photo credit Onterra.

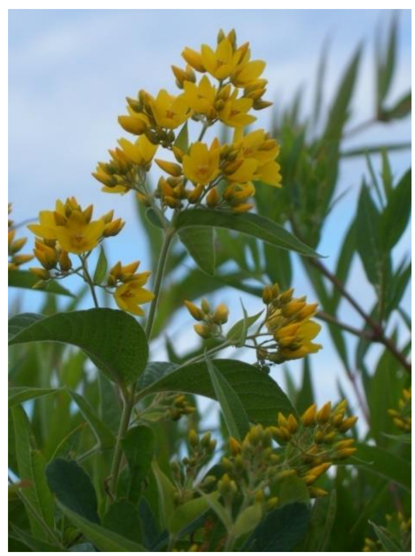
Purple loosestrife

Photograph 3.4-9. Purple loosestrife in shoreland area. Photo credit Onterra.

Purple loosestrife (*Lythrum salicaria*), like yellow garden loosestrife, is a perennial herbaceous 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 also can vegetatively spread from root or stem fragments. Populations of purple loosestrife were observed along the north and west shoreline areas Kettle Moraine Lake (Map 7).

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly. Control of purple loosestrife on Kettle Moraine Lake will be discussed in the Implementation Plan Section.

Yellow garden loosestrife



Photograph 3.4-10. Pale-yellow iris in shoreland area. Photo credit ERCLA.

Yellow garden loosestrife (*Lysimachia vulgaris*) is an escaped horticultural species that is potentially invasive in Wisconsin's wetland habitats. These plants can attain a height of greater than one meter, and produce a cluster of showy, yellow flowers at the top of the plant. This plant is now considered a restricted species in Wisconsin. On Kettle Moraine Lake, yellow garden loosestrife was located along the western shoreline (Map 7). Control of garden yellow loosestrife on Kettle Moraine Lake will be discussed in the Implementation Plan Section.

3.5 Aquatic Invasive Species in Kettle Moraine Lake

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

Table 3.5-1. AIS present within Kettle Moraine 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
	Pale yellow iris	*Iris pseudacorus*	Section 3.4 – Aquatic Plants
	Yellow garden loosestrife	*Lysimachia vulgaris*	Section 3.4 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 3.4 – Aquatic Plants
Invertebrates	Zebra mussel	*Dreissena polymorpha*	Section 3.1 – Water Quality
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.5 – Aquatic Invasive Species

Figure 3.5-1 displays the seven aquatic invasive species that Kettle Moraine Lake stakeholders believe are in Kettle Moraine Lake. Only the species present in Kettle Moraine 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

Aquatic Animals

Mystery snails

There are two types of mystery snails found within Wisconsin waters, 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).

