Lake Iola

Waupaca County, Wisconsin

Comprehensive Management Plan

March 2020

Sponsored by:

Lake Iola Lake District

WDNR Grant Program

LPL-1630-17

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Waupaca County, Wisconsin

Comprehensive Management Plan

March 2020

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Funded by: Lake Iola Lake District
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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:

Lake Iola Planning Committee

John Bertelson	Brian Lepak	Vicki Bellows
Jack Kuhr, Jr.	Lyle Nauman	Oscar Knoeck
Jerry Harvancik	Roger Olson	Gary Richards

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Wisconsin Dept. of Natural Resources

Ted Johnson
Jason Breeggemann

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1.0 INTRODUCTION

According to the 1964 recording sonar WDNR Lake Survey Map, Lake Iola is 206 acres. The WDNR website lists the lake as 220 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 2015. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 232 acres. Lake Iola, Waupaca County, is an impoundment with a maximum depth of 9 feet and a mean depth of 3 feet. This eutrophic lake has a large watershed when compared to the size of the lake. Lake Iola contains 45 native plant species, of which common waterweed is the most common plant. Three exotic plant species are known to exist in Lake Iola.

Field Survey Notes

Lake Iola contains a high number of aquatic species, including, slender bulrush, a NHI listed species. While the lake's downstream portion supports much development, the upstream portion supports a great deal of undeveloped and very important habitat.

Photograph 1.0-1. Lake Iola, Waupaca County

Lake at a Glance - Lake Iola

Morphology	
Acreage	232
Maximum Depth (ft)	12
Mean Depth (ft)	3
Shoreline Complexity	26.2
Vegetation	
Curly-leaf Survey Date	May 31, 2017
Comprehensive Survey Date	July 25 & 26, 2017
Number of Native Species	45
Threatened/Special Concern Species	Slender bulrush (*Schoenoplectus heterochaetus*)
Exotic Plant Species	Purple loosestrife, Hybrid watermilfoil, Curly-leaf pondweed
Simpson's Diversity	0.9
Average Conservatism	6.0
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Transitional
Water Acidity (pH)	7.5
Sensitivity to Acid Rain	Not Sensitive
Watershed to Lake Area Ratio	72:1

Lake Iola is located within the Village of Iola in Waupaca County, WI. Its water level is controlled by a hydroelectric dam at its southwest end. Upstream of Lake Iola, its inlet, the South Branch Little Wolf River, is an ASNRI Class I trout stream and ORW/ERW waterbody. Downstream of Lake Iola it is a Class II ASNRI trout stream.

Lake Iola is known to contain Eurasian water milfoil (EWM), hybrid Eurasian watermilfoil (HWM), curly-leaf pondweed (CLP), and purple loosestrife. Lake Iola Lake District (LILD) has conducted a harvesting program for over 25 years, conducted periodic herbicide treatments on EWM for over ten years and on CLP for over eight years. A water level drawdown was conducted on Lake Iola from 2011 to 2013. The drawdown was originally planned to end in 2012 but was extended to flush sedimentation buildup near the dam. The drawdown resulted in changes in lake volume and the aquatic plant community. Prior to the drawdown, a 2006 point-intercept survey conducted by Onterra lists Lake Iola's FQI as an exceptionally high value of 34, well above the median ecoregion value of 20.9. Lake Iola is known to contain NHI species that include the wood turtle, Blanding's turtle, and pugnose shiner.

2.0 STAKEHOLDER PARTICIPATION

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

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

General Public Meetings

The general public meetings were used to raise project awareness, gather comments, create the management goals and actions, and deliver the study results These meetings were open to anyone interested and were generally held during the summer, on a Saturday, to achieve maximum participation.

Kick-off Meeting

On June 3, 2017, a project kick-off meeting was held at Iola High School to introduce the project to the general public. The meeting was publicized through the district's annual meeting notice and personal contact by Lake Iola District board members. The approximately 35 attendees observed a presentation given by Mr. Tim Hoyman, an aquatic ecologist with Onterra. Mr. Hoyman'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 that lasted nearly 45 minutes.

Project Wrap-up Meeting

On June1, 2019 at the Lake Iola Lake District annual meeting, Tim Hoyman presented information regarding the completion of the Lake Iola Management Planning Project. Mr. Hoyman presented highlights of the results of the many studies that had been completed on the lake since 2017 and outlined the draft implementation plan that had been developed by the Planning Committee. He also answered many questions about the lake and how it should be managed.

Committee Level Meetings

Planning committee meetings, similar to general public meetings, were used to gather comments, create management goals and actions and to deliver study results. These three meetings were open to the planning committee and general public. The first meeting was held late in 2017 to create an interim aquatic plant management plan for the 2018 growing season. The planning committee members were supplied with the draft aquatic plant report section prior to the meeting and much of the meeting time was utilized to detail the results, discuss the conclusions and initial recommendations, and answer committee questions. The second meeting was held following the completion of all studies, including extra aquatic plant studies completed during the 2018 growing season and focused upon updating the committee members on those plant survey results and delivering the results of the other studies completed as a part of the project, including the water quality assessment, watershed modeling, shoreland condition survey, and the compilation of fisheries data. The third meeting was used to develop the framework of goals and actions that was transformed into the Implementation Plan found near the end of this document.

Planning Committee Meeting I

On December 5, 2017, Mr. Tim Hoyman and Mr. Eddie Heath, of Onterra, met with fourteen members of the Lake Iola Planning Committee for nearly 3 hours. In advance of the meeting, attendees were provided an early draft of the vegetation section and stakeholder survey results to facilitate better discussion. The primary focus of this meeting was to develop a plan for controlling aquatic invasive species (AIS) as well as plan to combat nuisance native aquatic plants.

Planning Committee Meeting II

On September 18, 2018, Tim Hoyman met with the members of the Planning Committee to review the aquatic plant data that had been discussed at the December 2017 meeting, but also to present the remaining project results, including water quality, watershed modeling, additional AIS monitoring, and the fisheries data that had been compiled.

Planning Committee Meeting III

The third and final planning meeting facilitated by Onterra staff for the Lake Iola Management Planning Project was held on February 26, 2019. The objective of this meeting was to develop the framework of the management goals and management actions that would make up the Lake Iola Implementation Plan. Following an exercise led by Tim Hoyman to create a list of challenges facing Lake Iola and the Lake Iola Lake District, that objective was met.

Additional Planning Committee Meetings

The Planning Committee met an additional 10 times to primarily discuss the future of the Lake Iola mechanical harvesting program. July 2017 the committee met to review and customize the questions for the stakeholder survey. In January of 2018, the committee had its first discussions on developing a district-operated harvesting program instead of hiring a replacement contractor, as the current contractor was retiring after the 2019 season. The March 2018 meeting was conducted to discuss the herbicide trial plan developed by Onterra. The remaining nine meetings were used to further develop the district harvesting program. At the August 2018 meeting, four bids for new equipment were reviewed, with questions taken back to the equipment suppliers for consideration to update their bids. Then in September, the updated bids were reviewed along with an offer from the current contractor to sell his equipment to the district. At the October 2018 meeting, the group decided to pursue the used equipment option to begin the district harvesting program. Meetings were held in November and December 2018, and January and February 2019, to further develop the harvesting program. The harvesting program was further developed in March 2019 and finalized in April, with the board also approving the plans. The evolution of the final harvesting plan, including draft maps presented to the WDNR as a part of the process, are located in Appendix I.

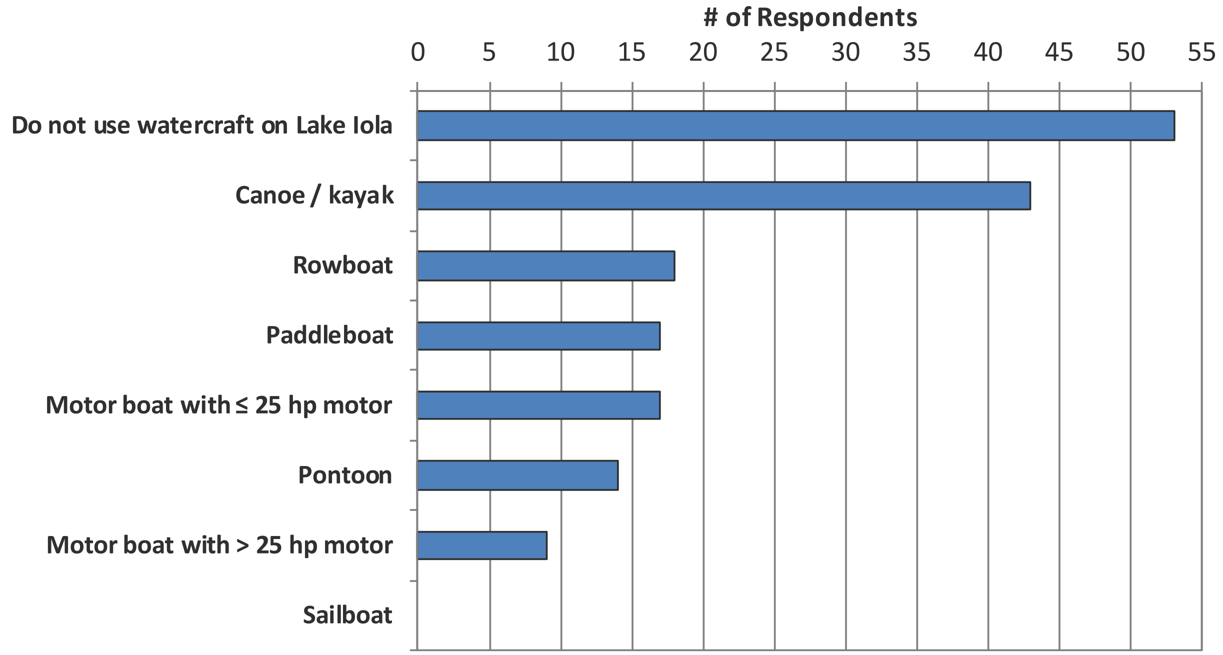
Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to lake district members within the village and town of Iola, WI. The survey was designed by Onterra staff and the Lake Iola District planning committee and reviewed by a WDNR social scientist. During October 2017, the nine-page, 33-question survey was posted online through Survey Monkey for district members 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 Lake Iola District volunteer for analysis. Twenty-one percent of the surveys were returned. (Approximately 60% of lake property owners returned the survey.) 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 Lake Iola. Sixty-six percent of survey respondents live within the boundaries of the Lake Iola district year-round, while 12% visit on weekends through the year, 11% did not fall into one of the standard categories (please see Appendix B), and 4% are rental properties. Twenty-four percent of stakeholder respondents have owned their property for five years or less while 25% 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. Approximately 44% of survey respondents indicate that they do not use watercraft on Lake Iola. Of the respondents who use watercraft on the lake, a canoe/kayak was the most popular choice, followed by a rowboat, paddleboat, motor boat with 25 hp or less motor, or a combination of these vessels (Question 13). As seen on Question 16, fishing was listed as the number one most important reason for owning property on or near Lake Iola, with relaxing/entertaining being number two and natural viewing being number three. Excessive aquatic plant growth and the introduction of aquatic invasive species were both listed as factors currently having a very large negative impact on Lake Iola (Question 24) and both were ranked within the top three on the list of stakeholder respondents' top concerns regarding Lake Iola (Question 25).

Question 13: What types of watercraft do you currently use on Lake Iola?



Question 16: Please rank up to three activities that are important reasons for owning your property on or near Lake Iola.

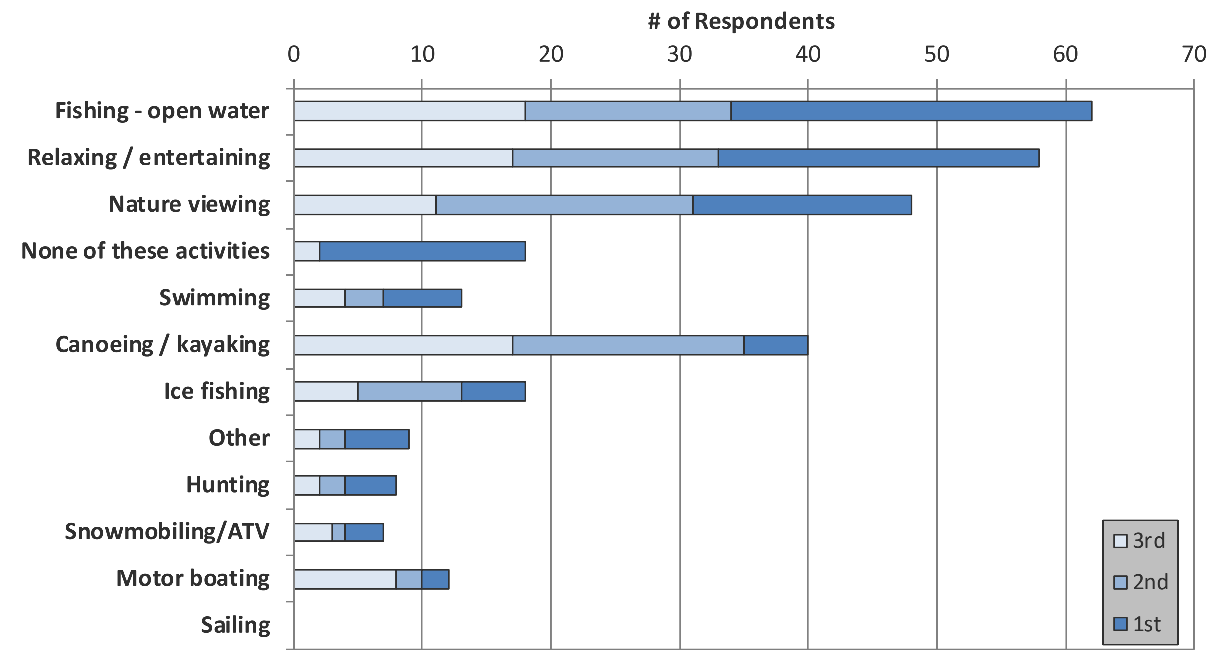
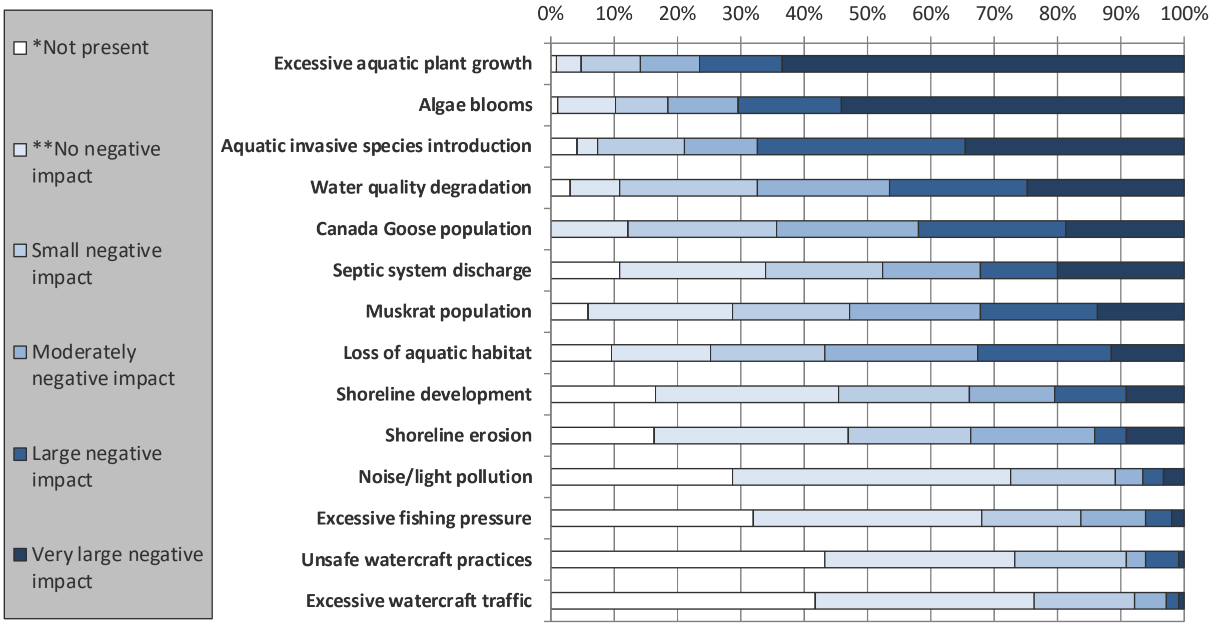


Figure 2.0-1. Select survey responses from the Lake Iola Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 24: To what level do you believe these factors may be negatively impacting Lake Iola?



Question 25: Please rank your top three concerns regarding Lake Iola.

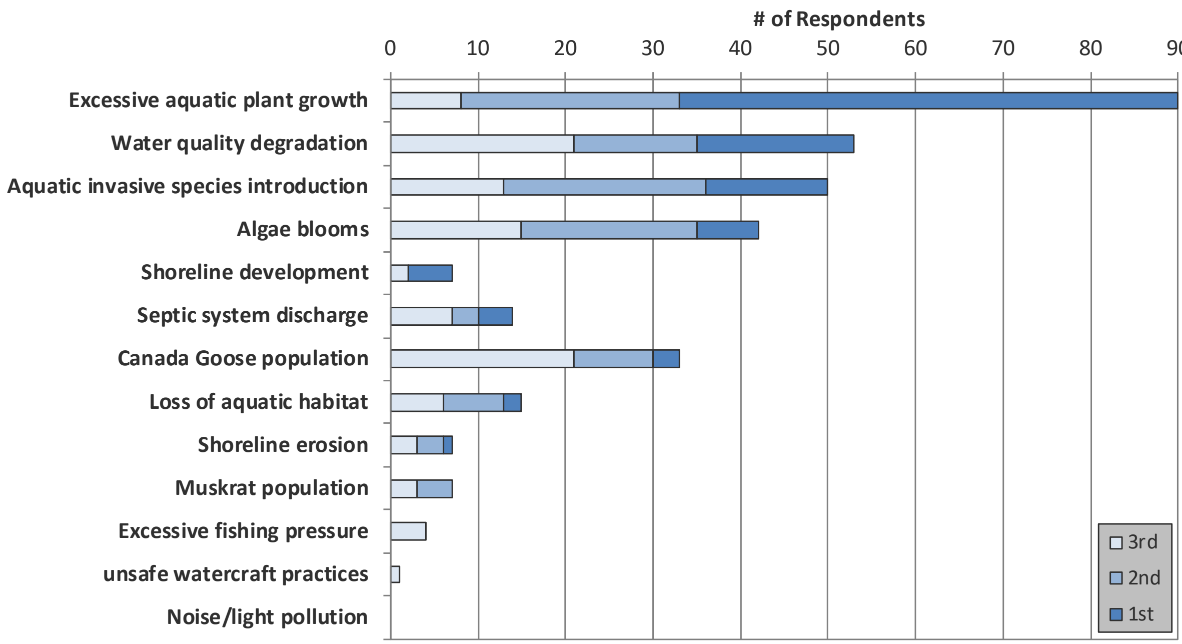


Figure 2.0-2. Select survey responses from the Lake Iola Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Management Plan Review and Adoption Process

On April 30, 2019, the Planning Committee accepted the management plan. That same day, it was also approved and accepted by the Lake Iola Lake District Board of Commissioners. The plan was then accepted by the district membership at their annual meeting on June 1, 2019.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, water quality values that may be considered poor for one lake may be considered good for another because judging water quality is often subjective. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water.

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality 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 Lake Iola 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 Lake Iola'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 epilimnion is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The hypolimnion is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The metalimnion, often called the thermocline, is the middle layer containing the steepest temperature gradient.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fish kills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical 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 2017) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Lake Iola 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, 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, large watershed and hydrology, Lake Iola is classified as a shallow lowland drainage lake (category 4 on Figure 3.1-1).

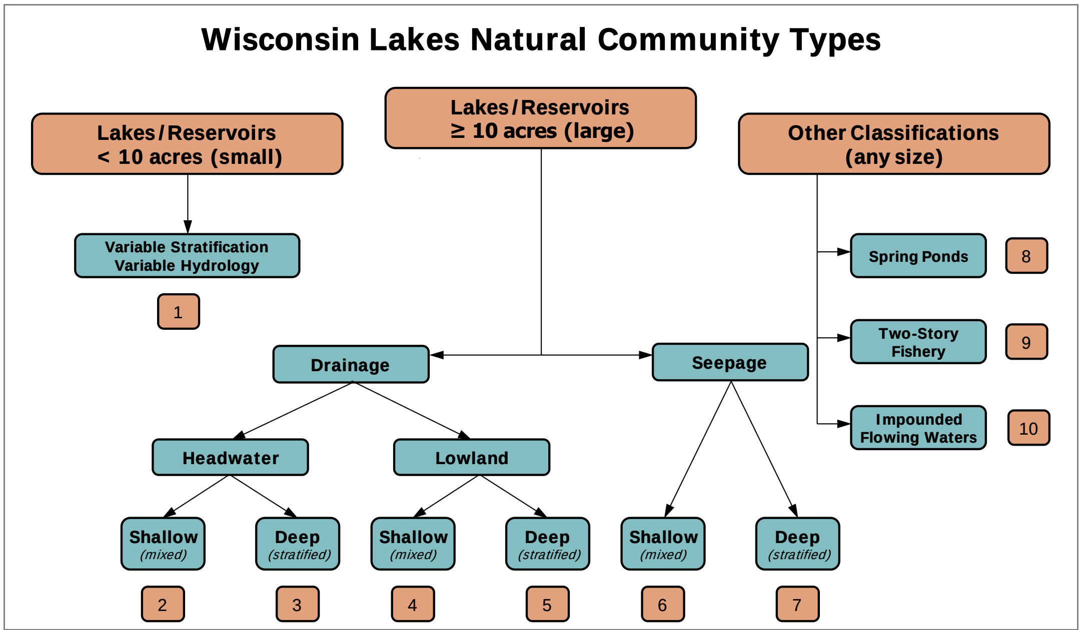


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. Lake Iola is within the North Central Hardwood Forests (NCHF) ecoregion.