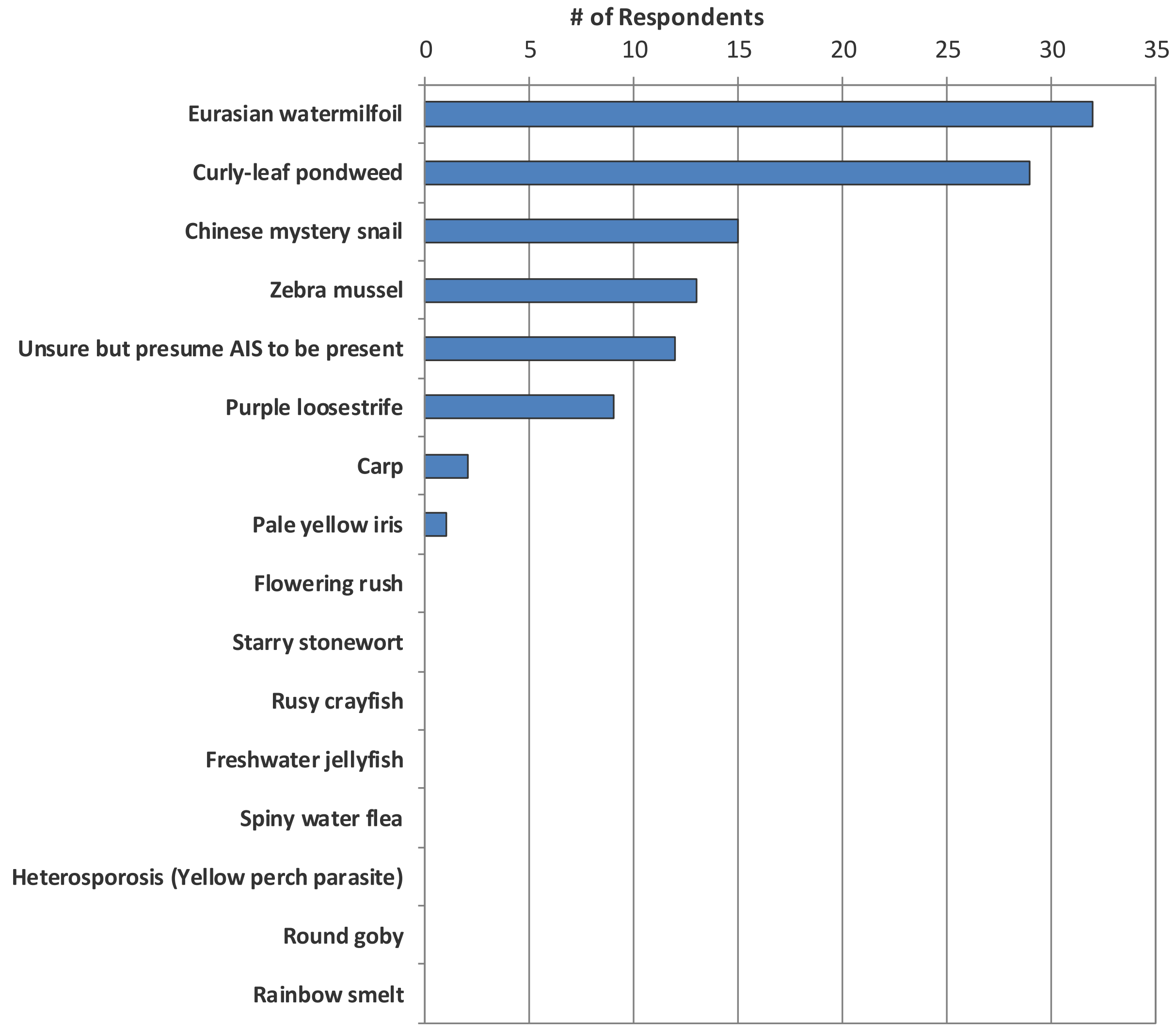


Figure 3.5-1. Stakeholder survey response Question #22. Which aquatic invasive species do you believe are in Kettle Moraine Lake?

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 Kettle Moraine 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) and personal communications with DNR Fisheries Biologist Travis Motl (WDNR 2018).

Kettle Moraine 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 Kettle Moraine 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.

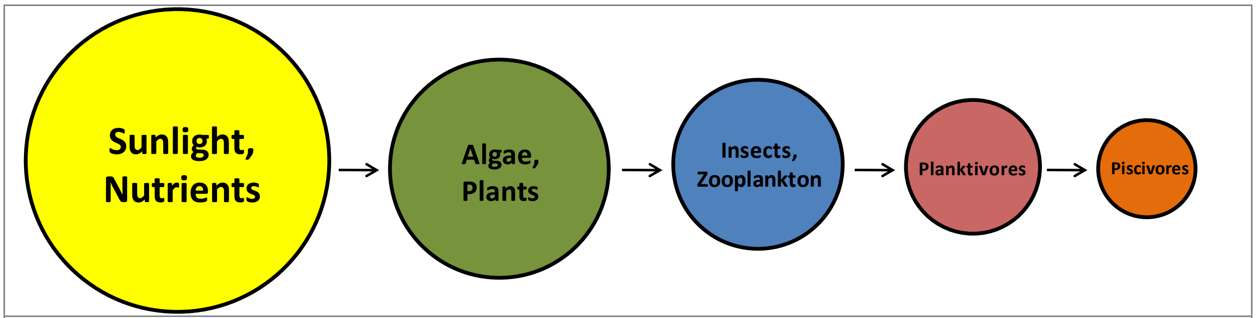


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Kettle Moraine Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Kettle Moraine Lake should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. 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 surveys of Kettle Moraine Lake include the white sucker (*Catostomus commersonii*).

Table 3.6-1. Gamefish present in Kettle Moraine Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead (*Ameiurus melas*)	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Brown Bullhead (*Ameiurus nebulosus*)	5	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation	Insects, fish, fish eggs, mollusks and plants
Channel Catfish (*Ictalurus punctatus*)	15	May - July	Dark cavities or crevices, rock ledges, beneath tree roots	Fish, insects, other invertebrates, seeds, plant materials
Green Sunfish (*Lepomis cyanellus*)	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small fish
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
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 electroshocking (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 easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking 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 positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fry, fingerling or adult fish in a waterbody that were raised in approved 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. Kettle Moraine has been stocked from 1976 to 2016 with walleye, northern pike and largemouth bass. The WNDR has conducted one-night electroshocking surveys in the fall of 2013, 2015, and 2016 to assess whether walleye stocking efforts have resulted in a naturally reproducing population. Walleye natural reproduction has not been documented in recent fisheries surveys in Kettle Moraine Lake, however, survival of stocked year classes of walleye exists (Motl 2018). Available historical stocking efforts from 1976 to 2016 are displayed in Table 3.6-2.

Photograph 3.6-2. Walleye Fingerling (Photo: UW-Stevens Point).

Table 3.6-2. Stocking data available for Kettle Moraine (1976-2016).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1986	Walleye	Unspecified	Fry	227,000	1
1987	Walleye	Unspecified	Fry	681,000	3
1988	Walleye	Unspecified	Fry	200,000	1
1989	Walleye	Unspecified	Fry	227,000	3
1990	Walleye	Unspecified	Fry	227,000	1
1992	Walleye	Unspecified	Fingerling	11,350	3
2012	Walleye	-	Large fingerling	2,300	-
2013	Walleye	Mississippi Headwaters	Small Fingerling	7,920	2
2014	Walleye	Rock-Fox	Large Fingerling	4,225	7.1
2016	Walleye	Upper Mississippi River	Large Fingerling	4,177	7.5
1977	Northern Pike	Unspecified	Fry	20,000	Unspecified
1976	Largemouth Bass	Unspecified	Fingerling	10,000	3

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the sixth most important reason for owning property on or near Kettle Moraine (Question #17). Figure 3.6-2 displays the fish that Kettle Moraine Lake stakeholders enjoy catching the most, with bluegill/sunfish and largemouth bass being the most popular. Approximately 74% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.6-3). Approximately 60% of respondents who fish Kettle Moraine Lake believe the quality of fishing has remained the same or is somewhat worse since they started fishing the lake (Figure 3.6-4).