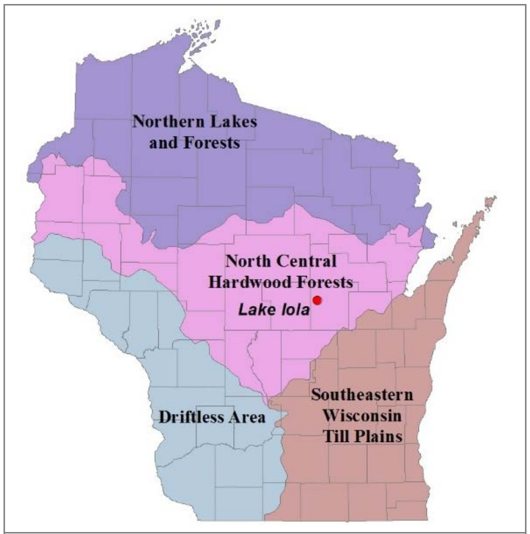


Figure 3.1-2. Location of Lake Iola within the ecoregions of Wisconsin. After Nichols 1999.

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 Lake Iola is displayed in Figures 3.1-3 - 3.1-8. 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.

Lake Iola Water Quality Analysis

Total Phosphorus

Lake Iola is an impoundment on the South Branch of the Little Wolf River. As such, it functions more like a river than a natural lake. Because of the very short hydrologic residence time, which averages less than 13 days, the lake's water quality reflects concentrations in the river. This means that precipitation events strongly impact water quality in the lake. With rapid water exchange, it is difficult to determine long term trends with only three or four samples per year. If sampling occurs soon after a significant precipitation event, phosphorus concentrations could be higher than would occur in the absence of precipitation. In other words, sample timing in relation to precipitation events may have a large effect on the water quality parameters being analyzed.

Total phosphorus data from Lake Iola are available from 1992-1994 and from 2003, 2006, and 2017 (Figure 3.1-3). Average summer total phosphorus concentrations ranged from 12 µg/L in 1993 to 103 µg/L in 2017. It should be noted that only one summer total phosphorus sample was collected in 1993 and is likely not representative of the 1993 summer average. It should also be noted that the high average summer concentration in 2017 is due to high total phosphorus concentrations measured in June and July of 106 µg/L and 187 µg/L, respectively. Phosphorus concentrations were highly variable in 2017, ranging from 15 µg/L in October to 187 µg/L in July. With the exception of October, the highest concentrations occurred when sampling was preceded by a precipitation event, while the lowest concentrations occurred when there had not been a precipitation event prior to sampling. The increased flow following a precipitation event either increases upstream phosphorus concentrations or washes plant material from upstream downstream to where the water quality samples were collected.

The strong influence of precipitation and flow events on the phosphorus concentrations makes it difficult to compare 2017 data with historical phosphorus levels. For example, there were significant precipitation events (0.4-1-inch events) preceding 3 water quality sampling events in 2017 but not in 2003 or 2006. As discussed, the higher average phosphorus concentration in 2017 is due to high concentrations measured in June and July, and the average concentration in 2017 does not necessarily indicate that there has been an increasing trend in phosphorus concentrations over time in Lake Iola. In order to further understand total phosphorus trends in the lake, concurrent phosphorus sampling would need to occur in the lake and upstream of Lake Iola.

Although the average growing season and summer phosphorus levels in 2017 would place Iola Lake in the *fair* or *poor* category, concentrations when rainfall did not proceed the sampling would place the lake in the *excellent* category, which aligns with previous years. If precipitation events are excluded, Lake Iola's average summer total phosphorus concentration is 20 µg/L, lower than the majority of other shallow lowland drainage lakes in the state and is lower than the majority of all lake types within the NCHF ecoregion.

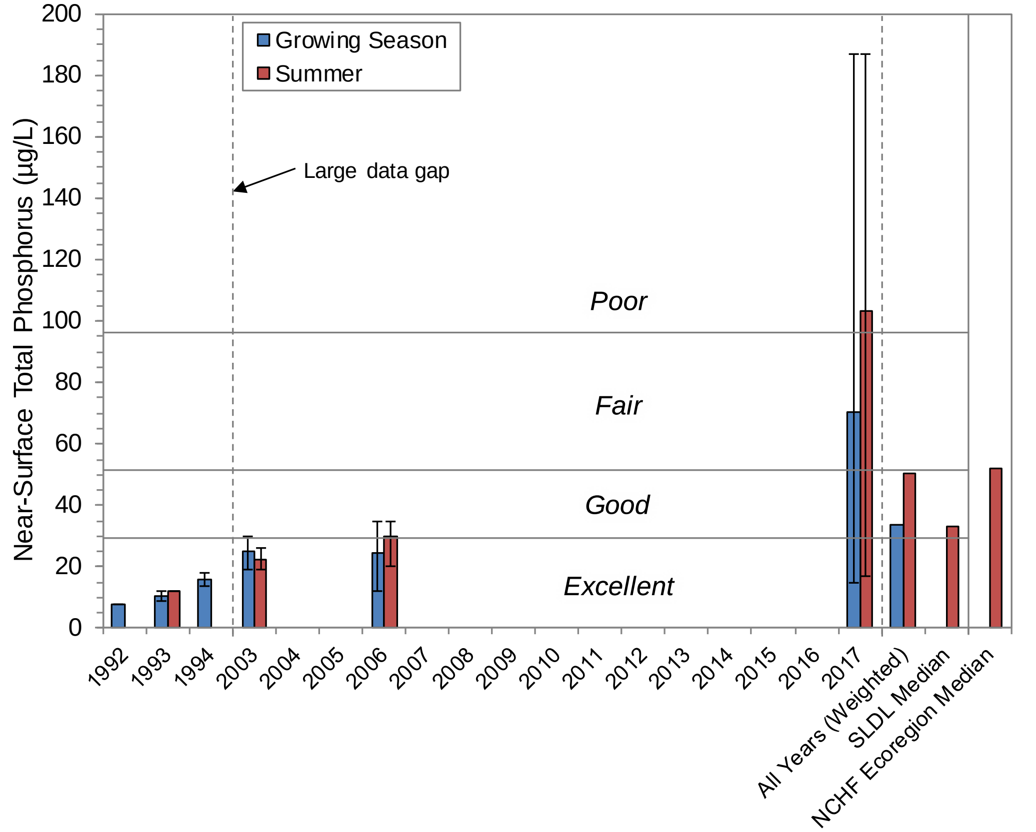


Figure 3.1-3. Lake Iola, shallow lowland drainage lakes (SLDL), and North Central Hardwood Forests (NCHF) ecoregion total phosphorus concentrations. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-*a*

Chlorophyll-*a* concentrations are available from 1992-1994, 2003, 2006, and 2017 in Lake Iola (Figure 3.1-4). Average summer chlorophyll-*a* concentrations ranged from 2 µg/L in 1993 to 27 µg/L in 2017. It should be noted that only one summer chlorophyll-*a* sample was collected in 1993 and may not be representative of the 1993 summer average. As was discussed previously, in the phosphorus discussion, the elevated chlorophyll-*a* concentrations in 2017 are likely the result of the elevated streamflow following rainfall prior to the June and July sampling. Lake Iola is a productive lake with a robust aquatic plant community, which provides ample habitat for benthic algae. It is likely that the increased flow resulted in algae associated with the dense macrophyte growth was dislodged and fragments collected in the nutrient bottles. Since high chlorophyll-*a* levels were associated with the high phosphorus concentrations it is probable that much of the elevated phosphorus is originating from samples containing fragments of algae, dislodged from precipitation events, from Lake Iola and not a result of phosphorus runoff upstream.

Although the average growing season and summer chlorophyll-*a* levels in 2017 would place Iola Lake in the *good* or *fair* category, concentrations when rainfall did not proceed the sampling would place the lake in the *excellent* category, which would agree with many of the previous years. If precipitation events are excluded, Lake Iola's average summer chlorophyll-*a* concentration is lower than the majority of other shallow lowland drainage lakes in the state and is lower than the majority of all lake types within the NCHF ecoregion.

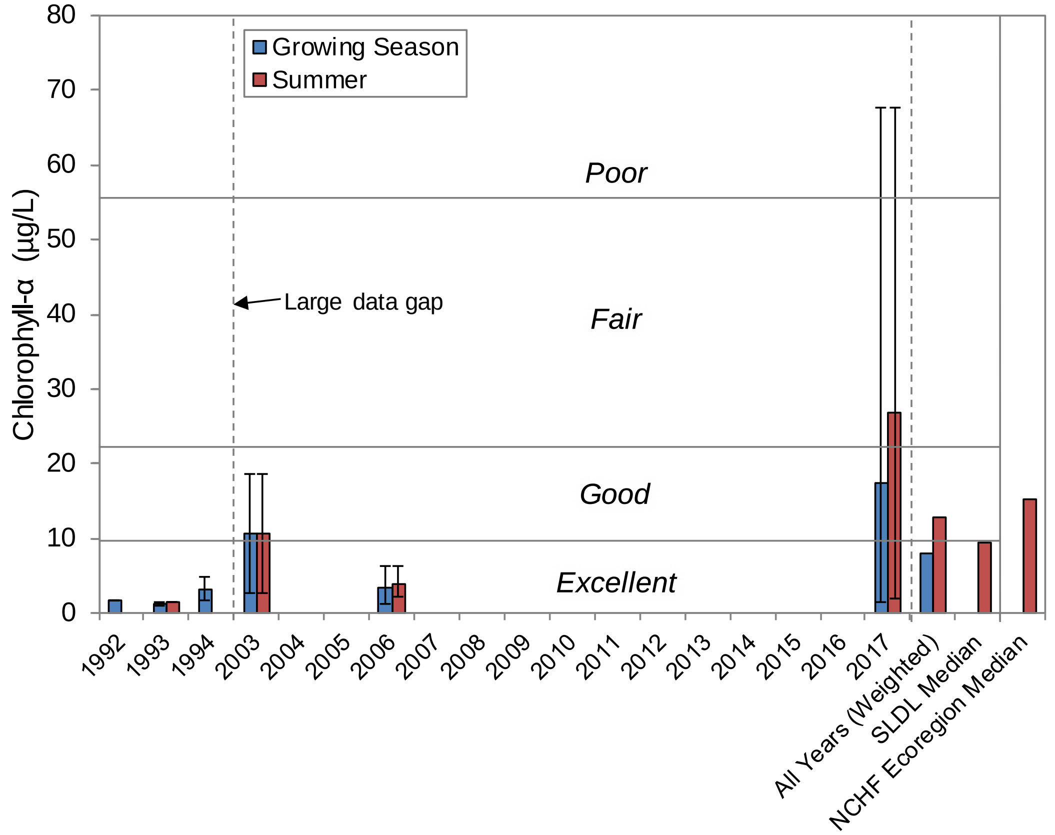


Figure 3.1-4. Lake Iola, shallow lowland drainage lakes (SLDL), and North Central Hardwood Forests (NCHF) ecoregion chlorophyll-*α* concentrations. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Water Clarity

Water clarity was measured using a Secchi disk in Lake Iola in 2003, 2006, and in 2017. However, all Secchi disk readings except one measurement in July of 2017 hit the bottom of the lake, indicating that water clarity exceeded the depth of the sampling location, which is approximately 6 feet. Because these measurements hit bottom, seasonal averages cannot be determined.

Water clarity is not only influenced by particulates such as phytoplankton and suspended sediments, but it is also influenced by dissolved components and elements in 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 color and reduce water clarity. True color values measured from Lake Iola in 2017 were 30 SU (standard units) and 60 SU in April and July, respectively, indicating the lake's water is *lightly tea-colored* to *tea-colored*. A precipitation event preceded the July 2017 sampling event, which is an indication that the lake's water is typically clear but may become stained for brief periods of time following precipitation events.

Limiting Plant Nutrient of Lake Iola

Using midsummer nitrogen and phosphorus concentrations from Lake Iola, a nitrogen:phosphorus ratio of 14:1 was calculated. This finding indicates that Lake Iola is phosphorus limited as are the vast majority of Wisconsin lakes; however, with large phosphorus inputs the lake could transition to being nitrogen limited. In general, this means that cutting both phosphorus and nitrogen inputs may limit phytoplankton growth within the lake.

Lake Iola Trophic State

Figure 3.1-5 contains the weighted average Trophic State Index (TSI) values for Lake Iola. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-a, and Secchi disk transparency data collected as part of this project with limited historical 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 other factors other than phytoplankton such as dissolved compounds in the water. It should be noted that TSI values were not calculated for Secchi disc transparency because the disc was nearly always on the lake bottom so it does not give an accurate indication of water clarity. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation. The TSI values for all total phosphorus and chlorophyll-*a* parameters place Lake Iola in a eutrophic state (Figure 3.1-5). It should be noted that the TSI values in 2017 are largely due to two sampling events. This does not likely indicate a degrading trend in Lake Iola's water quality but is likely due to high variability from precipitation and sample timing. Lake Iola is slightly more productive than other shallow lowland drainage lakes in Wisconsin and has similar levels of productivity as the majority of all lake types in the NCHF ecoregion.

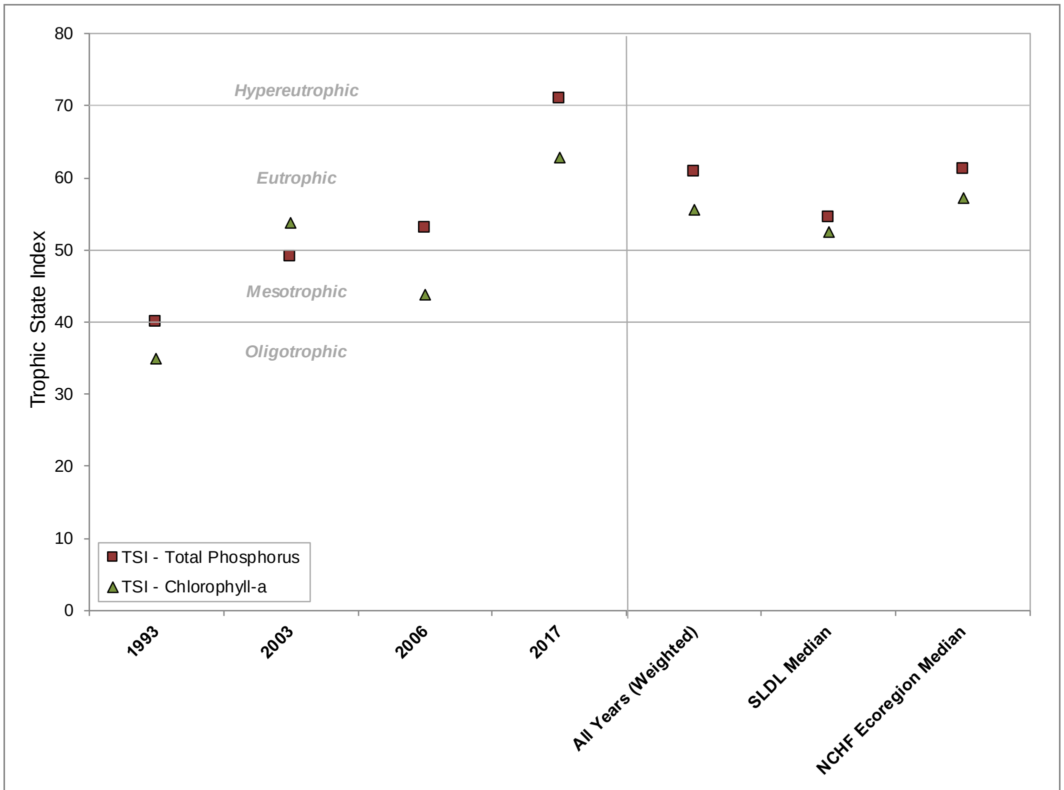


Figure 3.1-5. Lake Iola, state-wide shallow lowland drainage lakes (SLDL), and North Central Hardwood Forests (NCHF) ecoregion Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Shallow Lakes and Alternative Stable States

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

A number of factors which can lead to the loss of aquatic vegetation often cause shallow lakes to transition from the clear to turbid state. Excessive nutrient loading can lead to increased phytoplankton abundance, reductions in water clarity, and a reduction in aquatic plant habitat. As aquatic vegetation declines, bottom sediments become more susceptible to wind-induced sediments resuspension and water clarity declines further. The stabilization of water levels in shallow lakes can also lead to declines in aquatic vegetation as many species require natural, annual fluctuations for their persistence and reproduction. Studies have also documented declines in submersed aquatic vegetation and increases in nutrients and suspended solids, and a shift from a clear, submersed aquatic plant-dominated state to a turbid, phytoplankton-dominated state following the introduction of the non-native common carp (*Cyprinus carpio*) (Bajer and Sorensen 2015). Carp destroy macrophyte beds during their feed activities as they forage in the sediments uprooting the plants. Fortunately, common carp are not known to exist in Lake Iola at the time of this report.

Lake Iola's shallow nature in combination with nutrient-rich sediments and water creates ideal conditions for excessive aquatic plant growth. However, these plants are essential for maintaining Lake Iola's current clear-water state, and a loss of aquatic plants could result in the lake transitioning to a phytoplankton-dominated state with low water clarity as a result of phytoplankton blooms. As discussed previously, these plants provide habitat for zooplankton which limits phytoplankton production. The short hydraulic residence time (often less than two weeks) also inhibits phytoplankton growth because phytoplankton produced in the lake are washed downstream. However, if phosphorus concentrations were higher there could be enough phytoplankton produced in the lake to flip the lake to a turbid algal state. This has occurred in other Wisconsin impoundments that are located on streams and rivers.

Dissolved Oxygen and Temperature in Lake Iola

Dissolved oxygen and temperature were measured during water quality sampling visits to Lake Iola by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-6. Lake Iola is polymictic [lakes that are too shallow to thermally stratify and can mix throughout the growing season, lakes typically less than 20 feet in depth] and the temperature at the bottom was over 20°C in June and July 2017, indicating that the lake frequently mixes (Figure 3.1-6). The data also indicate that there was sufficient oxygen throughout most of the water column under the ice to support the fishery during late-winter sampling. On August 24, 2017 the dissolved oxygen levels were lower than normal, being about 4.5 mg/L. It is likely concentrations were depressed because stream flow was lower than earlier in the summer. Because of the large amount of organic matter from macrophytes and filamentous algae, this resulted in elevated respiration rates which resulted in lower oxygen levels. When flow rates are higher, the lake water is replenished more frequently and oxygen levels remain similar to concentrations found upstream of the lake which are higher. Although fish can become stressed when oxygen levels are below 5 mg/L for extended periods of time, this should not be a concern it this lake. Fish are easily able to move to areas with higher oxygen concentrations, such of closer to where the river enters the lake. Lower oxygen concentrations are more of a concern in lakes without inflowing streams or during ice cover since the fish are not able to move to areas with higher oxygen levels.

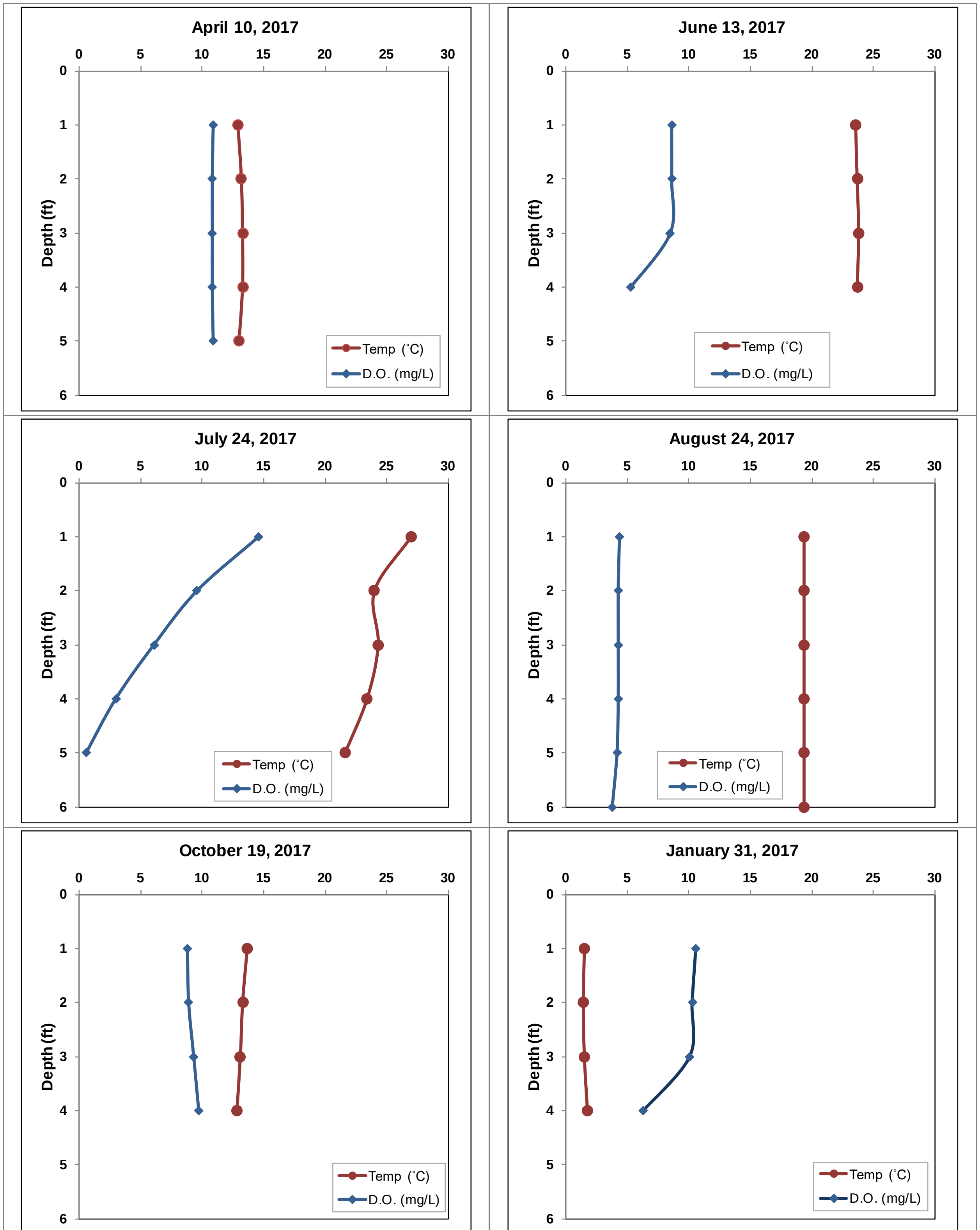


Figure 3.1-6. Lake Iola dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Lake Iola

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 Lake Iola's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The pH of the water in Lake Iola was found to be near neutral with a value of 7.5, and falls within the normal range for Wisconsin Lakes.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Lake Iola was measured at 215 (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.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Lake Iola's pH of 7.5 falls inside this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Lake Iola was found to be 52.9 mg/L, falling into the optimal range for zebra mussels.