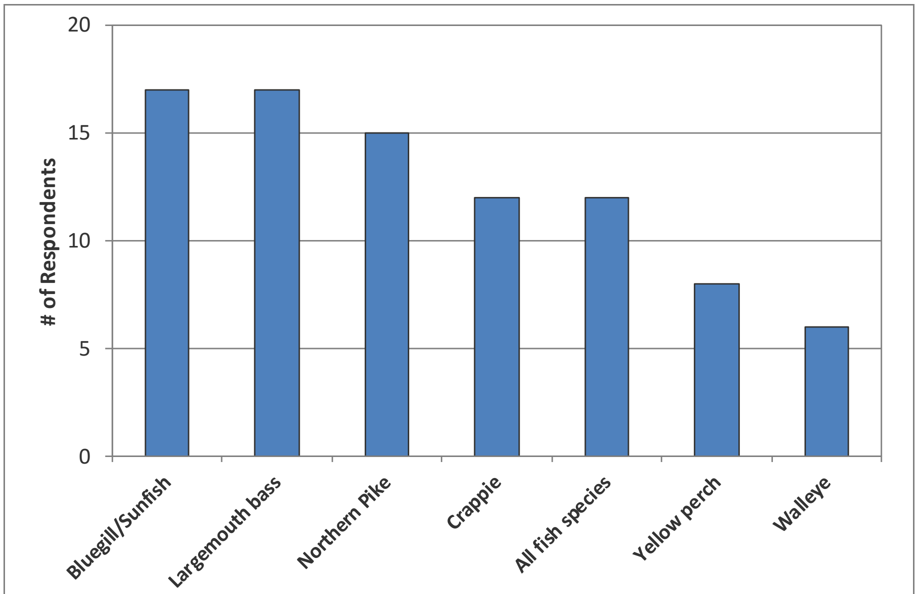


Figure 3.6-2. Stakeholder survey response Question #11. What species of fish do you like to catch on Kettle Moraine Lake?

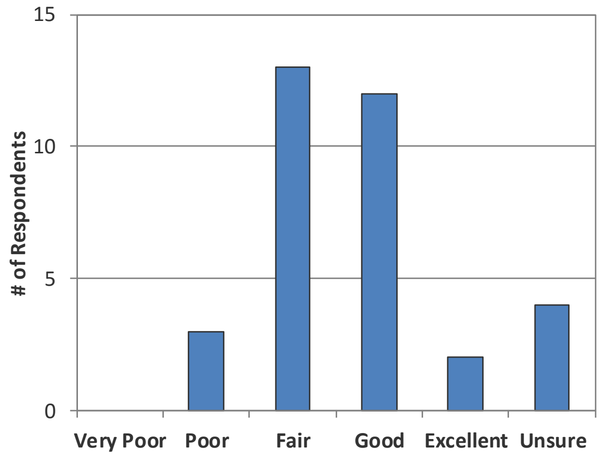


Figure 3.6-3. Stakeholder survey response Question #12. How would you describe the current quality of fishing on Kettle Moraine Lake?

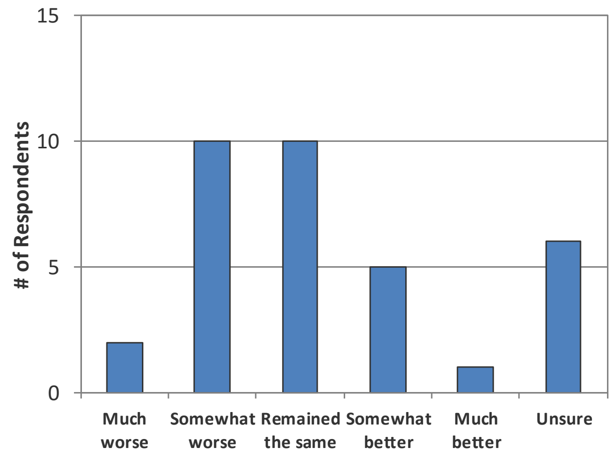


Figure 3.6-4. Stakeholder survey response Question #13. How has the quality of fishing changed on Kettle Moraine Lake since you started fishing the lake?

Fish Populations and Trends

Utilizing the fish sampling techniques and specialized formulas mentioned above, 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.

The 2012 WDNR survey found the northern pike, largemouth bass, bluegill and pumpkinseed present in Kettle Moraine Lake have growth rates lower than statewide averages. This may be partly due to the large amount of aquatic vegetation which provides the panfish cover from predators (Appendix F).

Kettle Moraine 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 2017, 93% of the substrate sampled in the littoral zone of Kettle Moraine were soft sediments, 4% was composed of rock and 3% was composed of sand sediments.

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 2006). A fall 2017 survey documented 16 pieces of coarse woody along the shores of Kettle Moraine Lake, resulting in a ratio of approximately 5 pieces per mile of shoreline.

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. 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 fish habitat structure that is placed on the lakebed. Installing fish cribs may 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.

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 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 (WDNR 2004).

Placement of a fish habitat structure in a lake does not require 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.

The KMLA should 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 Kettle Moraine Lake.

Regulations and Management

Regulations for Kettle Moraine Lake gamefish species as of April 2018 are displayed in Table 3.6-3. 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 3.6-3. WDNR fishing regulations for Kettle Moraine Lake (As of April 2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25 panfish may be kept	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 5, 2018 to December 31, 2018
Northern pike	5	None	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	18"	May 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 2 hooks, baits, or lures

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 3.6-5. 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 3.6-5. 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

The WDNR proposed several management recommendations following the comprehensive fisheries survey completed in 2012. Continuing aquatic plant treatments was recommended to help control the containment of Eurasian water milfoil and Curly leaf pondweed. These two invasive plants have historically produced dense colonies of aquatic plants in Kettle Moraine Lake. While colonies of aquatic plants are healthy for an aquatic ecosystem, a large population of plants give panfish a greater opportunity to escape predation. An overabundance of panfish may occur in this situation. Higher populations of panfish means more competition for food sources which can lead to stunting in the panfish community. The WDNR believes this is occurring with the bluegill population on Kettle Moraine Lake.

Historically, winter fish kills have periodically occurred and disrupted the fishery. Bluegill in particular have been affected by this. A winter aeration system, regulated by the lake association, has helped mitigate the winter fish kills on Kettle Moraine Lake. Monitoring of largemouth bass and panfish for size structure, monitoring northern pike for biological impacts from the regulation change in 2008, as well as an evaluation of walleye stocking are also WDNR management recommendations. The next evaluation of the fish community will occur during a WDNR comprehensive fishery survey scheduled for 2019.

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 Kettle Moraine Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil.
3) Collect sociological information from Kettle Moraine 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 Kettle Moraine Lake ecosystem, the folks that care about the lakes, and what needs to be completed to protect and enhance them.

Overall, the studies that were completed on the lake indicate that it is healthy in terms of its watershed and water quality. With the exception of two exotic species found in the lake, the aquatic plant community is also believed to be healthy.

Kettle Moraine Lake is considered a deep seepage lake since it has no inlet or outlet stream. The water quality analysis concentrated on the trophic parameters: total phosphorus, chlorophyll-*a*, and Secchi disk depth. The 2017 phosphorus concentration and Secchi disk depth place the lake in the good category while the chlorophyll-*a* concentration places the lake in the excellent category. The lower algal levels are likely because of the large aquatic plant community, especially coontail. Coontail receives much of its nutrients from the water column which results in the phosphorus being unavailable for algal growth. The concentrations of the trophic parameters in Kettle Moraine Lake are better than most lakes in the Southeastern Wisconsin Till Plains (SWTP) Ecoregion and place the lake in the mesotrophic classification.

Although the lake is reported to have zebra mussels, none were found during the survey in 2017. If zebra mussels were present in significant numbers, they would be expected to increase water clarity from what would be expected from the phosphorus concentration. The fact that water clarity is similar to what is predicted from the phosphorus concentration is further indication that zebra mussel numbers are low.

Kettle Moraine Lake has a very small watershed compared with the lake surface area with the ratio being 1:1. This low ratio means phosphorus input from the watershed is relatively low and helps maintain the lake's good water quality. The largest landuse in the watershed is pasture/grass followed by wetlands. The largest source of phosphorus to the lake is from the atmosphere in the form of precipitation falling directly on the lake surface.

Kettle Moraine Lake has an extensive aquatic plant community which covers 98 per cent of the lake surface. Since 2007, 60 aquatic plant species have been located in and adjacent to Kettle Moraine Lake. The most common native species from the most recent survey in their order of abundance are coontail, southern naiad, common waterweed, and muskgrasses. The two submergent exotics are Eurasian watermilfoil and curly-leaf pondweed. Eurasian watermilfoil is the second most common aquatic plant while in the lake while the presence of curly-leaf pondweed is much lower. The lake has more native species and a higher degree of species diversity than most other lakes in the SWTP ecoregion but is lower than most lakes statewide. The floristic quality index of the aquatic plant community is higher than other lakes in the SWTP ecoregion but lower than most lakes statewide.

From 2007-2016 the lake was treated with aquatic herbicides to reduce the amount of aquatic invasive species abundance. The principal herbicides used were endothall and 2,4 D. The herbicide treatments quickly reduced the amount of curly-leaf pondweed and kept it at low numbers.

During 2018, the CLP population from the Early Season AIS Mapping Survey indicated this species was widespread throughout the lake but likely below levels that are having a substantial impact on the overall ecosystem function and below levels that limit the navigability, recreation, or aesthetics to users. As has been discussed, 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, 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 KMLA would like to continue to periodically monitor the population of CLP, but aims to increase the tolerance of stakeholders regarding the presence of CLP in the lake and not actively manage the population.

The 2014 whole-lake combination 2,4-D and endothall treatment was the highest concentration of herbicides applied on Kettle Moraine Lake. The treatment approximately achieved target concentrations and resulted in 3 summers of reduced EWM populations. However, the cessation of the treatments in 2017 and 2018 resulted in large rebound of the EWM population to levels not observed on Kettle Moraine Lake in the past. As for many lake groups, EWM management is an important topic. There are a number of scientific studies published on the degree to which EWM populations can alter the ecosystem function of the lake. Some of the studies show large-scale changes and others indicate undetectable changes. The KMLA believe that a lowered EWM population would allow that lake to function closer to it had historically prior to EWM establishment. The caveat to that statement would be so long as the control actions were not negatively impactful to the flora and fauna of the system. What remains unknown is whether the reductions of some native plant species and other cascading impacts from the herbicide treatments are negatively impacting the lake greater than if the EWM population was not being managed.

While almost impossible to quantitatively document, the KMLA confirms that navigation, recreation, and aesthetic impairment has been observed on Kettle Moraine Lake in years with high EWM populations. This was particularly clear in 2018. Studies have documented decreases in lakefront property values when water-based recreational activities exist on lakes (Eiswerth et al. 2000, Horsch and Lewis 2009, Zhang and Boyle 2010). The KMLA has made it a priority to ensure that Kettle Moraine Lake continue to be a vacation destination and property values remain strong. The KMLA is hopeful that rotating herbicide strategies towards triclopyr or fluridone may result in longer-term control than previously achieved. Overall, this will require less herbicides to be required to manage the EWM population on Kettle Moraine Lake.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the KMLA Planning Committee and ecologist/planners from Onterra. It represents the path the KMLA 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 Kettle Moraine 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.