Zebra mussels (*Dreissena polymorpha*) are small bottom dwelling mussels, native to Europe and Asia, that found their way to the Great Lakes region in the mid-1980s. They are thought to have come into the region through ballast water of ocean-going ships entering the Great Lakes, and they have the capacity to spread rapidly. Zebra mussels can attach themselves to boats, boat lifts, and docks, and can live for up to five days after being taken out of the water. These mussels can be identified by their small size, D-shaped shell and yellow-brown striped coloring. Once zebra mussels have entered and established in a waterway, they are nearly impossible to eradicate. Best practice methods for cleaning boats that have been in zebra mussel infested waters is inspecting and removing any attached mussels, spraying your boat down with diluted bleach, power-washing, and letting the watercraft dry for at least five days.

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, Lake Iola was considered suitable for mussel establishment.

Stakeholder Survey Responses to Lake Iola 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. Figure 3.1-7 displays the responses of members of Lake Iola stakeholders to questions regarding water aesthetic appearance and how it has changed over their years visiting Lake Iola. When asked how they would describe the current aesthetic appearance of Lake Iola 36% of respondents indicated *very poor*, 26% indicated *poor*, 22% indicated *fair*, 14% indicated *good*, and 2% indicated they were *unsure*.

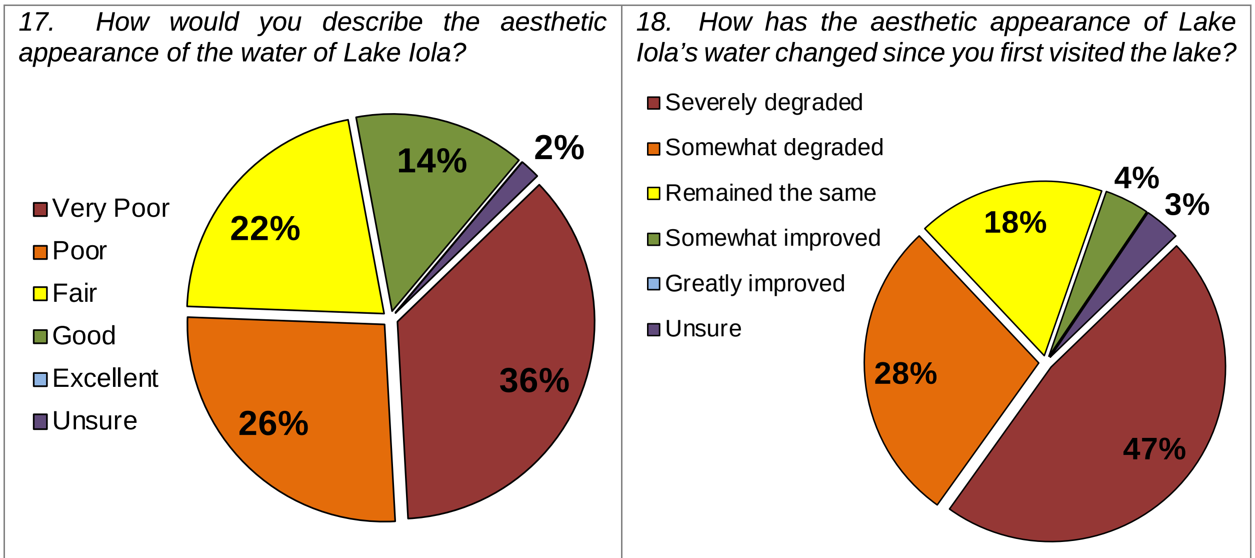
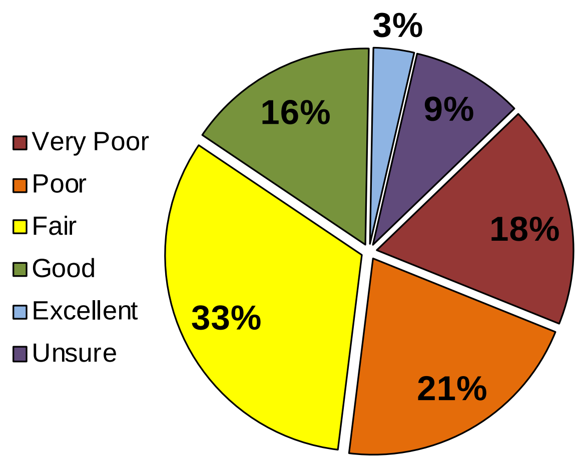


Figure 3.1-7. Lake Iola stakeholder survey responses to questions regarding perceptions of lake aesthetic appearance.

When asked how they believe the aesthetic appearance of Lake Iola's water has changed since they first visited the lake, 47% of respondents indicated it has *severely degraded*, 28% indicated is has *somewhat degraded*, 18% indicated it has *remained the same*, 4% indicated it has *somewhat improved*, and 3% indicated they were *unsure*.

Figure 3.1-8 displays the responses of Lake Iola stakeholder survey respondents to questions regarding overall water quality and how it has changed over their years visiting Lake Iola. When asked how they would describe the current overall water quality of Lake Iola, 33% of respondents indicated *fair*, 21% indicated *poor*, 18% indicated *very poor*, 16% indicated *good*, 9% indicated they were *unsure*, and 3% indicated *excellent*.

19. How would you describe the overall water quality of Lake Iola?



20. How as the overall water quality changed in Lake Iola since you first visited the lake?

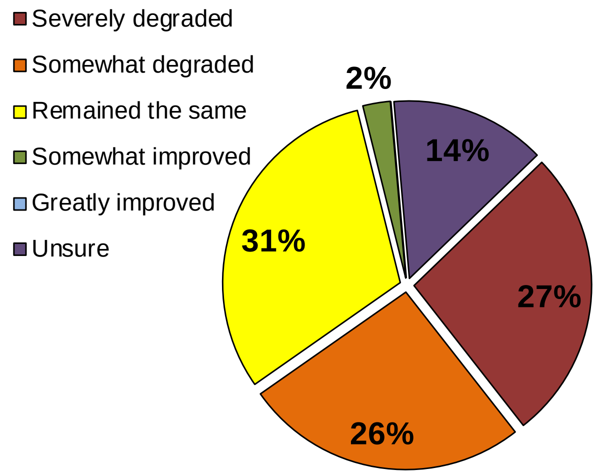


Figure 3.1-8. Lake Iola stakeholder survey responses to questions regarding perceptions of lake water quality.

When asked how they believe the overall water quality of Lake Iola has changed since they first visited the lake, 31% of respondents indicated it has remained the same, 27% indicated it has severely degraded, 26% indicated it has somewhat degraded, 14% indicated they were unsure, and 2% indicated it has somewhat improved.

As discussed in the previous section, total phosphorus and chlorophyll-*a* concentrations were higher in 2017 than in previous years; however, limited historical data is available for the lake. It is also important to remember that the lake's water levels are unnaturally maintained by a dam. Overall, while the lake's average water quality is good, water quality parameters collected in 2017 indicate the lake's water quality is worse than it was in 2006. Without additional historical data it is unsure if 2017 was an abnormal year due to precipitation or if a declining trend in water quality is present. Respondents who indicated that the overall water quality in the lake is very poor or poor may also be basing their perception of water quality in Lake Iola due to increased plant growth following the water level drawdown completed in 2013.

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.

Lake Iola Watershed Assessment

Lake Iola's watershed encompasses an area of approximately 17,038 acres, yielding a watershed to lake area ratio of approximately 72:1 (Map 2). The South Branch Little Wolf River enters Lake Iola on the north end of the lake. Flow estimates were measured in the Little Wolf River at a monitoring station at Erickson Road in 2011-2014 and total phosphorus samples were taken at the same site six times in 2015. Because data were collected at this site, the watershed upstream of this location was treated as a subwatershed within the WiLMS model. The remaining portion of the watershed will be referred to as Lake Iola's direct watershed. The average phosphorus concentration in the Little Wolf River in 2015 was 31.2 µg/L and this concentration was used to estimate annual phosphorus loading from the river to Lake Iola. Since flows were not measured for the whole year from 2011-2014, annual discharge from the Wolf River, which was continuously monitored by the USGS, was used to develop the relationship between annual flow in the Wolf River and the South Branch Little Wolf River.

Approximately 70% of Lake Iola's watershed is composed of the monitoring station subwatershed on the South Branch Lower Wolf River while the remaining 30% is comprised of Lake Iola's direct watershed (Figure3.2-1). Land cover within Lake Iola's direct watershed is comprised of forests (13%), row crop agriculture (10%), and pasture/grass/rural open space (3%). The remaining portions of the watershed are composed of Lake Iola's surface, rural residential areas, medium density urban areas, and high density urban areas, each comprising less than 1% of the watershed area, respectively.

Using the landcover described above and the measured input of phosphorus from the South Branch Lower Wolf River, it was estimated that on average, approximately 3,078 pounds of phosphorus enter Lake Iola on an annual basis (Figure 3.2-2). Phosphorus loading from septic systems was also estimated using data obtained from the 2017 stakeholder survey of riparian property owners, which indicated that only about 3 pounds, or roughly 0.09% of the annual phosphorus load is attributed to riparian septic systems.

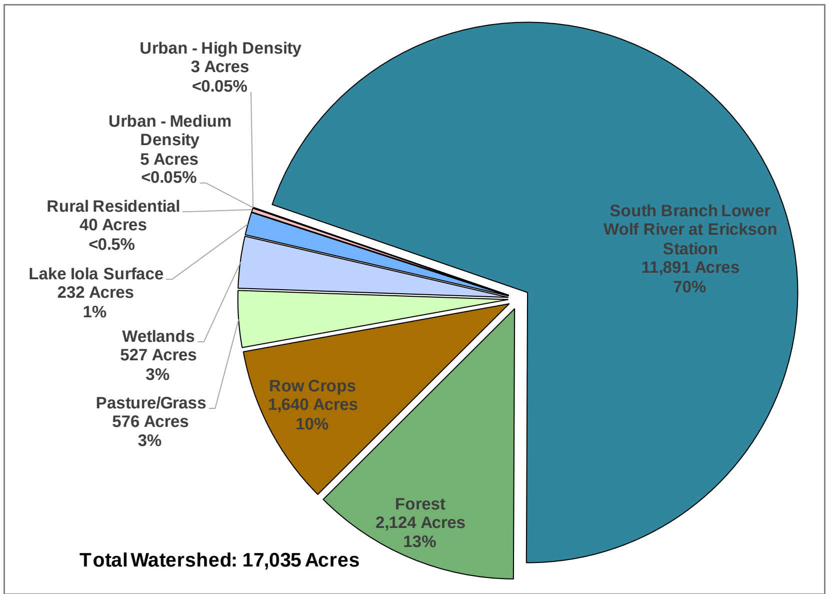


Figure 3.2-1. Lake Iola watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 3,078 pounds of phosphorus being delivered annually to Lake Iola, most (48%) is estimated to originate from row crop agriculture within the lake's direct watershed, 38% originates from the Little Wolf River subwatershed, 6% originates from forest, 5% originates from pasture grass, 2% originates from direct atmospheric deposition into the lake, and 1% originates from wetlands (Figure 3.2-2). The remaining phosphorus load (<1%) comes from rural residential areas, high density urban areas, septic systems, and medium density urban areas.

Using predictive equations, WiLMS estimates that given the average annual phosphorus load of 3,078 pounds, Lake Iola is predicted to have an average growing season mean total phosphorus concentration of approximately 17 µg/L to 47 µg/L. Due to well drained soils in Lake Iola's watershed, the South Branch Lower Wolf River likely is the primary source of phosphorus to the lake and WiLMS likely overestimated the amount of runoff and phosphorus being delivered to Lake Iola from its modeled direct watershed.

As discussed in the Water Quality Section, Lake Iola is eutrophic, meaning the lake is productive with higher nutrient levels. While a significant amount of phosphorus comes from agricultural sources within Lake Iola's watershed, it is important to remember that the lake's watershed is fairly large and the lake's water level is unnaturally maintained by a dam. Lakes with a watershed to lake ratio of 10-15:1 or higher have larger areas of land draining to them, and regardless of land cover have sufficient phosphorus resulting in a productive system.

Lake Iola has a watershed to lake area ratio of 72:1, and to demonstrate the impact of a watershed this size on the lake itself a scenario was developed using the WiLMS model created for the lake. The scenario illustrates phosphorus loading if 50% of the lake's direct watershed row crop agriculture were converted to forested land. Currently, Lake Iola's average growing season mean total phosphorus concentration correlates to a TSI value of 60.8, falling into the eutrophic category. Should 50% of the lake's row crop agriculture in the direct watershed be converted to forest, it is estimated that the lake would have a TSI value of approximately 50 to 57, still falling in the eutrophic category. This illustrates that even an unrealistic change within the watershed to reduce phosphorus loading would still result in Lake Iola being a eutrophic system.

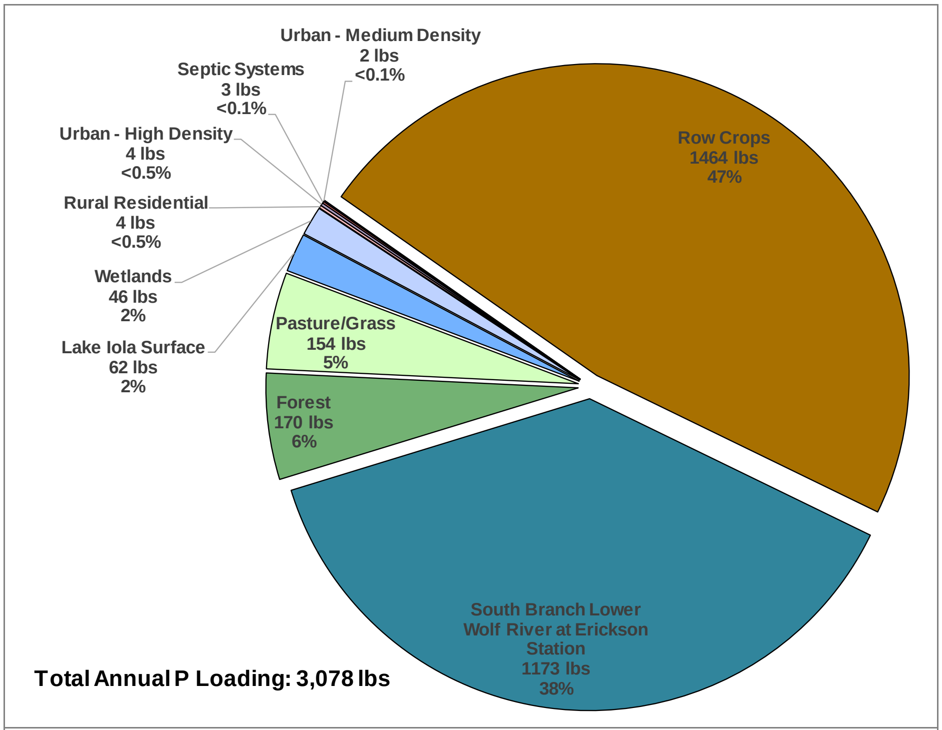


Figure 3.2-2. Lake Iola watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 Shoreland Condition

Lake Shoreland Zone and its Importance

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted stricter shoreland ordinances. 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).

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

- Impervious surface standards: 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.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet 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

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

Wisconsin Act 31

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

Shoreland Research

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

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

Shorelands provide much in terms of nutrient retention and mitigation, but also play an important role in wildlife habitat. Woodford and Meyer (2003) found that green frog density was negatively correlated with development density in Wisconsin lakes. As development increased, the habitat for green frogs decreased and thus populations became significantly lower. Common loons, a bird species notorious for its haunting call that echoes across Wisconsin lakes, are often associated more so with undeveloped lakes than developed lakes (Lindsay 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.

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

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

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area, as well as spawning habitat (Hanchin 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 not 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.

Lake Iola Shoreland Zone Condition

Shoreland Development

Lake Iola'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 Lake Iola, 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.

Lake Iola has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 8.2 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, 1.9 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Lake Iola 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.

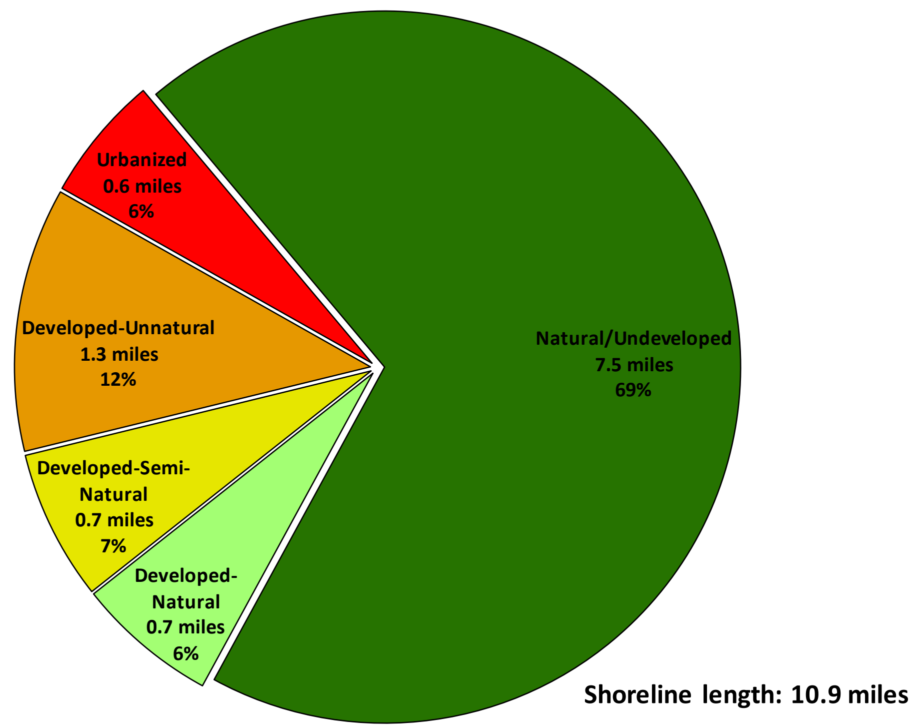


Figure 3.3-2. Lake Iola shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Map 3.

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

Coarse Woody Habitat

As part of the shoreland condition assessment, Lake Iola 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, 335 total pieces of coarse woody habitat were observed along 10.9 miles of shoreline (Map 4), which gives Lake Iola a coarse woody habitat to shoreline mile ratio of 31:1 (Figure 3.3-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Of the 335 total pieces of coarse woody habitat observed during the survey, 286 pieces were 2-8 inches in diameters, 49 were 8 inches in diameter or greater, and no clusters of pieces of coarse woody habitat were found. It should be noted that due to navigation limitations, binoculars were used to view coarse woody habitat along some of the shoreline in Lake Iola and some pieces of coarse woody habitat may not have been recorded.

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 Lake Iola 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 Lake Iola fell within the 70th percentile of these 75 lakes (Figure 3.3-3).