While the KMLA Board of Directors is listed as the facilitator of the majority of management actions listed below, many of the actions may be better facilitated by a sub-committee or an individual director (e.g. Education and Communication Committee, Water Quality Director/Committee, Invasive Species Committee, Shoreland Improvement Director/Committee). The KMLA will be responsible for deciding whether the formation of sub-committees and or directors is needed to achieve the various management goals.

Management Goal 1: Manage Existing and Prevent Further Aquatic Invasive Species Infestations within Kettle Moraine Lake

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at critical public access locations
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	Currently the KMLA monitors the public boat landings using training provided by the Clean Boats Clean Waters program. Kettle Moraine Lake is a popular destination by recreationists, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its access point, but also to prevent the infestation of other waterways with invasive species that originated in Kettle Moraine Lake. The goal would be to cover the landing 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. The KMLA has observed volunteer fatigue in regards to watercraft inspections. If the KMLA find it difficult to find sufficient volunteerism to conduct boat landing inspections, they may consider the stream-lined WDNR Clean Boats Clean Waters Grant Program that provide cost coverage for paid watercraft inspections. Volunteer efforts may be sufficient to use as the local match to fund the program.

		Often the Township sponsors the paid watercraft inspection program as they already have a mechanism for payroll.
Action Steps:		
	1.	Determine if volunteerism is sufficient to achieve 200 annual hours of watercraft inspection.
	2.	Potentially contact and enter into an agreement with the Town to assist with a paid watercraft inspection program.

Management Action:	Coordinate annual professional monitoring of AIS
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	An Early Season AIS Survey would be completed semi-annually (as needed) during June when CLP is at its peak growth, allowing for a true assessment of the amount of this exotic within the lake. This survey would include a complete meander survey of the lake's littoral zone by professional ecologists and mapping using sub-meter GPS technology. The AIS would be categorized using a combination of point-based on polygon-based mapping methods with defined density designations. If large colonies of dense (*dominant*, *highly dominant*, or *surface matting*) CLP is documented in the lake, the development of an CLP management goal may be considered. Continued monitoring of EWM populations would occur annually following similar protocols as discussed above for CLP but occurring towards the end of the growing season. This survey would serve three main roles: 1) document the EWM population at the peak of its growth stage in a given year, 2) access recent management efforts, and 3) be used to propose management for the future.
Action Steps:	
	See description above as this is an established program.

Management Action:	Coordinate Periodic Quantitative Vegetation Monitoring
Timeframe:	Point-Intercept Survey every 3years, Community Mapping every 10 years
Facilitator:	Board of Directors
Description:	For lakes conducting active management, a whole-lake point-intercept surveys should be conducted at a minimum once every 3 years. This will allow an understanding of the submergent aquatic plant community dynamics within the Kettle Moraine Lake. For lakes that

	conduct whole-lake management, the intensity of point-intercept surveys would be increased. Unless prompted by a specific rationale, repeating the floating-leaf and emergent community mapping every 10 years would help understand if these communities are changing. The community mapping survey was conducted for the first time in 2017.
Action Steps:	
	See description above as this is an established program.

<u>Management Action:</u>	Conduct Large-Scale Herbicide Management of EWM
Timeframe:	Potentially Spring 2019
Facilitator:	Board of Directors
Description:	Due to the large and broad shape of Kettle Moraine Lake, past attempts at conducting spatially targeted "spot" treatments have been only marginally effective. The KMLA agree that use of herbicides to control EWM need to have more favorable and predictable results for the control action to be worth the risk of using herbicides and the cost of the management strategy. It is also understood that targeting the EWM on a lake-wide basis, similar to conducted in 2014 will produce more predictable results. As discussed in the previous management action, the KMLA will have semi-annual point-intercept surveys conducted on to quantitatively track the EWM population over time, as well as how the native plant community is rebounded from previous management actions. Once the EWM population exceeds 20% littoral frequency of occurrence, the KMLA will initiate the planning and pretreatment steps necessary to conduct a large-scale treatment on the lake. This threshold was based upon coupling the point-intercept data at these levels with the Late-Summer EWM Mapping Survey data. When EWM populations exceeded 20%, *highly dominant* and *surface matted* conditions started becoming apparent. Once the trigger has been met and the pretreatment data is collected, the KMLA will review the information, and formally make a decision on whether to move forward with the control program based upon data collected and communication with the WDNR regarding the KMLA's intent, prior to a vote of the Board of Directors to move forward with such action. The decision to implement a large-scale treatment strategy would have flexibility, particularly if large acreages of high-density EWM colonies (*dominant*, *highly dominant*, or *surface matted*) are confirmed on the lake. Herbicide use patterns may require rotation to avoid population-level herbicide tolerance evolution from occurring. Specific details of the herbicide use pattern to be embraced will be included within the KMLA's annual report, being provided