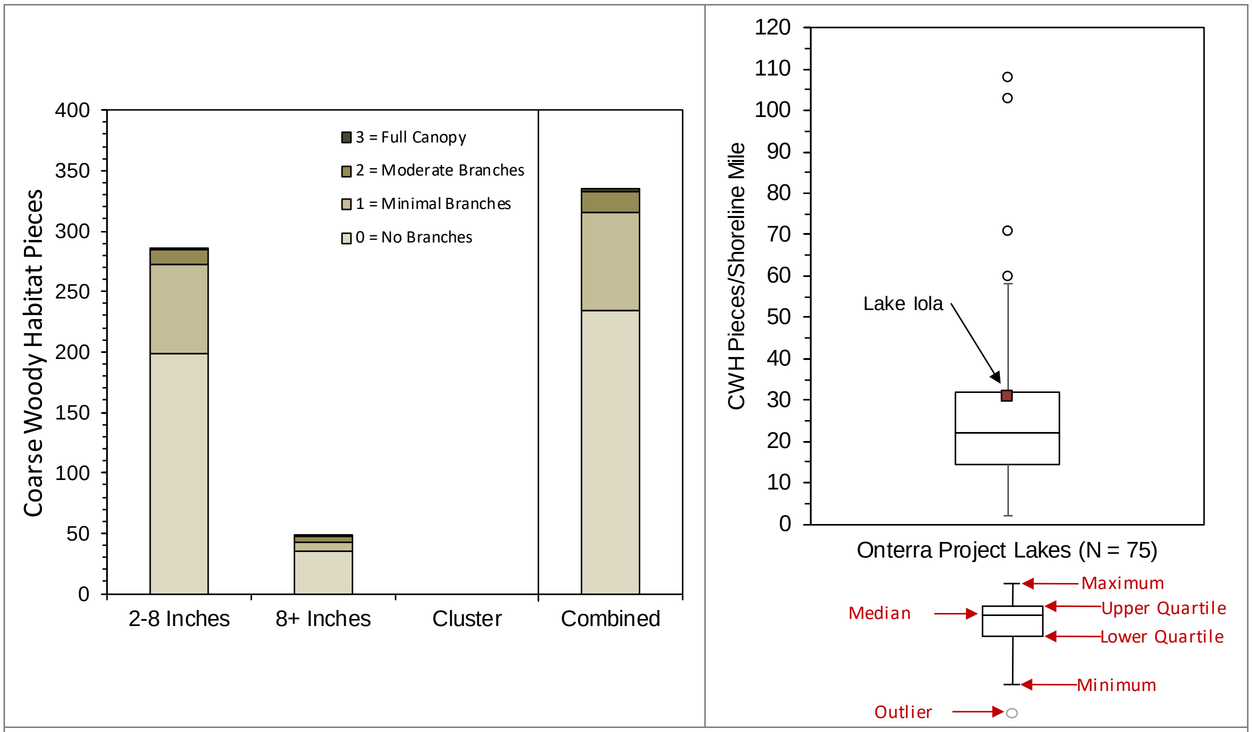


Figure 3.3-3. Lake Iola coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of Lake Iola coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

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

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

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

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

Aquatic Plant Management and Protection

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

Important Note:
Even though most of these techniques are not applicable to Lake Iola, 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 Lake Iola 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. The table below provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from Netherland (2009).

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

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.

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; Eurasian water milfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance natives species including duckweeds, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, 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.

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. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian watermilfoil. • 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 Lake Iola; 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 Lake Iola in 2006, 2014 and 2017. 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 Lake Iola, 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 Lake Iola 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. 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 Lake Iola is compared to data collected by Onterra and the WDNR Science Services on 85 lakes withn the North Central Hardwood Forests 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 Lake Iola 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.

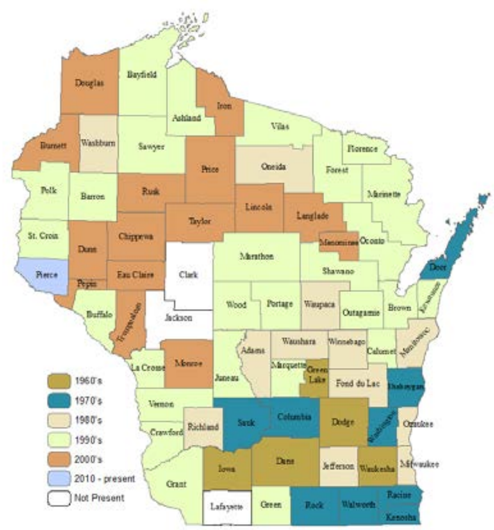


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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.

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

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

Lake Iola Aquatic Plant Survey Results

One of the primary goals of this management plan update for Lake Iola was to assess how Lake Iola's aquatic plant community had changed following the water level drawdown that took place between June of 2011 and May of 2013 and to develop management strategies for reducing aquatic invasive species. To attribute changes in Lake Iola's aquatic plant community to the water level drawdown, ideally surveys would have been conducted the year immediately prior to and the year immediately following the drawdown. However, it must be noted that the pre-drawdown data being used in the following analyses were collected in 2006, five years prior to the water level drawdown and post-drawdown data were collected in 2014 and 2017, one and four years following the lake's refilling, respectively. This delay was due to budget considerations as a 3-year project loan was being paid off. While the changes in aquatic plant community between these three surveys are likely largely a result of the water level drawdown, it cannot be said with scientific certainty that there were not additional factors (i.e. climate, etc.) that contributed to these changes.

A number of aquatic plant surveys were completed by Onterra ecologists on Lake Iola in 2017. During these surveys, a total of 51 aquatic plant species were located, three of which are considered to be non-native (exotic) species: Eurasian/hybrid watermilfoil, curly-leaf pondweed, and purple loosestrife (Table 3.4-1). Hybrid watermilfoil, confirmed via DNA analysis in 2014 in Lake Iola, is a genetic cross between the non-native Eurasian watermilfoil and the native northern watermilfoil. Because of their ecological, sociological, and economical significance, these non-native aquatic plant populations in Lake Iola are discussed in detail in the subsequent Non-Native Aquatic Plants section. Table 3.4-1 also contains the aquatic plant species recorded during the surveys completed by Onterra in 2006 and the WDNR in 2014 and shows that 13 native aquatic plant species were located in Lake Iola in 2017 that were not located in 2006 or 2014. These differences between the pre- and post-drawdown plant surveys are discussed in further detail later in this section.

Lakes in Wisconsin vary in their morphometry, water chemistry, and substrate composition, and all of these factors influence aquatic plant community composition. During the whole-lake point-intercept survey completed on Lake Iola by Onterra on July 25 and 26, 2017, substrate data were also recorded at each sampling location in one of three general categories: rock, sand, and soft sediments. These data indicate that the majority (84%) of sampling locations contained soft sediments, 16% contained sand, and 0% were found to contain rock (Figure 3.4-2 and Map 5).

Table 3.4-1. Aquatic plant species located on Lake Iola during August 2006 (Onterra), August 2014 (WDNR) and July 2017 (Onterra) surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2006	2014	2017
Emergent	*Calla palustris*	Water arum	9	I		
	Carex comosa	Bristly sedge	5	I		I
	Carex pseudocyperus	Cypress-like sedge	8			I
	Carex utriculata	Common yellow lake sedge	7			I
	Eleocharis erythropoda	Bald spikerush	3			I
	Eleocharis palustris	Creeping spikerush	6	X		I
	Iris versicolor	Northern blue flag	5	X		I
	Iris virginica	Southern blue flag	5			I
	Juncus effusus	Soft rush	4			I
	Lythrum salicaria	Purple loosestrife	Exotic	I	X	I
	Phalaris arundinacea	Reed canary grass	Exotic		X	
	Sagittaria latifolia	Common arrowhead	3	X	X	I
	Schoenoplectus acutus	Hardstem bulrush	5	X		I
	*Schoenoplectus heterochaetus**	Slender bulrush	10			I
	Schoenoplectus pungens	Three-square rush	5	X		
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I		I
	Scirpus cyperinus	Wool grass	4			I
	Sparganium eurycarpum	Common bur-reed	5	I		I
	Typha angustifolia	Narrow-leaved cattail	Exotic	I	X	
	Typha latifolia	Broad-leaved cattail	1	X		X
	Zizania palustris	Northern wild rice	8		X	
FL	*Nuphar variegata*	Spatterdock	6	X	X	X
	Nymphaea odorata	White water lily	6	X	X	X
	Persicaria amphibia	Water smartweed	5		X	I
FL/E	*Sparganium emersum* var. *acaule*	Short-stemmed bur-reed	8	X	X	
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X	X
	Chara spp.	Muskgrasses	7	X	X	X
	Elodea canadensis	Common waterweed	3	X	X	X
	Heteranthera dubia	Water stargrass	6	X	X	X
	Leptodictyum riparium	Wet thread moss	N/A			X
	Myriophyllum heterophyllum	Various-leaved watermilfoil	7	X	X	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X	X
	Myriophyllum sibiricum X *spicatum*	Hybrid watermilfoil	Exotic	X	X	X
	Myriophyllum verticillatum	Whorled watermilfoil	8	X	X	X
	Najas flexilis	Slender naiad	6	X		X
	Najas guadalupensis	Southern naiad	7		X	X
	Nitella spp.	Stoneworts	7		X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	
	Potamogeton berchtoldii	Slender pondweed	7			X
	Potamogeton crispus	Curly-leaf pondweed	Exotic		X	X
	Potamogeton foliosus	Leafy pondweed	6	X		
	Potamogeton friesii	Fries' pondweed	8		X	X
	Potamogeton gramineus	Variable-leaf pondweed	7		X	I
	Potamogeton illinoensis	Illinois pondweed	6	X	X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X	X
	Potamogeton praelongus	White-stem pondweed	8	X	X	X
	Potamogeton pusillus	Small pondweed	7		X	
	Potamogeton strictifolius	Stiff pondweed	8			X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X
	Ranunculus aquatilis	White water crowfoot	8	X	X	I
	Stuckenia pectinata	Sago pondweed	3	X	X	X
	Utricularia minor	Small bladderwort	10			X
	Utricularia vulgaris	Common bladderwort	7	X	X	X
	Vallisneria americana	Wild celery	6	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5		X	
	Sagittaria cuneata	Arum-leaved arrowhead	7			I
	Sagittaria graminea	Grass-leaved arrowhead	9	I	X	
FF	*Lemna minor*	Lesser duckweed	5		X	
	Lemna perpusilla	Minute duckweed	10		X	
	Lemna trisulca	Forked duckweed	6		X	
	Lemna turionifera	Turion duckweed	2			X
	Spirodela polyrhiza	Greater duckweed	5			X
	Wolffia borealis	Dotted watermeal	6			I
	Wolffia columbiana	Common watermeal	5			I
	Wolffia spp.	Watermeal spp.	N/A		X	

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as special concern in Wisconsin*

Like terrestrial plants, aquatic plants vary in their preference for a particular substrate type; some species are usually only found growing in soft sediments, others only course substrates like sand, while some are more generalists and can be found growing in either. Lakes with varying types of substrates generally support a higher number of aquatic plant species because of the different habitat types that are available. The majority of the aquatic plants located in Lake Iola in 2017 are typically found growing in soft substrates; however, some species, like slender naiad, were more frequently located in areas of sand.

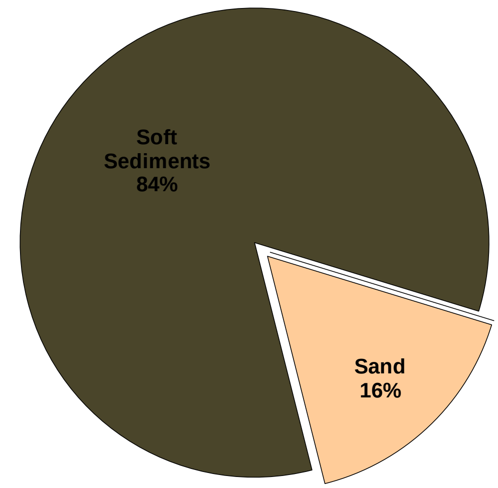


Figure 3.4-2. Lake Iola proportion of substrate types within littoral areas. Created using data from July 2017 aquatic plant point-intercept survey (N=201).

Of the 550 sampling locations that comprised the whole-lake point-intercept survey on Lake Iola, 201 were able to be sampled in 2017; the remaining 349 locations were inaccessible due to excessive plant growth or shallow water. Of the 201 point-intercept sampling locations sampled in 2017, 100% contained aquatic vegetation (Map 6). Aquatic plant rake fullness data collected in 2017 indicates that 5% of the 201 sampling locations contained vegetation with a total rake fullness rating of 1, 32% had a total rake fullness rating of 2, and 63% had a total rake fullness of 3 (Figure 3.4-3). The higher proportion of total rake fullness ratings of 2 and 3 indicates high plant biomass.

Of the 51 aquatic plant species located in Lake Iola in 2017, 31 were encountered on the rake during the whole-lake point-intercept survey (Figure 3.4-4). The remaining 19 species were located incidentally. Incidental species include those that were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 31 species encountered on the rake during the point-intercept survey, common waterweed, various-leaved watermilfoil, muskgrasses, and coontail were the four-most frequently encountered (Figure 3.4-4).

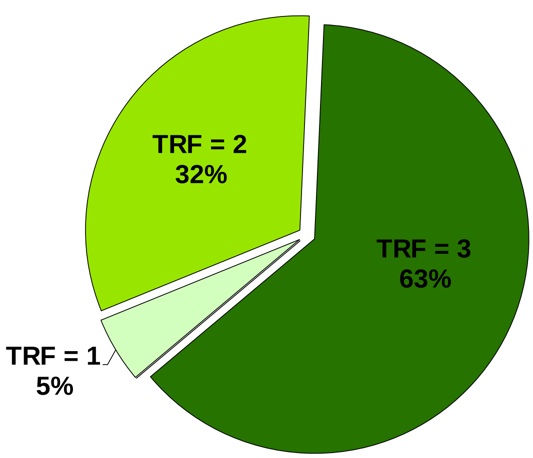


Figure 3.4-3. Lake Iola 2017 aquatic vegetation total rake fullness ratings. Created using data from July 2017 aquatic plant point-intercept survey (N = 201).

Common waterweed was the most frequently encountered aquatic plant species in Lake Iola during the 2017 whole-lake point-intercept survey with a littoral frequency of approximately 56% (Figure 3.4-4). Common waterweed is found in waterbodies across Wisconsin and is tolerant of low-light conditions, often making it one of the more abundant plants in eutrophic lakes. It prefers growing in soft sediments, and can often grow in dense beds that mat at the surface. Common waterweed's dense network of stems and leaves provide excellent habitat for aquatic wildlife, and its abundance in Lake Iola helps to maintain the clear-water state.

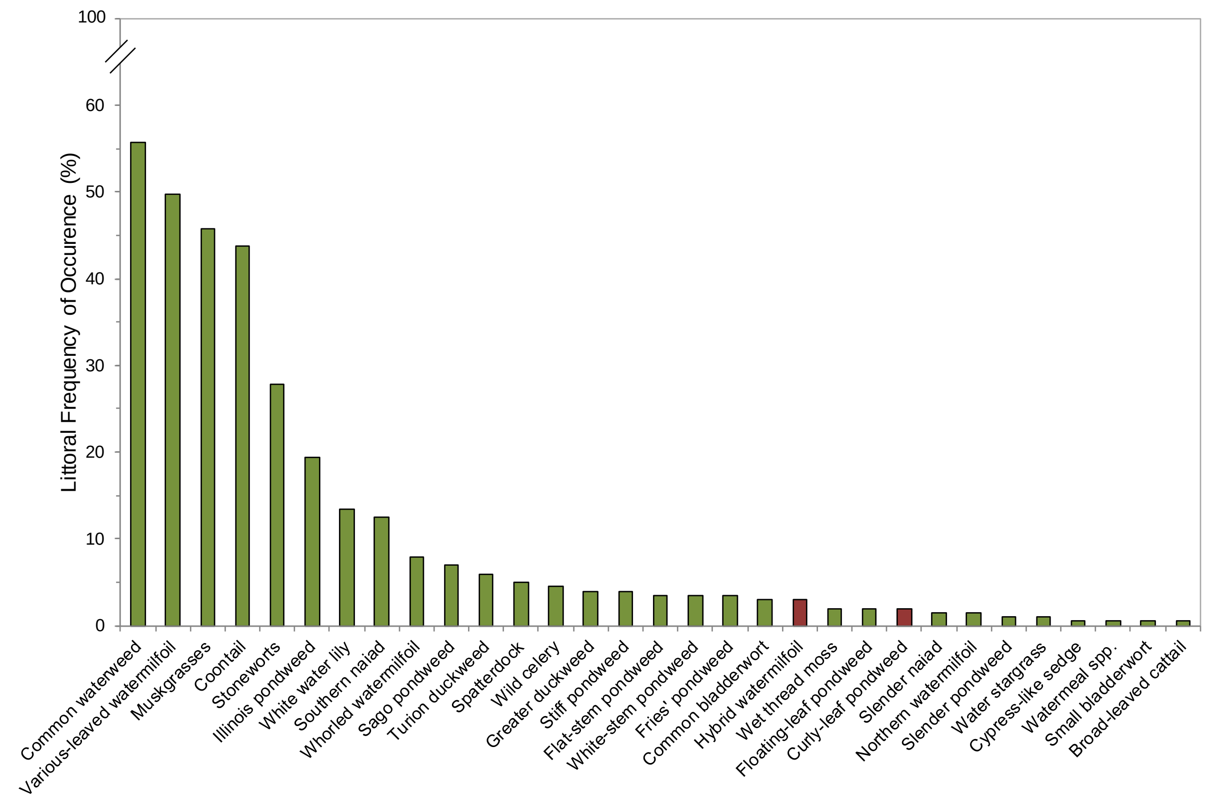


Figure 3.4-4. Lake Iola aquatic plant littoral frequency of occurrence. Non-native species indicated with red. Created using data from the 2017 whole-lake point-intercept survey.

Various-leaved watermilfoil (VLWM), one of the seven native milfoil species found in Wisconsin, was the second-most abundant aquatic plant species found in Lake Iola, with a littoral frequency of 50% (Figure 3.4-4). Like most of the other milfoil species in Wisconsin, VLWM has dense whorls of finely-dissected leaves which provide habitat for periphyton and trap detritus. In Lake Iola, VLWM was observed growing in dense colonies throughout the lake, often matted at the surface (Photo 3.4-5). These plants' robust stems make navigation through dense colonies difficult.

Various-leaved watermilfoil is classified as a non-native, invasive species in the northeast and western portions of the United States; however, its historical native range includes the Midwest and it is considered a native species in Wisconsin (Thum et al. 2011). While VLWM is not considered to be an invasive species in Wisconsin, when conditions are favorable this species can act aggressively and grow to excessive levels. Studies have shown that VLWM populations are most often found in more productive lakes lower in the drainage network with organic substrates and higher pH, alkalinity, calcium, and conductivity (Gerber and Les 1994; Thum and Lennon 2010). Lake Iola is a lowland lake with a large watershed, soft sediments, and water with higher pH (>8.0), alkalinity (215 mg/L as $CaCO_3$), calcium (53 mg/L), and conductivity (444 µS/cm). While it is not known which variable or combination of these variables favors the growth of VLWM, Lake Iola possesses the characteristics identified as being favorable for this species

(Thum and Lennon 2010). The response of VLWM to the water level drawdown completed in Lake Iola from 2011-2013 is discussed later in this section.

Photo 3.4-5. Nuisance growth of the native various-leaved watermilfoil (*Myriophyllum heterophyllum*) in Lake Iola. Photo credit Onterra 2017.

Muskgrasses are a genus of macroalgae of which there are seven species in Wisconsin. In 2017, muskgrasses were the third-most frequently encountered aquatic plants in Lake Iola with a littoral frequency of occurrence of approximately 46% (Figure 3.4-4). Higher abundance of muskgrasses is common in hardwater lakes like Lake Iola, and 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 higher water clarity, and their large beds help to 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).

Coontail, arguably the most common aquatic plant in Wisconsin, was the fourth-most frequently encountered species in Lake Iola with a littoral frequency of occurrence of approximately 44% (Figure 3.4-4). Coontail, as its name suggests, possess closely-spaced whorls of stiff leaves that give the plant a raccoon tail-like appearance. 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. Because it lacks true roots, coontail derives most 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 dominate in high-nutrient, eutrophic lakes. Coontail has the capacity to form dense beds which mat on the surface and can hinder recreation. However, in Lake Iola, most of the surface-matted vegetation observed was attributed to various-leaved watermilfoil and common waterweed. Coontail provides many benefits to the aquatic community. Its dense whorls of 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 Lake Iola's clear-water state.

Comparison of 2006, 2014 and 2017 Aquatic Plant Community Data

In an effort to control non-native aquatic plants such as hybrid watermilfoil and excessive growth of native aquatic plants and to increase water depth through sediment compaction, the district voted to conduct a water level drawdown of Lake Iola from 2011 to 2012. The water level drawdown began on June 1, 2011 and was extended through May 10, 2013 in an effort to flush sedimentation buildup near the dam. One of the primary objectives of the studies completed in 2017 on Lake Iola was to quantify the changes to the lake's aquatic plant community since 2006 and 2014.

The response of the aquatic plant community to a water level drawdown depends on the extent of the drawdown (i.e. how much lakebed becomes exposed), the time of year (summer versus winter), and the duration of the drawdown. The extent, timing, and duration of a water level drawdown depend on the management objective, either aquatic plant restoration or control. Aquatic plants have evolved and adapted to natural, seasonal fluctuations in water level and many depend on these seasonal fluctuations for reproduction. In Wisconsin, under natural conditions water levels are typically highest in the spring and decline to a minimum in late-summer. As water levels decline in early summer, both emergent and submersed aquatic plant species become established. However, dams have altered these natural water level fluctuations by stabilizing and maintaining high water levels during the summer, and this has led to alterations and even losses of aquatic plants in shallow lakes (Wang et al. 2016).

In instances where aquatic plant abundance and diversity has declined, water levels have been manipulated to mimic more natural conditions in an effort to reestablish aquatic plants. This involves the lowering of water levels in early summer and maintaining a lower water level until the fall. This type of water level drawdown was conducted on Pool 8 in the Mississippi River during the summers of 2001 and 2002. The water level was reduced by 1.5 feet from mid-June through mid-September of each year, and researchers found that these drawdowns significantly increased emergent and submergent aquatic plant abundance and diversity for at least five years following these drawdowns (Kenow and Lyon 2009).

In contrast, water level drawdowns have been conducted in the winter with a goal of reducing nuisance aquatic plant abundance, primarily for non-native aquatic plants such as Eurasian watermilfoil. Unlike most native aquatic plant species which overwinter via turions (asexual reproductive structures), seeds, or tubers, Eurasian watermilfoil generally overwinters as an entire plant with above-ground biomass making it vulnerable to freezing and/or desiccation. Greenhouse studies conducted by Stanley (1976) found that the biomass of dewatered Eurasian watermilfoil shoots and roots decreased by 99% when exposed to temperatures just below freezing for 96 hours. In addition, Eurasian watermilfoil plants that were left submersed (10 cm of water) and exposed to subfreezing temperatures for 96 hours saw a 35% decrease in biomass (Stanley 1976).