	to the WDNR with sufficient time to review if a WDNR AIS-EPC Grant is being pursued (i.e. 60 days). <u>Active Management Monitoring Strategy:</u> A cyclic series of steps will be used to plan and implement the control efforts. The series includes conducting the following surveys during the *year prior to the treatment*, *year of the treatment*, and *year following the treatment:* • A lake-wide mapping assessment of EWM completed while the plant is at peak growth stage (peak biomass). • A detailed assessment of bathymetric data from the lake, potentially augmenting with an acoustic survey of the lake. • Quantitative assessments of the native and non-native aquatic plant community of the lake utilizing point-intercept survey methodology. During the *year of the treatment*, the project would include verification and refinement of the treatment plan immediately before control strategies are implemented. This potentially would include refinements of herbicide application areas, assessments of growth stage of aquatic plants, and documentation of thermal stratification parameters that influence the final dosing strategy. Kettle Moraine Lake is polymictic, but attention to whole-lake and epilimnetic volumes will be made. Volunteer-based monitoring of temperature profiles would also be coordinated surrounding the treatment, as well as collection of post treatment herbicide concentration samples at multiple locations and sampling intervals. The success criteria of a large-scale treatment would be a 70% reduction in EWM littoral frequency of occurrence (LFOO) comparing point-intercept surveys from the *year prior to the treatment* to the *year after the treatment*. This means if the treatment occurs in 2019, the *year before treatment* would be 2018 and the *year after treatment* would be 2020. Regardless of treatment efficacy, a whole-lake treatment would not be conducted during the *year following the treatment*. If a 70% reduction of EWM LFOO is achieved during the timeline outlined, it is likely that the lowered EWM population will last 4-5 years before additional large-scale management would be needed. Integrated pest management activities, such as hand-harvesting and herbicide spot treatments, are outlined in the next management action (*Develop Long-Term Contingency Strategy for Rebounding EWM Populations in Kettle Moraine Lake*). If the KMLA's trigger for large-scale treatment occurs sooner than 4-5 years, the treatment will not meet long-term success criteria. Native plant impacts are anticipated from any large-scale management action, but evaluation of the long-term success will also take into account the native plant impacts and population rebound.

	If the large-scale management strategy does not meet the control goal criteria, the KMLA would review their goal of reducing the lake-wide EWM population within the lake. Initially, this would include investigation of alternative herbicides and use-patterns. This concept is elaborated on within the management action titled: *Investigate and Study Alternative Management Methodologies*. Short Term EWM Population Management Strategy Specifics: The KMLA's alternatives analysis yielded a pelletized fluridone treatment as its preferred option for 2019. The WDNR indicated the risk of native plant impacts from this form of treatment are too great to permit at this time, but would consider the KMLA pursuing a whole-lake liquid triclopyr control strategy. Triclopyr has a similar mode of action to 2,4-D, but is anticipated to have longer exposure time as it degrades differently (photolytically vs microbially). SePRO, the manufacturer of Renovate® 3, recommends direct application of this liquid triclopyr product over dense EWM colonies to reach lake-wide concentration of 0.2 ppm ae (Map 10). The tentative volunteer-based herbicide concentration monitoring plan would include sampling 4 locations at intervals of 1, 3, 5, 7, 14, 21, 28, 35, 49, 70, 100, 130 days after treatment with an integrated sampler (0-6 ft). SePRO anticipates triclopyr concentrations will exceed 1 ppb ae for 60 DAT. Samples will be sent in for analysis after 35 DAT to project additional sampling timing and intensity. During sampling intervals, volunteers would collect a temperature and dissolved oxygen profile at the deep hole location. In conjunction with the proposed whole-lake fluridone treatment on Kettle Moraine Lake, EWM mapping surveys and point-intercept surveys would be conducted the *year prior to treatment* (2018), the *year of treatment* (2019), and two *years after treatment* (2020 and 2021).
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3.	Initiate control and monitoring plan.

Management Action:	Develop Long-Term Contingency Strategy for Rebounding EWM Populations in Kettle Moraine Lake
Timeframe:	Potentially 2020
Facilitator:	Board of Directors
Description:	Many lake groups initiate a whole-lake herbicide strategy with the intention of implementing smaller-scale control measures (herbicide spot treatments, hand-removal) when EWM begins rebounding. This is referred to as Integrated Pest Management (IPM). The KMLA would implement IPM to preserve the gains from the large-scale effort. Conducting AIS management at a small scale can be difficult to reach control goals and is relatively expensive. Overall, the KMLA will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen. When a Late Season AIS Survey documents colonized EWM populations consisting of low-density occurrences (point-based or *highly scattered*), efforts to hand-remove the plants would occur. This would likely involve hiring a professional firm that has diver-assisted suction harvesting (DASH) equipment to increase efficacy. When a Late Season AIS Survey documents colonized EWM populations that are *dominant* or greater in density, herbicide spot treatment would be considered by the KMLA. Areas containing high use or riparian frontage would be prioritized for treatment, including consideration at *scattered* densities. The KMLA would devise a strategy where a sufficiently large treatment area can be constructed to hold concentration and exposure times, with attention to ensuring additive spot-treatments do not have additive lake-wide impacts. It is likely that these areas would need to be targeted with herbicides that require short exposure times (diquat, florpyrauxifen-benzyl [ProcellaCOR™]) or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.). If populations exceed spot-treatment thresholds, large-scale herbicide strategies may be given consideration. In late-winter, an herbicide applicator firm would be selected and a conditional permit application would be applied to the WDNR. The herbicide treatment would occur when surface water temperatures are roughly below 65°F and active growth tissue is confirmed on the target plants. A pretreatment survey, a week or so prior to treatment would be used to finalize the permit, potentially with adjustments, and dictate approximate ideal treatment timing. When spot-treatments are being conducted, the KMLA would like to put a condition on the application that it cannot occur when winds exceed 7-8 mph, and would prefer the application occur when winds are 0-5 mph. Occasionally, the EWM rebounds in a fashion that does not lend well to IPM. If the rebounded EWM population exceeds a level that can be controlled using best management practices, the KMLA will cease coordinated

	population level management until the population again exceeds the predefined threshold to trigger another whole-lake treatment. Although EWM population-level control efforts would be ceased, active management may be directed towards areas that are impacting the recreation and navigation of the lake. The management activities would contain the smallest footprint possible to reach the stated goal as well as not limiting the effectiveness of the control action. Spot herbicide treatments likely will need to embrace herbicides or herbicide combinations thought to be more effective under short exposure situations. Specific details of the proposed control strategy will be included within the KMLA's annual report, being provided to the WDNR with sufficient time to review if a WDNR AIS-EPC Grant is being pursued.
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR Aquatic Invasive Species Grant based on developed project design. Please note that conducting management for the purpose of increasing navigability or recreation are not currently eligible for WDNR grants.
3.	Initiate control and monitoring plan.