The water level drawdown in Lake Iola occurred for just under two years (approximately 23 months), and spanned over two winters. Given what is known about water level drawdowns and their effects on the aquatic plant community, it was hypothesized that this drawdown would have resulted in a reduction in the lake's hybrid watermilfoil and curly-leaf pondweed populations, and likely a reduction in the occurrence of all vegetation within the lake. Unfortunately, whole-lake point-intercept surveys were not completed the year immediately preceding the water level drawdown in Lake Iola. However, whole-lake point-intercept data collected in 2006 (pre-drawdown) can be compared against the whole-lake point-intercept data collected in 2014 and 2017 (post-drawdown) to determine the changes that have occurred over this time period. It must be noted that not all of the changes found between the surveys can be attributed to the drawdown due to the span of time between the surveys.

In 2006, 251 locations were sampled, and in 2014, 385 locations were sampled. The point-intercept data collected pre- and post-drawdown in Lake Iola show that the littoral occurrence of aquatic vegetation did not change between these three surveys, with 100% of the sampling locations in 2006, 2014, and 2017 containing vegetation (Figure 3.4-5). However, the total rake fullness (TRF) data collected during these surveys indicate that aquatic plant biomass likely declined following the water level drawdown. In 2006, 98% of the sampling locations had the highest TRF rating of 3 with the remaining 2% having a TRF rating of 2, indicating high plant biomass. In 2014, one year following the drawdown, only 13% of the sampling locations had a TRF rating of 3, while 49% had the lowest TRF rating of 1 and 38% had a TRF rating of 2. The 2017 data indicate that aquatic plant biomass has increased since 2014, with 63% of the sampling locations having a TRF rating of 3, 32% with a TRF rating of 2, and 5% with a TRF rating of 1.

Figure 3.4-5. Littoral frequency of occurrence of aquatic vegetation and total rake fullness ratings (TRF) from 2006 (N = 251), 2014 (N = 385), and 2017 (N = 201) point-intercept surveys on Lake Iola. Created using data from Onterra 2006, WDNR 2014, and Onterra 2017 point-intercept surveys.

Figure 3.4-6 displays the littoral frequency of occurrence of aquatic plant species in Lake Iola as determined from the 2006, 2014, and 2017 whole-lake point-intercept surveys. It should be noted that only those species with a littoral frequency of occurrence of at least 5% in one of the three surveys are applicable for analysis (Chi-square $\alpha = 0.05$). However, the littoral occurrence of the non-native curly-leaf pondweed is included in Figure 3.4-5 despite having a littoral occurrence of less than 5% in all three surveys.

In 2006 prior to the water level drawdown, hybrid watermilfoil had a relatively high littoral occurrence of 18% (Figure 3.4-6). In 2014 following the water level drawdown, the occurrence of hybrid watermilfoil was found to have declined to 1%, representing a statistically valid 96% reduction in occurrence. This large reduction in hybrid/Eurasian watermilfoil following a winter water level drawdown has been observed on other systems such as Buffalo Lake in Marquette County and Lac Sault Dore Lake in Price County where the occurrence of Eurasian watermilfoil was found to have declined by 83% and 99%, respectively (Onterra 2013 and Onterra 2017). In 2017, five years following the water level drawdown, the littoral occurrence of hybrid watermilfoil in Lake Iola was found to still be low at 3% and not statistically different from its occurrence in 2014 (Figure 3.4-6).

Curly-leaf pondweed was not recorded during the 2006 aquatic vegetation point-intercept survey but was confirmed within the lake in 2006. The littoral occurrence of curly-leaf pondweed remained low in 2014 and 2017 at 2% in each survey (Figure 3.4-6). However, it must be noted that the occurrence of curly-leaf pondweed in Lake Iola was likely underestimated in all three of these surveys due to the time of year they were conducted. Curly-leaf pondweed typically reaches its peak growth in late-May into June before naturally senescing (dying-back) in early July. To accurately assess the full extent of a curly-leaf pondweed population ideally a survey should be completed in June. The 2006 and 2014 whole-lake point-intercept surveys were completed in August with the 2017 survey being conducted in July. These surveys coincide with the peak growth of most native plants, and because of this, they likely did not capture the full extent of the curly-leaf pondweed population in Lake Iola. The mapping of curly-leaf pondweed in Lake Iola in May of 2017 indicates that the population is likely larger than indicated by the point-intercept survey data (Map 7).

In the field, it is often difficult to distinguish between certain species of aquatic plants that are very similar morphologically, especially when flowering/fruiting material is not present. Because of this, the littoral occurrences of the following morphologically-similar species were combined for this analysis: various-leaved and whorled watermilfoil, muskgrasses and stoneworts, slender and southern naiad, and lesser and turion duckweed. In 2017, it was noted that most the various-leaved and whorled watermilfoil plants encountered had flowering material, allowing these species to be readily separated during this survey.

The 2017 point-intercept survey indicated the following species exhibited statistically valid declines in their littoral occurrence between 2006 and 2017: white water lily (72% decline), spatterdock (91% decline), common bladderwort (83% decline), Illinois pondweed (92% decline), sago pondweed (86% decline), wild celery (89% decline), white-stem pondweed (80% decline), and the combined occurrences of various-leaved and whorled watermilfoil (34% decline) (Figure 3.4-6). The large declines in the occurrence of these species, especially those of the floating-leaf species white water lily and spatterdock, can likely be attributed to the water level drawdown. While these species were still present in Lake Iola in 2017, their populations were smaller when compared to the survey completed in 2006.

In 2006, various-leaved (VLWM) and whorled watermilfoil (WWM) had the highest littoral occurrence of during the survey of 87%. Following the water level drawdown, the occurrence of these species declined to 19%, representing a statistically valid reduction in occurrence of 78%. However, the littoral occurrence of VLWM-WWM increased between 2014 and 2017 to 57%, representing a statistically valid increase of 34%. Studies have shown that VLWM has to be completely desiccated (dried out) during water level drawdowns to be effective at controlling this plant. A study which assessed the effects of varying degrees of desiccation on a number of aquatic plant species found that VLWM had to be desiccated to nearly 80% of its original mass to reduce its viability by 50% upon rewetting (Barnes et al. 2013). This study also found that even when VLWM lost 100% of its mass from desiccation, the plants still had a 10% probability of being viable upon rewetting. Given the large reduction in VLWM measured between 2006 and 2014 indicates that the water level drawdown was largely effective at desiccating and/or freezing a large portion of the VLWM population. However, given the favorable conditions for this species discussed earlier in Lake Iola, the occurrence of VLWM has increased relatively quickly since 2014.

While a number of native aquatic plant species declined following the water level drawdown, some were found to have increased in occurrence from 2006 to 2017 (Figure 3.4-6). These include common waterweed (174% increase), coontail (69% increase), and the combined occurrence of slender and southern naiad (141% increase). In 2014 immediately following the drawdown, the occurrence of common waterweed was not statistically different from its pre-drawdown occurrence in 2006. From 2014 to 2017 the occurrence of common waterweed increased by 150%.

Michelle Nault, a water resources management specialist with the WDNR, provided data from 12 lakes in Wisconsin that have not seen any active control of aquatic plants and have had their plant communities monitored annually for a number of years. The common waterweed populations in some of these lakes have exhibited large interannual variations, indicating that common waterweed populations have the capacity to fluctuate markedly from year-to-year in response to naturally-driven environmental changes. However, the conditions that cause these fluctuations are not fully understood. The higher occurrence of common waterweed recorded in Lake Iola in 2017 may not represent an increasing trend and may solely be an indication of favorable conditions for common waterweed in 2017.

In 2014 following the drawdown, coontail increased to an occurrence of 56% from an occurrence of 26% in 2006 (Figure 3.4-6). Coontail has since declined slightly to an occurrence of 44% in 2017. The increase in coontail immediately following the drawdown may be due to this plant expanding and occupying areas where other native plants had declined and were slower to recover. Its slight decline in 2017 may indicate increased competition with other native plants like common waterweed and VLWM.

Slender naiad is an annual, relying on seed production for reproduction each year while southern naiad is a perennial which maintains green shoots under the ice (Susan Knight personal comm.). Southern naiad has the ability to form dense, non-navigable beds in shallow lakes and, like coontail, the increase in slender and southern naiad within Lake Iola may be due to expansion into areas where other native plants declined. Emerging research is indicating that hybrids between southern naiad subspecies exist and are often observed acting aggressively, growing to nuisance levels and displacing other species (Les et al. 2010). However, it is not known if the southern naiad population in Lake Iola is of hybrid origin and this species was not observed to be creating nuisance conditions anywhere in the lake in 2017 and is not a concern at this time.

Lesser and turion duckweed are small, free-floating aquatic plants which float at the water's surface and derive all of their nutrients from the water. While the point-intercept survey data indicate that the occurrence of lesser/turion duckweed increased from a pre-drawdown occurrence of 0% in 2006 to occurrences of 14% and 6% in 2014 and 2017, respectively, this perceived increase is believed to be due to differences in survey methodology in 2006. Because these species float on the surface and their location is often subject to wind and water movement, it was not always common practice to record these species during point-intercept surveys. While these species were likely present in 2006, given the fact they were not recorded it cannot be said if their occurrence changed following the water level drawdown.

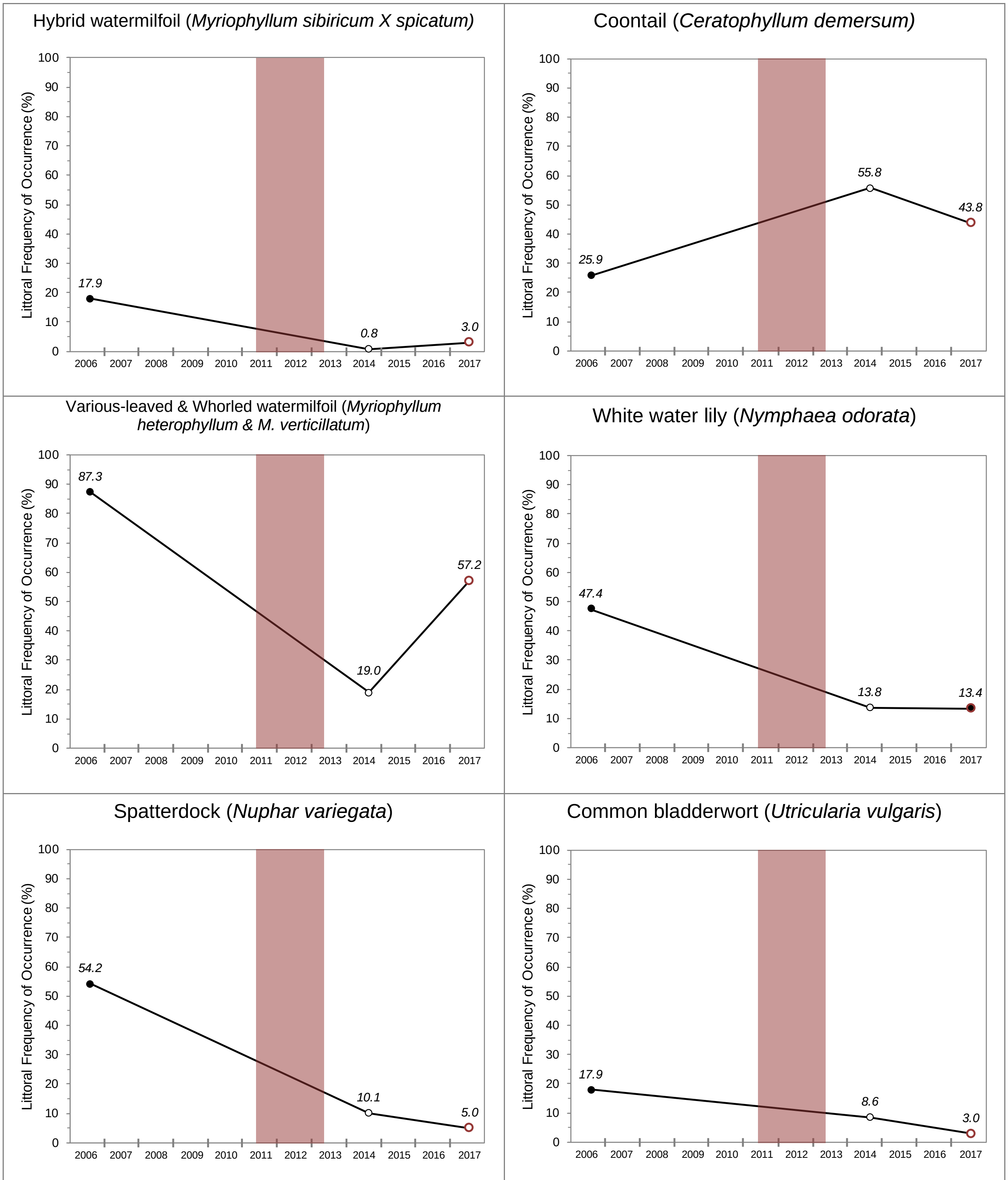


Figure 3.4-6. Lake Iola littoral frequency of occurrence of aquatic plant species from 2006 (pre-drawdown), 2014 and 2017 (post-drawdown). Pink-shaded area indicates period of water level drawdown. Open circle indicates statistically valid change in occurrence from previous survey; red circle outline in 2017 indicates statistically valid change in occurrence from 2006 (Chi-square α = 0.05). Created using data from 2006 (N = 251), 2014 (N = 385) and 2017 (N = 201) whole-lake point-intercept surveys.

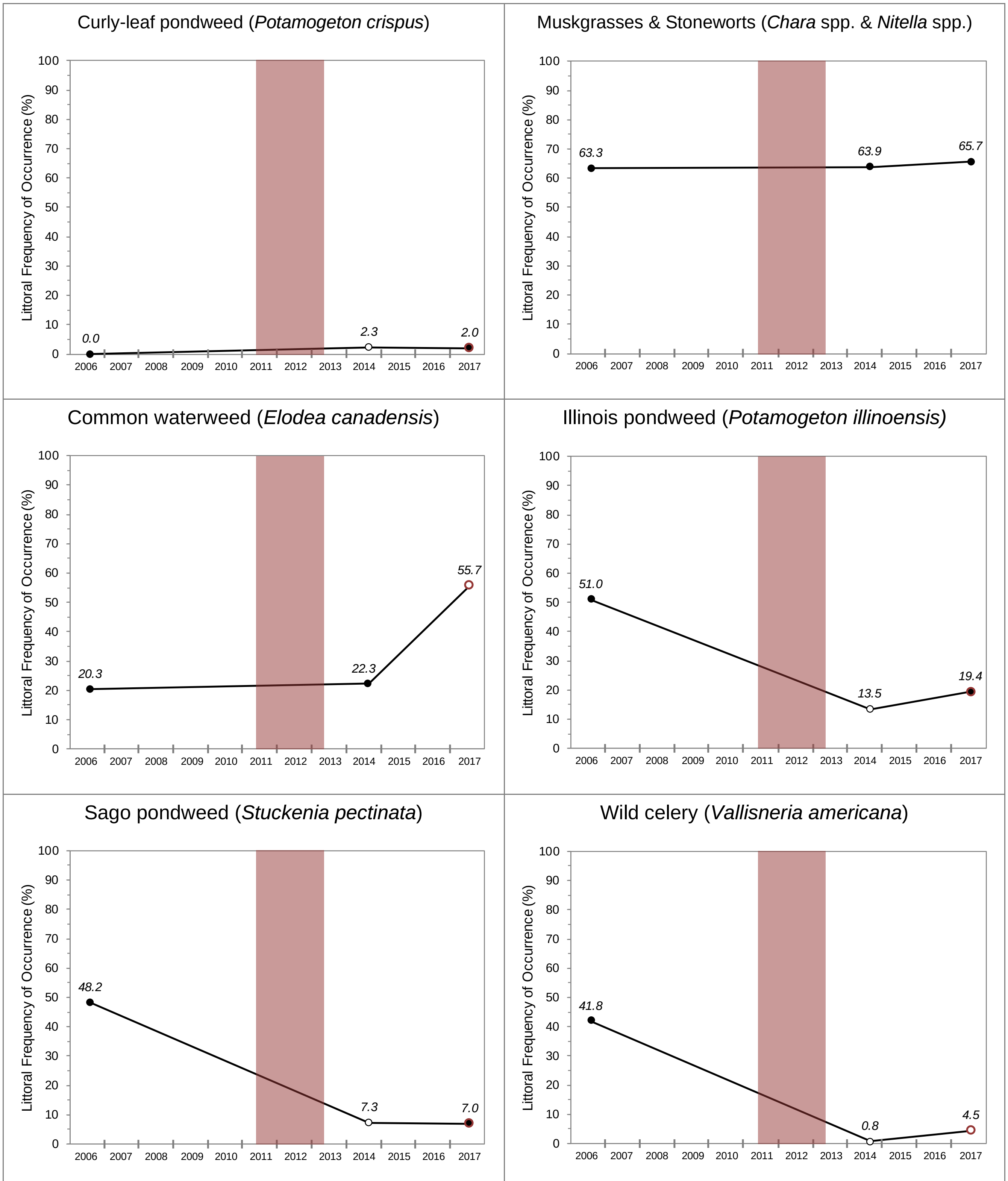


Figure 3.4-6 continued. Lake Iola littoral frequency of occurrence of aquatic plant species from 2006 (pre-drawdown), 2014 and 2017 (post-drawdown). Pink-shaded area indicates period of water level drawdown. Open circle indicates statistically valid change in occurrence from previous survey; red circle outline in 2017 indicates statistically valid change in occurrence from 2006 (Chi-square α = 0.05). Created using data from 2006 (N = 251), 2014 (N = 385) and 2017 (N = 201) whole-lake point-intercept surveys.

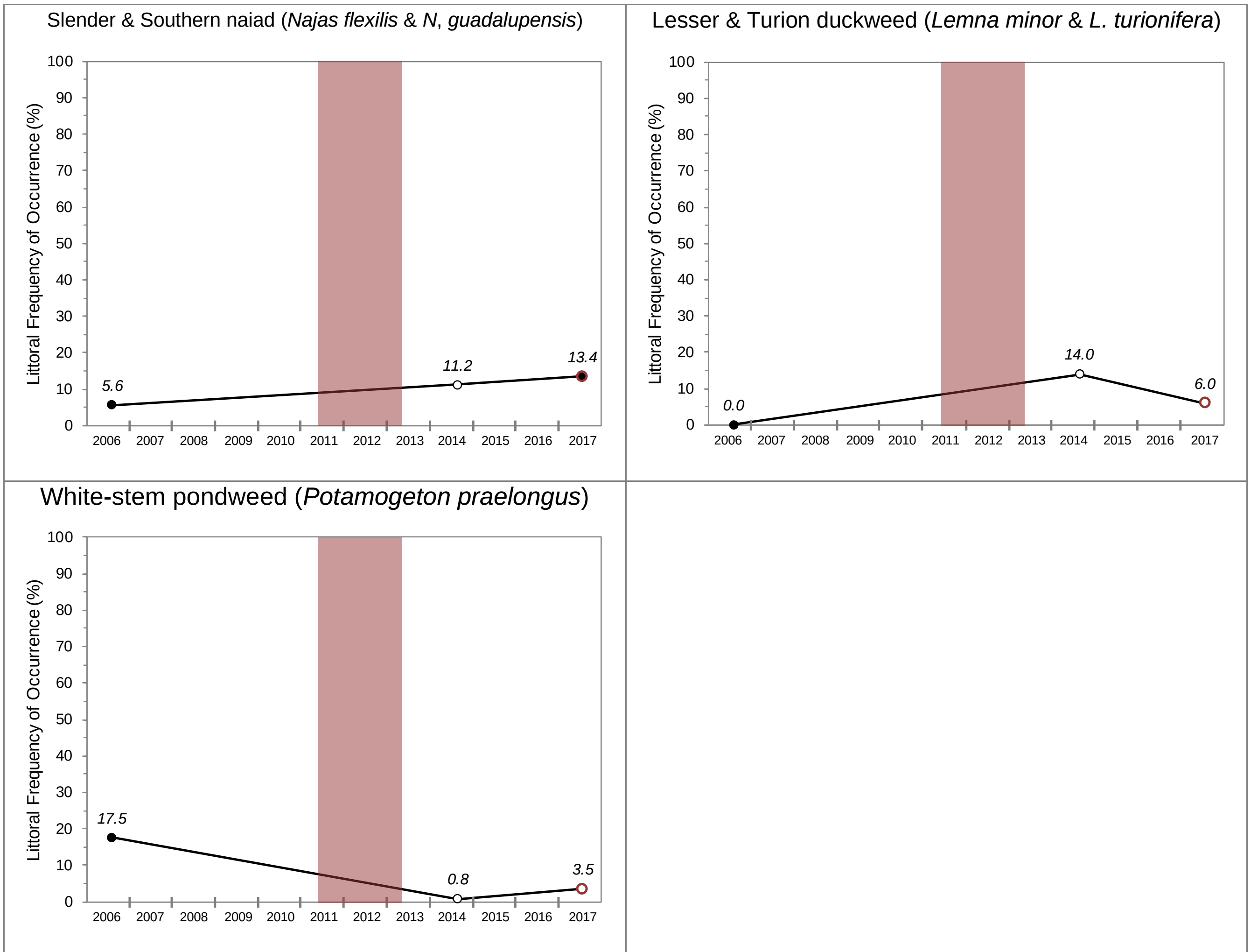


Figure 3.4-6 continued. Lake Iola littoral frequency of occurrence of aquatic plant species from 2006 (pre-drawdown), 2014 and 2017 (post-drawdown). Pink-shaded area indicates period of water level drawdown. Open circle indicates statistically valid change in occurrence from previous survey; red circle outline in 2017 indicates statistically valid change in occurrence from 2006 (Chi-square α = 0.05). Created using data from 2006 (N = 251), 2014 (N = 385) and 2017 (N = 201) whole-lake point-intercept surveys.

As discussed in the primer section, the calculations used to create 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 incidentally located species. The native species encountered on the rake during the 2006, 2014, and 2017 point-intercept surveys and their conservatism values were used to calculate the FQI of Lake Iola's aquatic plant community for these three years (equation shown below).

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

Figure 3.4-7 compares the 2006, 2014, and 2017 FQI components of Lake Iola to median values of lakes within the North Central Hardwood Forests (NCHF) ecoregion and lakes throughout Wisconsin. The number of native aquatic plant species recorded on the rake during the point-intercept surveys, or the native species richness, increased from 27 in 2006 prior to the water level drawdown to 37 in 2014 following the water level drawdown. Native species richness then decreased from 37 in 2014 to 29 in 2017.

The decrease in native species richness from 2014 to 2017 is believed to be due to differences in sampling effort between these two years and is not an indication that native species were lost from the lake between these two surveys. As mentioned earlier, given the lower biomass of aquatic plants in 2014 following the drawdown, surveyors were able to access and sample over 180 more sampling locations in 2014 which were not accessible in 2017 due to increased plant growth. Many of the additional species recorded on the rake in 2014 included emergent species, most of which were recorded as incidentals in 2017. Again, the change in species richness between 2014 and 2017 is largely due to differences in sampling effort and does not represent a loss of species. The native species richness recorded in all three years exceeds the upper quartile value for lakes in the NCHF ecoregion and for lakes statewide.

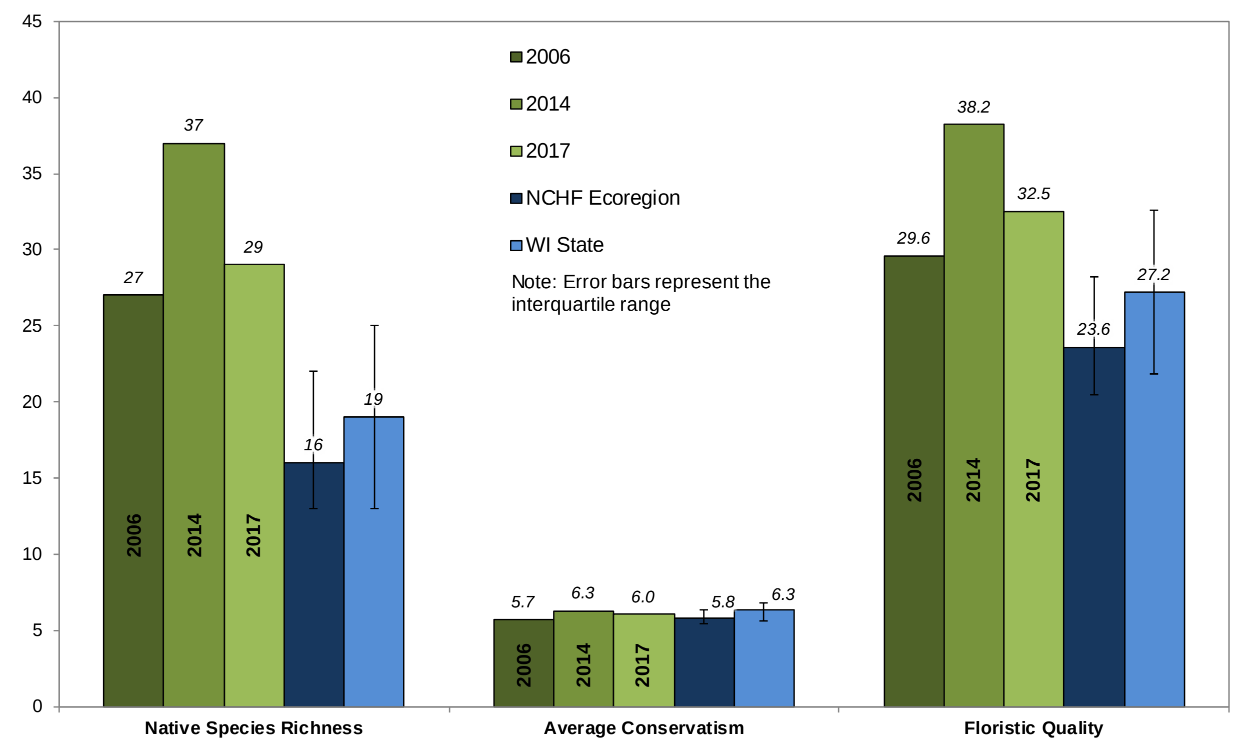


Figure 3.4-7. Lake Iola 2006, 2014 and 2017 Floristic Quality Assessment. Created using data from Onterra 2006, WDNR 2014 and Onterra 2017 point-intercept surveys. Analysis follows Nichols (1999).

The average conservatism of Lake Iola's aquatic plant community increased from 5.7 in 2006 to 6.3 in 2014 (Figure 3.4-7). The average conservatism decreased slightly from 6.3 in 2014 to 6.0 in 2017. Lake Iola's 2017 average conservatism falls above the median value for lakes within the NCHF ecoregion but below the median for lakes stateside. In other words, Lake Iola contains a higher number of environmentally-sensitive aquatic plant species when compared to other lakes within the ecoregion, but contains a lower number of environmentally-sensitive plant species when compared to other lakes throughout Wisconsin.

Using Lake Iola's native species richness and average conservatism to calculate the FQI (equation above) indicates that the lake's FQI increased from 29.6 in 2006 to 38.2 in 2014. The FQI in 2017 declined slightly to 32.5 but still exceeds the 75th percentile for lakes within the NCHF ecoregion and is near the 75th percentile for lakes throughout Wisconsin (Figure 3.4-7). Overall, this analysis indicates that the quality of Lake Iola's native aquatic plant community has increased between the 2006 pre-drawdown and 2014 and 2017 post-drawdown surveys. The native aquatic plant community in Lake Iola is currently of higher quality than the majority of lakes within the NCHF ecoregion.

As explained earlier, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Lake Iola contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Lake Iola's diversity value ranks. In addition, this analysis allows for a comparison of aquatic plant diversity in Lake Iola from pre- and post-drawdown. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 85 lakes within the NCHF Ecoregion (Figure 3.4-8). Using the data collected from the 2006, 2014, and 2017 point-intercept surveys shows that aquatic plant diversity remained high in all three surveys with a value of 0.90. In other words, if two individual aquatic plants were randomly sampled from Lake Iola in 2017, there would be a 90% probability that they would be different species. Lake Iola's 2017 species diversity value exceeds the median value for both lakes within the NCHF ecoregion and lakes throughout Wisconsin.

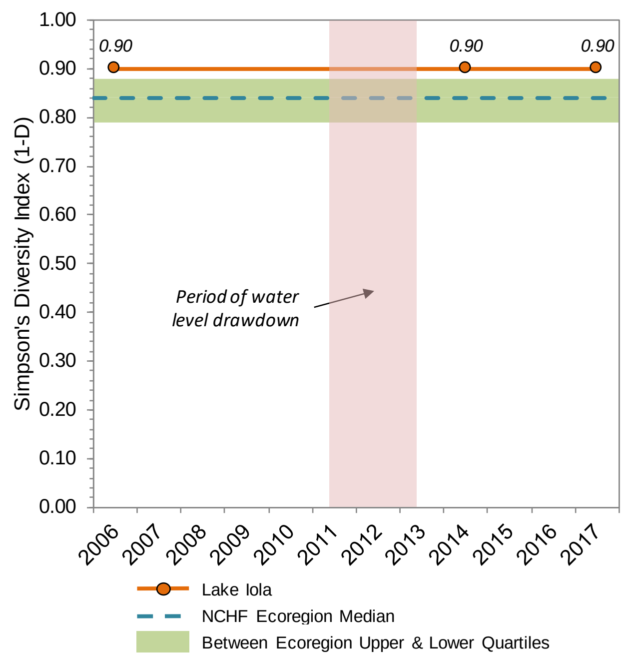


Figure 3.4-8. Lake Iola 2006, 2014 and 2017 aquatic plant community Simpson's Diversity Index. NCHF = North Central Hardwood Forests. Created using data from Onterra 2006, WDNR 2014 and Onterra 2017 whole-lake point-intercept surveys.

As explained earlier, 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 common waterweed was found at 56% of the littoral sampling locations in Lake Iola in 2017, its relative frequency of occurrence is 17% (Figure 3.4-9). Explained another way, if 100 plants were randomly sampled from Lake Iola, 17 would be common waterweed, 15 would be various-leaved watermilfoil, 14 would be muskgrasses, etc.

Figure 3.4-9 displays the relative frequency of occurrence of aquatic plant species in Lake Iola from 2006, 2014 and 2017. Overall, in all three surveys approximately 50% of the aquatic plant community is comprised of four species and while the species composition has changed slightly from 2006 to 2017, the lake is not overly-dominated by one or two species. The lack of one or two dominant plant species in Lake Iola yields high species diversity.

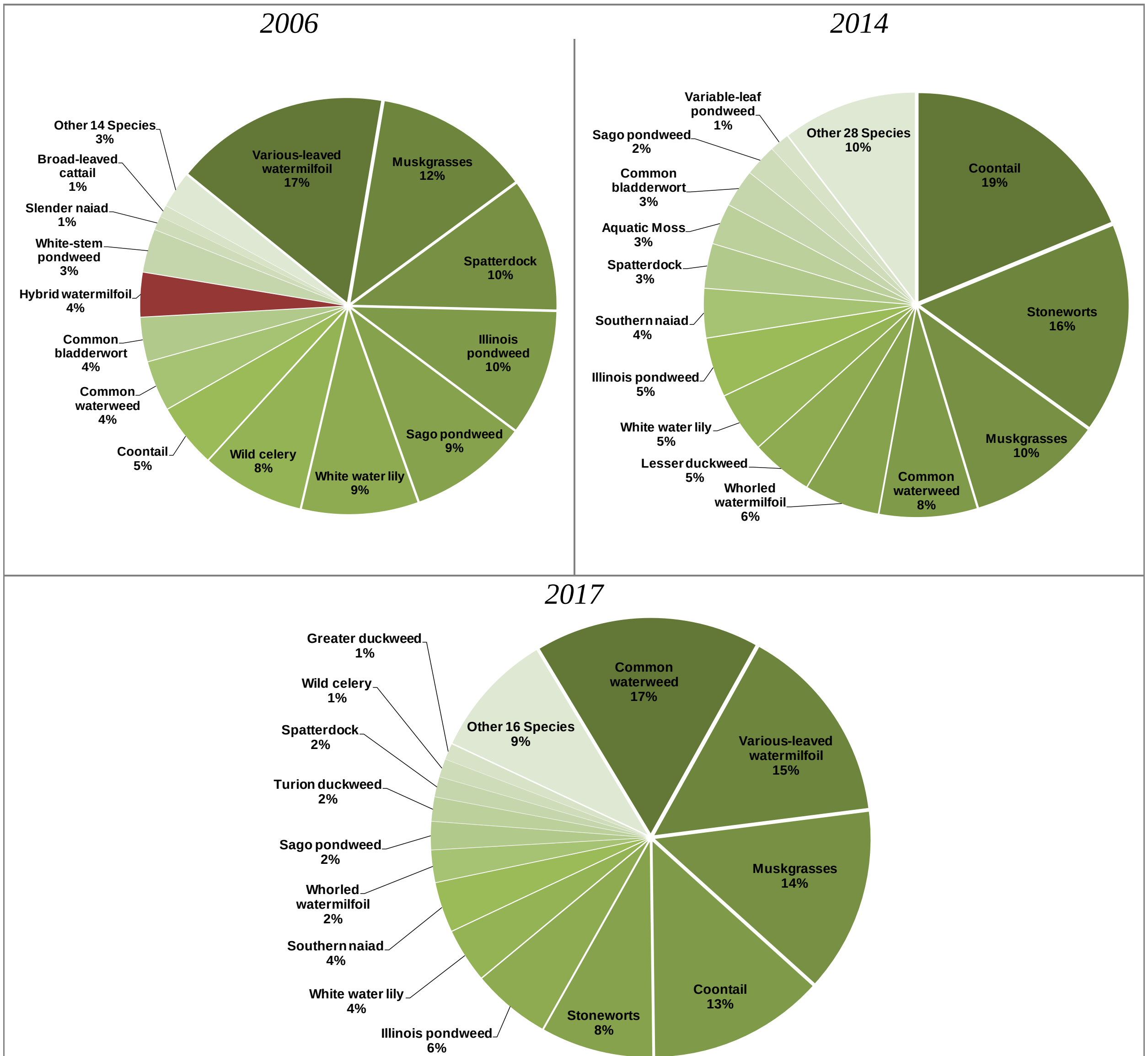


Figure 3.4-9. Lake Iola relative plant littoral frequency of occurrence. Created using data from Onterra (2006), WDNR (2014) and Onterra (2017) point-intercept surveys.

Emergent & Floating-leaf Aquatic Plant Communities

The 2017 community mapping survey indicated that approximately 135 acres contains emergent and floating-leaf aquatic plant communities (Table 3.4-2 and Maps 8-9). These communities were comprised of 19 aquatic plant species, four more than were located during the surveys in 2006 (Table 3.4-1). These communities typically respond positively to water level drawdowns and initially increase in area. However, these communities tend to decrease in subsequent years with stable water levels. In 2006 approximately 172 acres contained emergent and floating-leaf plant communities. Onterra ecologists were unable to map these communities in the upstream-most portion of the lake in 2017 due to aquatic plant growth and shallow water. Comparing the same areas of the lake that were mapped in both 2006 and 2017 indicates that emergent and floating-leaf aquatic plant communities have increased by approximately 30 acres over this time period. While the areal coverage of these communities increased between 2006 and 2017, the point-intercept survey indicates they have become less dense as indicated by the reductions in occurrence of spatterdock and white water lily.

Table 3.4-2. Lake Iola 2006 and 2017 acres of emergent and floating-leaf aquatic plant communities. Created using data from the 2006 and 2017 aquatic plant community mapping survey. Locations of these communities are displayed in Maps 8 & 9. Please note that upstream-most area which was mapped in 2006 was not accessible and not mapped in 2017.

Plant Community	2006 Acres	2017 Acres
Emergent	1.7	0.3
Floating-leaf	70.1	36.1
Mixed Emergent & Floating-leaf	100.4	99.0
Total	**172.3**	**135.4**

In 2017, a plant specimen collected and initially identified as hardstem bulrush (*Schoenoplectus acutus*) was later identified as slender bulrush (*S. heterochaetus*) by the UW-Stevens Point Herbarium. Slender bulrush is very similar in appearance to hardstem bulrush and is listed as critically imperiled in Wisconsin due to very few population occurrences (WDNR NHI 2016). The common and widespread hardstem bulrush was recorded in Lake Iola in previous surveys, so it is unclear if the lake supports populations of both hardstem and slender bulrush or if previously-identified hardstem bulrush were misidentified. In 2017, the hardstem and/or slender bulrush populations were primarily located growing in shallow water around the islands and the adjacent shoreline in the southeastern portion of the lake (Map 9). Given slender bulrush is listed as critically imperiled in Wisconsin, the LILD should focus on protecting these important emergent plant communities.

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 Lake Iola. 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.

Non-native Plants in Lake Iola

Curly-leaf pondweed

Curly-leaf pondweed (Photograph 3.4-6) was first documented in Lake Iola in 2006. During the 2017 late-May Early-Season AIS Survey in Lake Iola, Onterra ecologists mapped approximately

6.3 acres of CLP (Map 7). Of the 6.3 acres, approximately 4.5 acres (72%) was comprised of colonies with a density rating of *scattered*, while 1.8 acres (28%) was comprised of *highly scattered* plants. While CLP is widespread throughout the lake, the population observed in 2017 was mainly comprised of single plants, clumps of plants, and low-density colonies. In a follow-up survey completed in June 2018, CLP was mapped utilizing the same methodology as in 2017. CLP was found to occur in approximately the same areas during 2018 as in 2017. During 2018 a total of 8.7 acres of CLP was mapped via polygons and was nearly equally split between *scattered* and *high scattered* plants. This is a slight increase in acreage, but overall, including the fact that less point-mapped data were marked overall (Map 7), the CLP population in Lake Iola did not see significant change from 2017 to 2018.

The upstream-most portion of the lake was non-navigable due to a combination of shallow water and surface-matted plants in 2017 and 2018, but the CLP population did extend into this area. As discussed earlier, CLP naturally senesces in early summer, and its littoral occurrence of 2.0% as determined from the July 2017 point-intercept survey likely underestimates this population. If the point-intercept survey had been completed in early summer when CLP was at or near it peak growth, its littoral occurrence would likely have been higher.

Eurasian watermilfoil & Hybrid watermilfoil

Eurasian watermilfoil (EWM; Photograph 3.4-6) was first documented in Lake Iola in 2011. Hybrid watermilfoil (HWM), a cross between EWM and the native northern watermilfoil and often more aggressive plant than pure-strain EWM, was confirmed in 2014 via DNA analysis. Mapping of HWM typically occurs in mid- to late-summer as this is when this plant is at or near is peak growth. However, given the thick mats of native plants within Lake Iola during the late summers of 2017 and 2018, mapping of HWM was not completed at that time. Because of this, locations of HWM mapped during the Early-Season AIS Survey are discussed here for both 2017 and 2018. The Early-Season AIS Surveys revealed that the HWM population in Lake Iola is primarily comprised of single plants with some larger clumps of plants observed (Map 10).

As is discussed earlier in this section, winter water level drawdowns have shown to be an effective strategy for controlling EWM populations. In Lake Iola, the HWM population declined in occurrence by 96% from its pre-drawdown occurrence of 18% in 2006 to 1% in 2014. While the occurrence of HWM in 2017 was measured at 3%, this was not statistically different from its occurrence in 2014 indicating that the population has remained small over this three-year period. Comparing the mapping results from 2017 and 2018 (Map 10) shows that the populating likely saw insignificant change from one growing season to the next. While HWM certainly has the capacity to create nuisance conditions, most of the nuisance growth of aquatic plants in Lake Iola in 2017 and 2018 was caused by the native various-leaved watermilfoil and common waterweed.

Curly-leaf pondweed	Eurasian watermilfoil	Purple loosestrife
		

Photograph 3.4-6. Non-native aquatic plants located in Lake Iola in 2017. Photo credit Onterra.

Purple Loosestrife

Purple loosestrife (Photograph 3.4-6) is a perennial herbaceous wetland plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

Purple loosestrife occurrences were located growing in a number of wetland areas along Lake Iola's shoreline (Maps 8 & 9). All of these occurrences were comprised of a single or few plants, and no large monotypic colonies were observed. 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.

Stakeholder Survey Responses to Aquatic Vegetation within Lake Iola

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.4-10 and 3.4-11 display the responses of members of Lake Iola to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed.

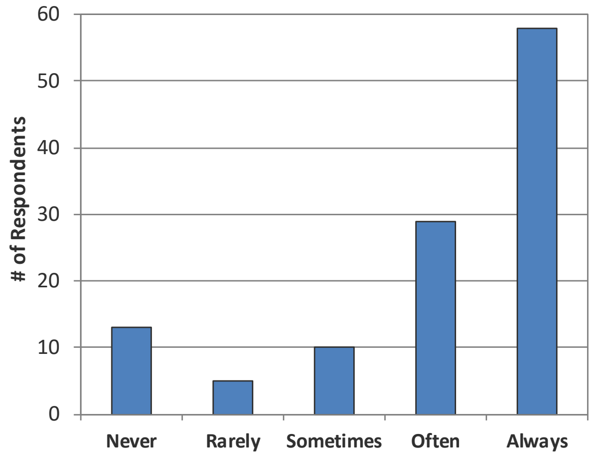
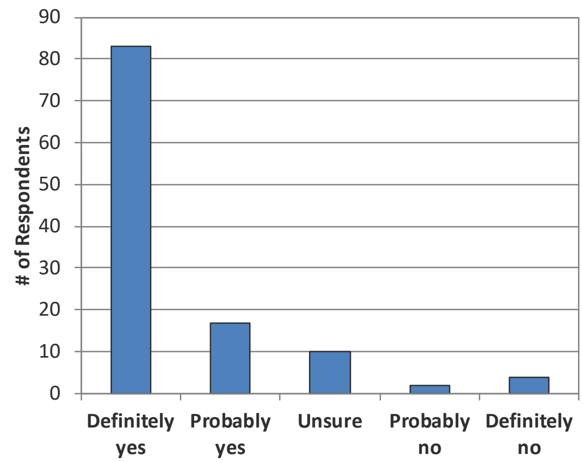
	

Figure 3.4-10. Stakeholder survey response Question #26. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Lake Iola?	**Figure 3.4-11. Stakeholder survey response Question #27.** Do you believe aquatic plant control is needed on Lake Iola?

When asked how often aquatic plant growth during the open water negatively impacts enjoyment of Lake Iola, the majority of stakeholder survey respondents (76%) indicated *often* or *always*, 9% indicated *sometimes*, 4% indicated *rarely*, and 11% indicated *never* (Figure 3.4-10). Given the excessive aquatic plant growth in Lake Iola, 86% of stakeholder survey respondents indicated that they believe aquatic plant control is *definitely* or *probably* needed in Lake Iola, while 5% indicated aquatic plant control is *probably not* or *definitely not* needed, and 9% were *unsure* (Figure 3.4-11). As is discussed in the Aquatic Plant Primer section, a number of management strategies are available for alleviating nuisance aquatic plant growth. The management strategy that will be taken to manage nuisance aquatic plant growth in Lake Iola is discussed within the Implementation Plan section.