Management Goal 2: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality of Kettle Moraine Lake through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors
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 Kettle Moraine 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. Since 2009, the KMLA has been collecting Secchi disk transparency as a part of the CLMN program. The KMLA would like to enroll in the advanced CLMN program where water chemistry samples would also be collected (chlorophyll-*a*, and total phosphorus). Samples would be collected three times during the summer and once during the spring.

		Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff should be contacted to enroll in this program, ensure the proper training occurs, and the necessary sampling materials are received. As a part of the program the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer. It also must be noted that the CLMN program may be changing in the near future, as enrollment in the program is currently capped. If there is not an ability for the KMLA to participate in the advanced CLMN program, they are open to considering self-funding the analysis of these samples on an annual or semi-annual basis.
Action Steps:		
	1.	Contact Sandra Wickman (715.365.8951) to enroll in the CLMN program.
	2.	Trained CLMN volunteer(s) collects data, enters data into SWIMS, and report results to district members during annual meeting.
	3.	CLMN volunteer and/or KMLA would facilitate new volunteer(s) as needed

Management Action:	Continue the winter aeration program
Timeframe:	Ongoing
Facilitator:	Board of Directors
Description:	As discussed within the Fisheries Data Integration Section (3.6), the LSGLPRD maintains and operates an aeration system during the winter months. An aspect of the aeration program includes placing and removing the safety barriers required by Wisconsin statues. As a productive lake, the decay of aquatic plants under the ice can use up much of the lake's oxygen and results in fish kills. A KMLA volunteer collects a dissolved oxygen profile at approximately 4 locations around the lake during the winter. If oxygen levels fall below 4 mg/L, the winter aeration program is initiated for the remainder of the ice-on conditions.
Action Steps:	
	See description above

Management Goal 3: Increase KMLA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Use education to promote lake protection and enjoyment through stakeholder education
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	Education represents an effective tool to address many lake issues. The KMLA regularly distributes a bi-annual newsletter and maintains Facebook presence for social announcements and communication. The KMLA will continue to make the education of lake-related issues a priority. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. *Example Educational Topics* • Specific topics brought forth in other management actions • Aquatic invasive species identification • Basic lake ecology • Boating safety & ordinances • Noise, air, and light pollution • Shoreline habitat restoration and protection • Fireworks • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Dredging • Mechanical harvesting • Loon monitoring
Action Steps:	
	See description above as this is an established program.

Management Action:	Continue KMLA's involvement with other entities that have responsibilities in managing (management units) Kettle Moraine Lake
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	The KMLA is dedicated to enhancing, preserving and protecting the quality of Kettle Moraine Lake for future generations through effective environmental and education policies. The KMLA promotes policies and practices that protect the interests of Kettle Moraine Lake stakeholders and enhance their ability to maximize enjoyment of their shared resource. 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 KMLA actively engage with all management entities to enhance the association'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 pages:
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Osceola	Kay Wege, Clerk (kwege@townofosceola.org) townofosceola.org	Kettle Moraine Lake falls within the Town of Osceola	Once a year, or more as needed. May check website (http://www.townofosceola.org) for updates.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
Fond du Lac County Land and Water Conservation Dept.	Paul Tollard, County Conservationist (paul.tollard@wi.nacdnet.net)	Oversees conservation efforts for land and water projects.	As needed	Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Addie Dutton, Fisheries Biologist (adeline.dutton@wisconsin.gov)	Manages the fishery of Kettle Moraine Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Mary Gansberg–(mary.gansberg@wisconsin.gov)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Nick Miofsky, Conservation Warden (920.579.2751)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367)	Contact regarding suspected violations pertaining to recreational activity on Kettle Moraine Lake, include fishing, boating safety, ordinance violations, etc.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	<u>Late winter</u>: arrange for training as needed, in addition to planning out monitoring for the open water season. <u>Late fall</u>: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	LLPLD members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.
Long Lake Preservation Association	Judy Peterson, President (63696judy@msn.com)	Parallel association to KMLA on nearby Long Lake	As needed	Ensure there is not a duplication of local watershed monitoring, watercraft inspection programs, and input on Town water patrol.
Tiki Beach Resort	General contact: TikiBeachResort@gmail.com	This resort and restaurant is a large fixture of Kettle Moraine Lake.	Multiple times a year to make sure the KMLA and Tiki Bar are in tune with management activities and use of the lake	The Tiki Bar attracts numerous vacationers that use the lake. Having an open line of communication will ensure that issues that will undoubtable arise will be addressed promptly and in a manner that balances the needs of both parties.