3.5 Aquatic Invasive Species in Lake Iola

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

Table 3.5-1. AIS present within Lake Iola

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Hybrid watermilfoil	*Myriophyllum spicatum X M. sibiricum*	Section 3.4 – Aquatic Plants
	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.4 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 3.4 – Aquatic Plants
Invertebrates	Banded mystery snail	*Viviparus georgianus*	Section 3.5 - Aquatic Invasive Species

Figure 3.5-1 displays the aquatic invasive species that Lake Iola stakeholder survey respondents believe are in Lake Iola. Only the species present in Lake Iola 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).

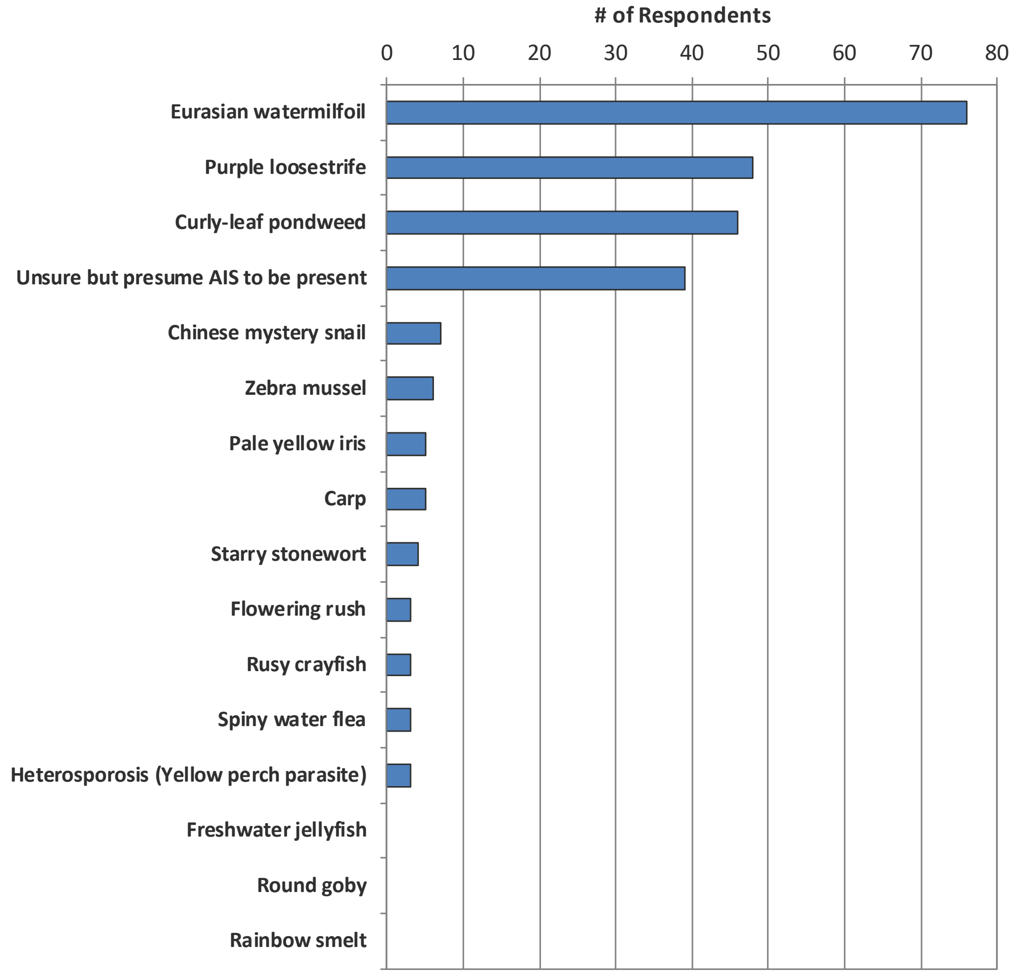


Figure 3.5-1. Stakeholder survey responses to Question #23. Which aquatic invasive species do you believe are in Lake Iola?

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 Lake Iola. 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 Jason Breeggemann (WDNR 2018).

Lake Iola 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 Lake Iola 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.

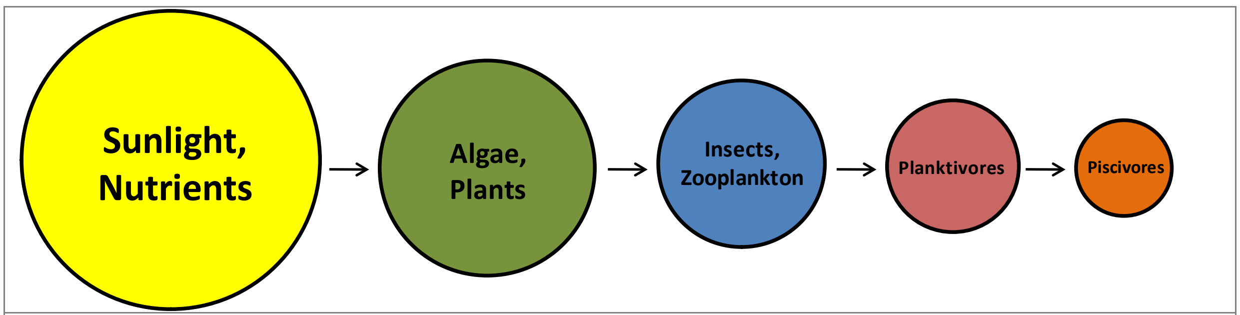


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Lake Iola is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Lake Iola should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. 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 fish species found in past surveys of Lake Iola include white sucker (*Catostomus commersonii*), blackchin shiner (*Notropis* *heterodon*), common shiner (*Luxilus cornutus*), creek chub (*Semotilus atromaculatus*), golden shiner (*Notemigonus crysoleucas*), grass pickerel (*Esox americanus vermiculatus*) and the lake chubsucker (*Erimyzon sucetta*). The lake chubsucker is a special concern species in Wisconsin due to a restricted range, few populations, recent declines, or other factors (WDNR NHI 2016). Its global status, however, is considered secure and at a very low risk for extinction.

Table 3.6-1. Gamefish present in Lake Iola 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
Brown Trout (*Salmo trutta*)	18	October - December	Large streams to small spring-fed tributaries with gravel bottom	Aquatic invertebrates, terrestrial insects, worms, fish, and crayfish
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
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

Photograph 3.6-2. Fingerling largemouth bass.

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 permitted hatcheries (Photograph 3.6-2). Stocking of 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. Prior to the drawdown in 2011-2012, Lake Iola was a self-sustaining fishery, meaning no stocking was needed. However, stocking began in 2013 to assist in rebuilding the fishery after the drawdown (Breeggemann 2018). Lake Iola was stocked from 2013 to 2018 with northern pike, bluegill, yellow perch, and largemouth bass (Table 3.6-2). As of 2017, stocking for largemouth bass and bluegill was suspended due to documentation of a sustainable naturally reproducing population of both species. Future stocking efforts of yellow perch and black crappie are being considered by the WDNR because of low population numbers documented in recent fisheries surveys (Breeggemann 2018).

Table 3.6-2. Stocking data available for Lake Iola (2013-2018).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
2013	Largemouth Bass	Unspecified	Large Fingerling	5,148	2.1
2013	Northern Pike	Mud Lake, Madison Chain of Lakes	Small Fingerling	15,451	4.5
2014	Largemouth Bass	Unspecified	Large Fingerling	5,125	3.2
2014	Northern Pike	Mud Lake, Madison Chain of Lakes	Small Fingerling	15,442	2.7
2015	Largemouth Bass	Unspecified	Large Fingerling	11,012	1.9
2016	Bluegill	Unspecified	Large Fingerling	18,925	0.5
2018	Yellow Perch	Unspecified	Large Fingerling	661	5.0

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the most important reason for owning property on or near Lake Iola (Question #16). Figure 3.6-2 displays the fish that Lake Iola stakeholders enjoy catching the most, with bluegill/sunfish, largemouth bass and northern pike being the most popular. Approximately 76% of these same respondents believed that the quality of fishing on the lake was either fair or poor (Figure 3.6-3). Approximately 75% of respondents who fish Lake Iola believe the quality of fishing is somewhat worse or much worse since they first started fishing the lake (Figure 3.6-4). It is likely that angler perception of the quality of the fishery stems from the relatively recent impacts to the fishery caused by the drawdown.

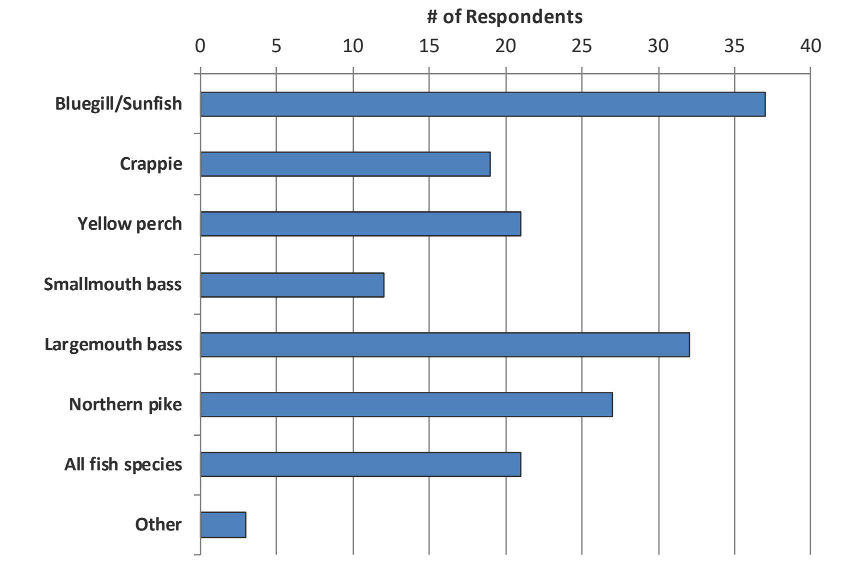


Figure 3.6-2. Stakeholder survey response Question #10. What species of fish do you like to catch on Lake Iola?

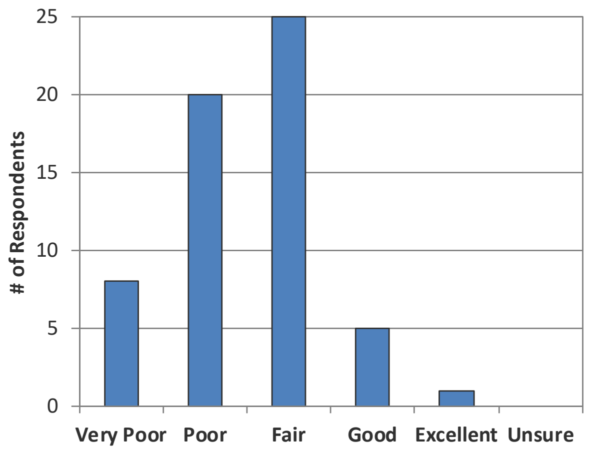
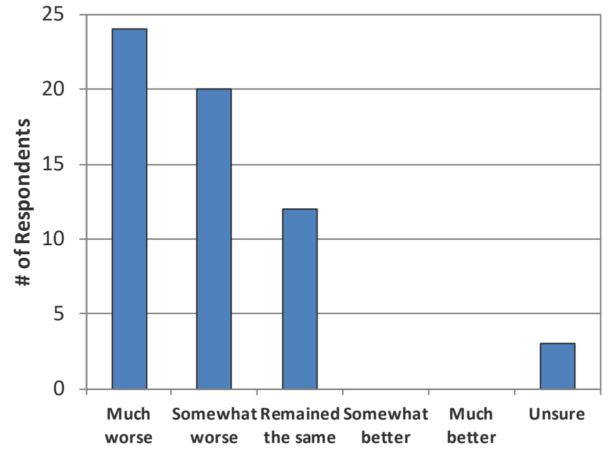
	

Figure 3.6-3. Stakeholder survey response Question #11. How would you describe the current quality of fishing on Lake Iola?	**Figure 3.6-4 Stakeholder survey response Question #12**. How has the quality of fishing changed on Lake Iola since you have started fishing the lake?

Fish Populations and Trends

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

The recovery of gamefish in Lake Iola after the drawdown, has been closely monitored by the WDNR. Surveys were conducted every year from 2013 to 2017. The 2016 survey was intended to assess the largemouth bass and sunfish populations. The 2016 report reviews management objectives and the overall progress of Lake Iola fishery restoration (Appendix F). Largemouth bass was the dominant gamefish captured in 2016, with size structure and abundance at moderate levels (WDNR 2016). The panfish populations were mainly comprised of bluegill and pumpkinseed with moderate abundance and low size structure (WDNR 2016).

Lake Iola 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, 84% of the substrate sampled in the littoral zone of Lake Iola were soft sediments and 16% was composed of sand.

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 335 pieces of coarse woody habitat along the shores of Lake Iola, resulting in a ratio of approximately 31 pieces per mile of shoreline. Fisheries Biologists do not suggest a specific number of fish sticks for a lake but rather highly encourage their installation wherever possible. To learn how Lake Iola's coarse woody habitat is compared to other lakes in its region please refer to section 3.3.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats. 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 Lake Iola Lake District 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 Lake Iola.

Regulations

Regulations for Lake Iola gamefish species as of February 2020 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.

Iola Lake harbors an excellent panfish fishery which receives a lot of fishing pressure during the winter months. The WDNR worked with the Lake Iola Lake District to change the panfish regulation on Iola Lake from a daily bag limit of 25 to 10 to help protect this fishery. This proposal underwent review at the state legislature and governor's office during the winter of 2019/2020. The proposal was signed into law and will go into effect on April 1, 2020.

Table 3.6-3. WDNR fishing regulations for Lake Iola (As of February 2020).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass and largemouth bass	5	14"	May 4, 2019 to March 1, 2020
Muskellunge and hybrids	1	40"	May 25, 2019 to November 30, 2019
Northern pike	5	None	May 4, 2019 to March 1, 2020
Walleye, sauger, and hybrids	5	15"	May 4, 2019 to March 1, 2020
Bullheads	Unlimited	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with up to 3 hooks, baits, or lures, per angler.

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 primary goal by the WDNR is to ensure that the Lake Iola fishery recovers following the drawdown. (Breeggemann 2018). During the 2017 WDNR fisheries survey, 12 largemouth bass between 2.8 – 4 inches were captured (Breeggemann 2018). This suggests natural reproduction of largemouth bass is occurring rendering stocking unnecessary. Overall the fishery is recovering well, and there may be a future possibility of yellow perch and black crappie stocking to provide additional fishing opportunities (Breeggemann 2018). The next comprehensive WDNR fish survey is scheduled for Spring 2020.

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 Lake Iola ecosystem.
2) Collect detailed information regarding invasive and native plant species within the lake to better understand the impact the June of 2011 to May of 2013 full water level drawdown had on Lake Iola's aquatic plant community.
3) Collect sociological information from Lake Iola 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 Lake Iola ecosystem, the folks that care about the lakes, and what needs to be completed to protect and enhance them.

Lake Iola provides many recreational opportunities for shoreland property owners, Village of Iola residents, and others that visit the area; including boating, fishing, wildlife viewing, and of course the tranquility of a lake. The lake was created by small dam on the South Branch Little Wolf River. It is a manmade lake and that fact must be strongly considered in managing the system and in the expectations lake users have for its condition. This concept was a primary talking point at all meetings with the LILD and within the report sections above.

Lake Iola has a very large surface watershed draining to it. In fact, for each acre of lake surface, there is 72 acres of land draining to it. Natural lakes with that high of a watershed to lake area ratios are rare because sufficient water flows through the lake to erode any barriers holding the water back. As discussed in the Watershed Section 3.2, the size of Lake Iola's watershed impacts the lake's water quality greatly. So, it is not just the way the land is used, for example, croplands or forests, it is actually the amount of land draining to the lake. A water quality modeling exercise was completed as a part of this project that simulated converting 50% of the existing row crop landcover, which exports the greatest amount of phosphorus/acre, to forest land, which exports the least amount of phosphorus/acre. Currently, Lake Iola is considered to be eutrophic- meaning it is highly productive in producing aquatic plants. Even with completing a likely unrealistic action such as converting 50% of the watershed's existing row crop acreage to forest, the lake would still be eutrophic. This is not unique to Lake Iola; all millponds exhibit this issue to some extent.

As alluded to above, Lake Iola is considered highly productive, which means that it can support high biomasses of aquatic plants. Plant growth in Lake Iola is largely controlled by the amount of phosphorus available to support that growth. Little water quality data exists for Lake Iola, which makes long-term trend analysis impossible. The phosphorus readings collected during 2017, as discussed in the Water Quality Section 3.1, were the highest recorded in Lake Iola's limited database. However, two of the five phosphorus samples analyzed during the 2017 growing season were collected following large storm events, which lead to high amounts of runoff and elevated phosphorus levels. Under normal conditions, Lake Iola's phosphorus levels are considered good for shallow lowland drainage lakes. Free-floating algae (phytoplankton) are normally relatively low in Lake Iola. Which leads to the lake's typically clear water.

Shallow, productive lakes like Iola are either in a *clear state* or a *turbid state*. Turbid state lakes are those where phytoplankton dominate the system and there are few vascular plants (complex plants mostly with roots, stems, and leaves). These lakes have frequent algae blooms, turbid water, and often look like pea soup. Clear state lakes, like Lake Iola, exhibit their productivity in the form of vascular plants and not phytoplankton. As a result, these lakes have clear water. While competition for nutrients and light between the vascular plants and phytoplankton is part of what determines if a lake is in a clear state or turbid state, zooplankton, which are very small crustaceans, such as daphnia and copepods, play a large role in the determination as well. The high biomass of vascular plant growth in clear state lakes provides ample cover for zooplankton from predation by fish. If the vascular plants are removed, the lake's zooplankton population is severely impacted by fish predation and phytoplankton levels increase. Therefore, without its vascular plant population, Lake Iola would be in a turbid state.

Lake Iola does frequently suffer from filamentous algae mat buildup, especially in areas supporting high densities of submerged aquatic plants. These types of algae are different than the phytoplankton discussed above. Most species of filamentous algae start growing on the bottom of the lake in long strings of cells (filaments) by up taking nutrients directly from the sediment. As the population grows, the filaments become denser. Often, there is a build-up of gases from decomposition and photosynthesis under the dense mats, which lifts them to the surface. These mats then get tangled on submergent vegetation. This is unsightly, especially as the algae mats decay. Unfortunately, there is nothing that can be done to prevent this from occurring; it is a symptom of a eutrophic waterbody with good water clarity and high nutrient levels in its sediments.

Lake Iola supports high level of vascular plant biomass in the form of submergent, emergent, and floating-leaf aquatic plants. In many areas of the lake these plants become so dense that they negatively impact recreation on the lake and are a nuisance. Still, the aquatic plant community in Lake Iola is considered very healthy in a number of ways. It is diverse and exhibits a floristic quality higher than most lakes of its type in the state and most lakes in its ecoregion. And, as described above, it is this plant community that allows Lake Iola to sustain such clear water.

The full water level drawdown that was conducted on Lake Iola over a 23-month period from June 2011 to May 2013 definitely had impacts on the lake's aquatic plant community. The Aquatic Plant Section 3.4 contains an in-depth discussion of those changes. It also discusses that we cannot attribute all of the changes measured in the lake's plant community to the drawdown because a point-intercept survey was not completed the year or even two years prior to the drawdown. In fact, the pre-drawdown data is from 2006, so many natural changes could have occurred from then to the time the drawdown was initiated.

The point-intercept survey method is the primary methodology used in Wisconsin for collecting quantitative data about a lake's aquatic plant community. Utilizing the point-intercept methodology allows for data from the same lake collected from different years to be statistically compared. It also allows for surveys from different lakes to be compared as well. Point-intercept surveys were completed on Lake Iola during 2006, 2014, and 2017. The surveys completed after the drawdown indicated that while aquatic plants occurred in the same areas before and after the drawdown, following the drawdown, they were slightly less dense. Floristic quality showed an increase immediately following the drawdown, but was back down to slightly above pre-drawdown levels by 2017. Species diversity, which is high in Lake Iola, stayed exactly the same over the three surveys. The occurrence of some aquatic plant species decreased following the drawdown while others increased or stayed relatively the same. Of interest, various-leaved/whorled milfoil, the most common species in the lake in 2006, and the one that was likely cause the most nuisance, decreased significantly following the drawdown, but returned pre-drawdown levels by 2017. Eurasian watermilfoil/hybrid water milfoil was significantly lower following the drawdown and remained low during 2017. Onterra crews mapped Eurasian watermilfoil/hybrid water milfoil during 2018 and those results indicate that it remained low at that time as well. Eurasian watermilfoil/hybrid water milfoil are typically greatly controlled with drawdowns, even drawdowns that extend through a single winter.

In 2017 and 2018, aquatic plant surveys completed by Onterra staff indicated that the two primary invasive plant species of concern in Lake Iola, curly-leaf pondweed and Eurasian watermilfoil/hybrid water milfoil were at low densities and did not require control actions. This is an updated approach compared to the guidance provided by Onterra during the 2006 project. In 2006, best management practices called for treating of aquatic invasive plant species with herbicides to keep populations low. Since 2006, lake managers, including managers at Onterra, have learned that utilizing small treatment areas (those smaller than 5 acres), do not provide greater than seasonal control. In other words, treatments done in open water in areas less than 5 acres do not really kill the target species, they just knock it back for the year. Studies have shown that this applies to liquid and granular forms of herbicides. Best management practices utilized currently do not include spot treatments of areas less than 5 acres unless those areas are enclosed on three sides, like in a small bay or channel. The Implementation Plan in Section 5.0 utilizes current best management practices for the control of aquatic invasive plant species.