Management Action:	Continue to support Town of Osceola Water Patrol to promote boating safety
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	The KMLA has a long and continued partnership with the Town of Osceola. The KMLA supports the Water Patrol, an augmented enforcement entity of the Town of Osceola that enforces slow-no-wake zones, AIS watercraft inspections, and full lake slow-no-wake emergency rules during high water to protect shorelines from erosion. Currently the emergency rules go into effect on both Long Lake and Kettle Moraine Lake when water levels on Long Lake are determined to be high. Long Lake has a watershed to lake area ratio of 27:1, whereas Kettle Moraine Lake as a ratio of 1:1. The much larger watershed of Long Lake can bring much higher water levels during precipitation events than occurs on Kettle Moraine Lake. The KMLA would like to work with the Town to set lake-specific triggers of when emergency rules would be enacted on Kettle Moraine Lake. This may be accomplished by first installing a permanent gauging station, potentially using an existing permanent pier as a benchmark. Then a specific water height could be used to trigger the emergency rules.
Action Steps:	
	See table guidelines on previous page.

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Every 5-6 years
Facilitator:	Board of Directors or possible coordinator
Description:	Approximately once every 5-6 years, an updated stakeholder survey would be distributed to the Kettle Moraine 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 2017, 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 Goal 4: Maintain and Improve Lake Resource of Kettle Moraine Lake

Management Action:	Educate Stakeholders on the Importance of Shoreland Condition and Shoreland Restoration
Timeframe:	Ongoing effort
Facilitator:	Board of Directors or possible coordinator
Description:	As discussed in the Shoreland Condition Section (3.3), the shoreland zone of a lake is highly important to the ecology of a lake. This is particularly important for lakes with small watersheds like Kettle Moraine 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. In 2017, the shoreland assessment survey indicated that about a half mile, or approximately 45% of the Kettle Moraine Lake's 3.0-mile shoreline, consists of *urbanized* or *developed-unnatural* areas. The KMLA would focus specific education on the importance of shoreland condition, the resources that are available (planning and funding), and a goal of getting 3 properties to conduct formal shoreland enhancement activities within the next 5 years. Partial funding for shoreland restoration activities is available through the WDNR Healthy Lakes Initiative. The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through Fond du Lac County. • 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance • Maximum of $1,000 per 350 ft^2 of native plantings (best practice cap) • Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances • Must be at least 350 ft^2 of contiguous lakeshore; 10 feet wide • Landowner must sign Conservation Commitment pledge to leave project in place and continue maintenance for 10 years • Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice)
Action Steps:	
	See description above

Management Action:	Determine feasibility of coarse woody habitat additions (i.e. fish sticks projects) on Kettle Moraine Lake
Timeframe:	Initiate 2019
Facilitator:	Board of Directors

Description:	KMLA stakeholders must realize the complexities and capabilities of the Kettle Moraine Lake ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. This is especially true for Kettle Moraine Lake, as the average lot has less than 70 feet of frontage on the lake. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.6) discuss the benefits of coarse woody habitat in detail.
	
	The KMLA would also like to work with the WDNR to determine if a coarse woody habitat improvement project would be applicable on the privately-owned island. One important limitation is that living trees are not present on this location, so trees will need to be brought from outside locations. The KMLA would ensure the selected locations of fish sticks projects would not cause recreation nor navigation impediment. This may provide an example for riparians with larger lot sizes to consider adding woody habit.
	
	The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for coarse woody habitat improvements (fish sticks). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.
	• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
	• Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
	• Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
	• Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or:
	  o The landowner would need to commit to leaving the area un-mowed
	  o The landowner would need to implement a native planting (also cost share thought this grant program available)

	• Coarse woody habitat improvement projects require a general permit from the WDNR • Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years
Action Steps:	
1.	Recruit facilitator from Planning Committee (potentially same facilitator as previous management actions).
2.	Facilitator contacts WDNR Fisheries Biologist to gather information on initiating and conducting coarse woody habitat projects.

Management Action:	Control and Discourage Canada Goose Populations
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors
Description:	Vegetated and wooded natural shorelines are the best way to discourage geese from coming on to properties. But green space exists around the lake as it allows riparians to use the nearshore areas for recreation. High populations of geese can leave aesthetically unpleasing waste behind as well as damage valuable native plants and landscaping. In the spring, KMLA volunteers identify nest sites for control through addling. Addling is the process of applying an oil to the egg to terminate embryo development but leave the egg intact so the goose does not lay additional eggs. The KMLA hires a professional to conduct this work and secure the appropriate permits. When resident geese populations exceed 30 geese (approximately every 4 years), the KMLA will contract with USFS to harvest geese. Egg addling is not recommended during harvest years.
Action Steps:	
	See description above as this is an established program.

Management Action:	Conduct muskrat population control
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors
Description:	The natural shorelines of Kettle Moraine are ideal habitat for muskrats. If muskrat populations are left unchecked, damage and destruction of riparian shorelines can occur. The KMLA would periodically hire a professional trapper to harvest muskrats during the permitted season. This action would be on an as-needed basis.
Action Steps:	
	See description above as this is an established program.

6.0 METHODS

Lake Water Quality

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

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

In addition, during each sampling event Secchi disk transparency was recorded and a temperature and dissolved oxygen profile was completed using a HQ30d with a LDO probe.

Watershed Analysis

The watershed analysis began with an accurate delineation of Kettle Moraine 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 – Fry et. al 2011) 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)

Aquatic Vegetation

Early Season AIS Survey

Early Season AIS Surveys have been completed annually on Kettle Moraine Lake in order to correspond with the anticipated peak growth of curly-leaf pondweed and pale yellow iris.. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Kettle Moraine 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) was used to complete this study. A point spacing of 54 meters was used resulting in approximately 287 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Kettle Moraine Lake (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

AIS Monitoring and Management

The methodologies used to monitor the AIS management program are included within their respective annual reports from 2012 to 2017.

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