Section 5.0 contains the Implementation Plan developed through a series of three meetings, each lasting 3 or more hours, with the LILD Planning Committee. That committee also met on its own for over a dozen hours to determine the district's path in continued harvesting on the lake (see Appendix G for the meeting minutes). The plan is based upon management goals created by the committee. Under each goal are two or more actions the district will initiate to meet the goal. The goals and actions cover the many challenges facing Lake Iola and the challenges facing the district in managing the lake; including informational initiatives, assuring recreational opportunities on the lake, fostering partnerships with other entities involved in managing the lake, controlling invasive species, protecting and enhancing the fishery, and continued monitoring and planning needs. The plan was created by the district to guide how it will manage Lake Iola for the benefit of the people that enjoy the lake and for the lake itself; however, even the best conceived and written plan is worthless if it is not implemented.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the LILD Planning Committee and ecologist/planners from Onterra. It represents the path the LILD 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 Lake Iola stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Protect and Improve the Ecological Health of Lake Iola

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	As soon as possible.
Facilitator:	LILD Board of Commissioners
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. Lake Iola's current planning effort suffered because of a lack of water quality data available to substantiate or dispel lake user comments regarding worsening water quality in the lake. In the past two decades, the only substantial water quality collections have been completed as a part of the district's management planning efforts, which is far too infrequent to allow for long-term trends analysis. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. The LILD volunteers would be trained to monitor the deep hole site as a part of the advanced CLMN program. This includes collecting Secchi disk transparency and sending in water chemistry samples (chlorophyll-a, and total phosphorus) to the Wisconsin State Laboratory of Hygiene for analysis. The samples are collected once during the spring and three times during the summer. It is important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS). It will be the Board of Commissioner's responsibility to ensure that a volunteer is prepared to communicate with WDNR representatives and collect water quality samples each year.
Action Steps:	

1. Trained CLMN volunteer(s) collects data and report results to WDNR and to district members during annual meeting.
2. CLMN volunteer and/or LILD Board of Commissioners facilitate new volunteer(s) as needed
3. Coordinator contacts Ted Johnson (920.424.2104) to acquire necessary materials and training for new volunteer(s)

Management Action: Conduct AIS population control utilizing herbicide spot treatments and winter drawdowns

Timeframe: Begin 2019

Facilitator: LILD Board of Commissioners

Possible Grant: AIS or Small-Scale Planning Grants for monitoring.

Description: The 2008 management simply called for the control of AIS (EWM and CLP) in Lake Iola. The only real limitation to the acreage treated each year was the funding level acceptable to the district members. A great deal has been learned about the effective use of herbicides to battle AIS since that plan was written. This is especially true regarding the characteristics of spot treatments that lead to effective results beyond seasonal control. This management plan utilizes current best management practices regarding the use of herbicides in spot treatment scenarios, taking into account the size of the treatment and susceptibility of dilution due to flow and surrounding, untreated waters.

The EWM and CLP populations were mapped during 2017 and 2018 and found to be infrequent throughout much of the lake. At this level, neither is causing recreational or ecological issues. While the LILD has completed CLP treatments in the past, those treatments were not completed in a manner that would manage the plant on a population scale by repeatedly treating the same areas with the aim of reducing the sediment turion base. Consequently, it is believed that the CLP population in the lake has typically been low. Because the CLP population is currently low and has historically been low, the strategy described below targets EWM only because it has been documented to be as high as 18% (2006 littoral frequency of occurrence (LFOO)). In general, the intent of the spot treatments would be to keep the EWM population below the 30% LFOO that would initiate discussions regarding a winter drawdown. During 2017 the EWM LFOO was 3%.

<u>*Herbicide Spot Treatment*</u>

If the following trigger is met, the LILD would initiate pretreatment monitoring and begin discussions, regarding conducting herbicide spot treatments:

> *Colonized (polygons) areas of dominant EWM where a sufficiently large treatment area can be constructed to hold concentration and exposure times.*

The minimum area would be approximately 3 acres which 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.). Larger areas (>5 acres) or sites in protected parts of the lake are to be targeted with an herbicide spot treatment, more traditional systemic herbicides like 2,4-D may be appropriate and considered. 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 for from the WDNR. The herbicide treatment would occur when surface water temperatures are roughly below 60°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.

Overall, the LILD will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen. Any financial cost will first be approved by the LILD Board of Commissioners.

Winter Water Level Drawdown
The LILD initiated a drawdown between June of 2011 and May of 2013. As discussed in the Vegetation Section 3.4, the drawdown brought about many changes to the lake's aquatic plant community. One being a significant decrease in the EWM population. Winter water level drawdowns are widely known to control EWM if desiccation and/or freezing of sediments occurs in areas that EWM occupies. Still, winter level drawdown also has negative aspects, like the loss of certain native species, short-term impacts to the fishery, and of course the loss of winter recreational opportunities. Therefore, the LILD elects to only consider utilizing a winter water level drawdown if and when the EWM population is very high as evidenced by a FOO of 30% or greater. Please see the following action regarding periodic vegetation monitoring on Lake Iola.

Action Steps:

1. Perform periodic vegetation monitoring as outlined in this management plan.
2. Utilizing local professional assistance and WDNR expertise, assess potential need for herbicide spot treatments based upon examining dense areas of EWM in late-summer and utilizing thresholds described above.
3. If areas are thought to meet the thresholds, an herbicide applicator should be contacted to assess the areas, create a strategy, submit a permit application, and perform the treatment.

4. If the most recent point-intercept survey indicates a 30% EWM FOO, the district board should discuss the issue and contact the WDNR for guidance and permit needs.

Management Action: Conduct periodic quantitative vegetation monitoring on Lake Iola.

Timeframe: Point-Intercept Survey every 3-5 years, Community Mapping every 7-10 years, AIS survey every 2 years.

Possible Grant: Small-Scale Lake Planning Grant or AIS-Education, Prevention, and Planning Grant in <$10,000 category.

Facilitator: LILD Board of Commissioners

Description: As part of the ongoing AIS and nuisance vegetation management program, a whole-lake point-intercept survey will be conducted at a minimum once every 3-5 years. This will allow a continued understanding of the submergent aquatic plant community dynamics within Lake Iola. A point-intercept survey was conducted on Lake Iola in 2017; therefore, the next point-intercept survey will be completed between 2020 and 2022, depending on the level or anticipated need of AIS management being completed.

In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Lake Iola, a community mapping survey would be conducted every 7-10 years. A community mapping survey was conducted on Lake Iola in 2017 as a part of this management planning effort. The next community mapping survey will be completed between 2024 and 2028.

There is a potential for EWM to expand in both density and area more rapidly than can be effectively monitored with the point-intercept surveys; therefore, the LILD will hire consultants to complete meander surveys every two years to monitor primarily EWM.

Action Steps:

See description above.

Management Action: Educate stakeholders on the importance of shoreland condition of Lake Iola.

Timeframe: Initiate 2020

Facilitator: LILD Board of Commissioners

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. 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.

Approximately 18% of Lake Iola's shoreline is considered completely urbanized or developed unnatural (Figure 3.3-2). This limits shoreland habitat, but it also reduces natural buffering of shoreland runoff and allows nutrients to enter the lake. However, 69% of Lake Iola's shoreline remains as undeveloped and natural; therefore, the primary basis of this action is not to drive shoreland restoration on developed property, but to educate shoreland property owners about the importance of protecting existing shorelines that are in natural or near-natural states to keep Lake Iola healthy. If shoreland property owners are interested in restoring their shorelands, information regarding an appropriate WDNR Grant program is below.

As a part of implementing this management plan, the LILD will be creating and utilizing electronic and hardcopy methods of communication with the district members. One of the educational topics that will be visited frequently will be about the importance of healthy and natural shorelands and what property owners can do to make sure their properties are not impacting the lake's ecological health.

The WDNR's Healthy Lakes Initiative Grant program 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 Waupaca 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 provide continued maintenance for 10 years
- Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available

Action Steps:

See description above.

Management Action: Enhance Lake Iola fishery through proper stocking and coarse woody habitat additions.

Timeframe: Initiate 2020

Facilitator: LILD Board of Commissioners

Description: Lake Iola is a relatively productive system with excellent capacity and habitat diversity to produce a high-quality fishery. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Many anglers assume that a lake's fishery can be 'forced' to its potential through stocking efforts. This is not the case in any lake as habitat availability, existing fish populations, level and make up of forage fish populations, and of course angler pressure, are critical to reaching and maintaining fishery potential. A primary objective of this action is to initiate frequent and productive communications with WDNR fisheries personnel to; 1) provide information regarding Lake Iola's fishery potential to district members, 2) assure that the LILD is doing what it can to aid local fisheries staff in performing their duties, and 3) that the WDNR staff understands the goals and concerns of the LILD regarding Iola's fishery. Ultimately, this will lead to a productive and effective stocking program on Lake Iola.

Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. Or, which is the case regarding much of Lake Iola's shoreline, prior to the lake being created, the area was a wetland that did not support large tree growth, so there is little natural CWH. 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 WDNR's Healthy Lakes Initiative Grant allows partial cost coverage for coarse woody habitat improvements (referred to as "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:
  - The landowner would need to commit to leaving the area un-mowed
  - The landowner would need to implement a native planting (also cost share through 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 or Board of Commissioners to direct this initiative.
2. Facilitator contacts WDNR Lakes Coordinator and WDNR Fisheries Biologist to gather information on current stocking efforts, future stocking efforts and regarding initiating and conducting coarse woody habitat projects on Lake Iola.
3. The LILD will encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites for future projects.
4. The LILD promotes a better understanding of the lake's fishery and its capacity via educational topics included in electronic and hardcopy communications with district members.

Management Action: Continue Canada goose population control on and around Lake Iola.

Timeframe: Continuation of current effort.

Facilitator: LILD Board of Commissioners

Description: Since 2015, the LILD has actively controlled Canada goose populations in and around Lake Iola through egg addling with oil and adult goose collection and euthanasia. Vegetated and wooded natural shorelines are the best way to discourage geese from coming on to properties. Still, green space exists around the lake as it allows riparians to use the nearshore areas for recreation. High populations of geese can leave massive quantities of aesthetically unpleasing waste behind as well as damage valuable native plants, landscaping, and agricultural crops. Further, geese are a host in the lifecycle of the swimmers' itch parasite and their feces can bring about other human health issues.

The LILD completes two actions as a part of this program with proper permitting from the US Fish and Wildlife Service and WDNR; 1) egg addling with corn oil and 2) gathering of live adults while they are molting and having them euthanized by professionals. 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. Egg addling is initiated by volunteers following ice-out and the need for the adult action is discussed at the annual meeting and based upon an estimate of 40 adults or more being spotted around the lake. If the adult harvest is needed, it is completed by the end of June and the goose meat is distributed to local food pantries.

Action Steps:

1. Obtain egg oiling and other permits in the spring.
2. Locate nests and oil eggs until nesting season is over.
3. Determine need for harvest at LILD annual meeting.
4. Volunteer group to work with USFWS group to round up geese during their annual molt.
5. Processed meat from juveniles goes to the MacKenzie Center in Poynette, WI for animal feed, while processed meat in 1-lb packages from the adults are donated to food pantries either locally or around the state.

Management Goal 2: Assure Open Water Recreational Opportunities on Lake Iola

<u>Management Action:</u>	**Utilize mechanical harvesting to provide riparian access to open water areas of Lake Iola**
Timeframe:	Continuation of current effort with updated harvesting map and the use of a Village of Iola-owned mechanical harvester that would be leased and operated by the LILD.
Potential Grant:	Wisconsin Waterways Commission Grant
Facilitator:	LILD Board of Commissioners
Description:	The LILD understands the importance of native aquatic vegetation within Lake Iola. However, nuisance aquatic plant conditions exist in much of the lake, primarily caused by various-leaved watermilfoil, loosely-rooted vegetation (coontail, common waterweed, southern naiad), and floating matts of filamentous algae.

The LILD supports the reasonable and environmentally sound actions to facilitate navigability on Lake Iola. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns and fishing. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area than necessary.

The following typical mechanical harvesting permit conditions will be adhered to:

1) Mechanical harvesting will not begin, in any given year, prior to June 1st.
2) Harvesting schedule will be available upon request. The WDNR Water Resources Biologist may schedule and conduct an on-site supervision of harvesting activities.
3) Only areas contained within the permit (Map 11) will be harvested without an additional permit from the WDNR.
4) A copy of the current harvesting permit will be kept onboard the harvester at all times. All operators will read and understand the limitation and conditions of the aquatic plant management plan and harvesting permit before they harvest aquatic plants.
5) All harvesting shall not disturb the lake bed sediments of Lake Iola, Waupaca County.
6) All aquatic plants harvested will be removed immediately from the lake. Disposal of plant material occur only areas specified within the permit and in accordance with county and local regulations. Plant material will not be disposed of in wetlands.
7) All mechanical harvesting records will be maintained and readily available to the WDNR upon request. An annual report

summarizing harvesting activities will be provided each year by November 1. The report shall include a map of areas harvested, the total acres harvested, and the total amount of plant material removed from the waterbody.

The WDNR oversees the management of aquatic plants on inland lakes. The manual cutting and raking of native aquatic plant species within a 30-foot-wide area containing a pier, boatlift, or swim raft is exempt from a state permit provided that the cut plants are removed from the lake. However, the use of mechanized or mechanical devices requires a WDNR permit.

Beginning in 2020, management of nuisance levels of aquatic plants will occur on portions of the lake using a mechanical harvester first purchased by the Village of Iola and then leased-to-own by the district (see Appendix H). Harvesting operations will not begin until June 1 or later and follow the harvest and skimming areas displayed on Map11. Harvest operations will be completed in areas 3' or deeper and the cutting deck will not be lower than ½ the depth of water in the area being harvested. Skimming will include the removal of floating vegetation and filamentous algae by placing the cutting deck of the harvester no more than 1' below the water surface. Efforts will be made to minimize the disturbance of sediments during all harvester operations. Harvested vegetation will be land spread at department approved sites.

Action Steps:

1. A new 5-year WDNR permit for mechanical harvesting with the updated harvesting map will be needed in early 2020.

Management Action:	**Conduct nuisance plant treatments using herbicides on an as-needed basis in common use areas of Lake Iola.**
Timeframe:	Continuation of an effort tested in 2018 with an updated treatment map.
Potential Grant:	Not applicable
Facilitator:	LILD Board of Commissioners
Description:	As described in the action above, Lake Iola supports nuisance levels of native aquatic plants that interfere with recreational use, including boating, swimming, and fishing. As described in the action above, the LILD utilizes mechanical harvesting to relieve the nuisance brought on by these plants in appropriate common use areas. Some areas of Lake Iola supporting nuisance vegetation are not appropriate for mechanical harvesting because of shallow water or obstructions, such as near piers or in narrow channels. To alleviate the nuisance brought on by abundant vegetation in these areas, the LILD will utilize herbicide treatments as needed and approved by the department. Two general types of areas will be considered for treatment annually by the LILD;

1) common use lanes primarily located in channels and 2) private use areas consisting of lanes extending 15' on both sides of private piers and extending to open water (likely a harvest area or common use lane).

The areas displayed on Map12 will be considered for treatment each year by the LILD. A consultant will inspect the common use lanes each spring and recommend what areas will be treated at the district's expense. The private use lanes would be treated at the same time as the common use lanes. The total cost of the private use lane application would be divided evenly by the property owners. For the private use lane treatments to be considered, at least 10 property owners must be slated to receive treatment each year. The LILD will submit a single herbicide application permit to the WDNR to cover all of these herbicide treatments. The district will fund the permit application fees each year and keep in mind the following general conditions when proposing areas for herbicide control:

1) Mechanical harvesting is the preferred method for providing pier and channel access where the water is sufficiently deep (appr. 4') to allow harvester operations without disturbing the lakebed.
2) Where water is too shallow for normal harvesting operations, navigation must be substantially obstructed by aquatic plant growth for herbicides to be considered for nuisance relief.
3) Conditions vary from year-to-year; therefore, WDNR supervision may be required prior to herbicide treatments.

In 2018 two channels were treated with a total area of 1.3 acres. The applicator used a mixture of diquat and flumioxazin to complete the treatment. One channel was completely enclosed so a concentration of 1.25 gallons/acre diquat and .33 gallons/acre flumioxazin was applied. The other channel was open on one side so a higher concentration of each herbicide was utilized (1.75 gallons/acre and 0.50 gallons/acre, respectively). This dosing strategy is considered the current best management practice (BMP) for this strategy and resulted in less plants in the application area, but not within the entire channel. Over time, as different herbicides are developed or different species of plants become an issue or do not continue to pose issues, the LILD will update the strategy with guidance applied by the WDNR and applicator.

Action Steps:

1. Utilizing professional assistance and WDNR expertise, assess potential need for herbicide treatment in the four designated channels based upon examining dense areas of all aquatic plants in late spring/early summer.
2. If treatment is needed, follow plan displayed on Map 12.
3. Areas treated will not be harvested, but skimming will be considered on an as-needed basis.
4. Pier treatments for property owners will be considered.
5. LILD creates proposal for bid and selects qualified applicator. Together they complete permit for WDNR for approval.

Management Goal 3: Improve District Member Interest and Involvement

Management Action: Use information to promote lake protection and enjoyment through stakeholder education

Timeframe: 2019

Facilitator: LILD Board of Commissioners

Description: Education represents an effective tool to address many lake issues. The LILD currently maintains a district webpage on the Village of Iola's website and has recently started a Facebook group. The district has considered publishing periodic newsletters and mailing them to all district members. This would involve substantial printing and postage costs with the risk of few off-lake property owners reading the information; therefore, the LILD has not utilized this type of communication.

However, the district has access to several electronic forms of communication, including Facebook, the village website, and of course email. The webpage the district currently maintains is a very useful repository for district information; including meeting minutes and announcement, general district information, and educational materials; however, it requires that the interested individual check back for updates periodically; therefore, it is not reliable for disseminating information quickly. Facebook utilizes a newsfeed to display the information posted by 'friends' and groups the user follows. Facebook is excellent for groups, like the LILD, to get short bits of information out to those that follow the district Facebook group. This can include announcements, pictures, short videos, and links to websites. The links to websites are useful because they allow the district to keep their followers informed regarding updates and additions made to the LILD webpage. The disadvantage to utilizing Facebook is that it requires users to have a subscription, which is free, and check their newsfeed regularly. Email is another useful form of electronic communication that allows the district to disseminate news quickly at low cost. Emails can contain short informational pieces, pictures, and links to information on the web.

The LILD will work to build followers of the district Facebook group and to obtain email addresses of district members. However, some district members do not have access to the internet, so it is very important that information will be provided as a part of the announcement of the annual district meeting.

Example Educational Topics for Webpage, email, and Facebook

- Specific topics brought forth in other management actions
- Aquatic invasive species identification
- Basic lake ecology

- Advantages and limitations of mechanical harvesting
- Sedimentation
- Boating safety (promote existing guidelines)
- Shoreline habitat restoration and protection
- Noise and light pollution
- Swimmers itch
- Lake water levels
- Fishing regulations and overfishing
- Minimizing disturbance to spawning fish
- Recreational use of the lake

Action Steps:

See description above.

Management Action:	Promote winter recreation on the lake by organizing an annual Ice Fishing Contest for Youth, held during the Iola Winter Carnival Weekend.
Timeframe:	Annually, the first Saturday in February.
Facilitator:	LILD Board of Commissioners
Description:	Public relations are an important consideration behind all that we do. This event began in 2005 as a way for LILD members to give back to the community for their support of our lake management activities. No tax money is used for the event and the LILD Board maintains a separate fund to support it. Youth aged 16 and younger are eligible for the contest, but families are encouraged to help. Funds are primarily raised at three Saturday summer brat fries, sponsored by the local Sentry Foods store. Special prizes are awarded based on the fish caught, but every child receives something. Photos showing scale are accepted to encourage catch-and-release.

Action Steps:

1. Select available dates for brat fries at Iola Sentry Foods.
2. LILD volunteers run brat fries.
3. LILD Board of Commissioners approves budget.
4. LILD volunteers solicit prizes from area businesses and purchase award prizes with funds raised through brat fries and other donations.
5. LILD volunteers run the contest with assistance from members of local Lions Club.

Management Goal 4: Improve the Capacity of the Lake Iola Lake Management District to Effectively Manage Lake Iola

Management Action: Participate in annual Wisconsin Lakes Partnership Convention.

Timeframe: Annually

Facilitator: LILD Board of Commissioners

Description: Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events throughout the state. The primary event is the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the nation and is specifically suited to the needs of lake associations and districts. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/district.

The LILD will sponsor the attendance of 1-3 district members annually at the convention. Following the attendance of the convention, the members will report specifics to the board of commissioners regarding topics that may be applicable to the management of Lake Iola and operations of the LILD. The attendees will also create a summary in the form of a webpage article and if appropriate, update the district membership at the annual meeting.

Information about the convention can be found at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/convention/default.aspx.

Action Steps:

See description above.

Management Action: Continue LILD's involvement with other entities that have responsibilities in managing (management units) Lake Iola

Timeframe: Continuation of current efforts

Facilitator: LILD Board of Commissioners

Description: The waters of Wisconsin belong to everyone and therefore the objective 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 LILD actively engage with all management entities to enhance the district's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table below:

Action Steps:

See guidelines in Table 5.0-1.

Table 5.0-1 Management Partner List.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Village of Iola	Village Clerk/Treasurer (Betty Aanstad 715.445.2913)	Lake Iola falls within this township.	Once a year, or more as issues arise.	Village staff may be contacted regarding ordinance reviews or questions, and for information on community events
Golden Sands Resource Conservation & Development Council	Staff (715.343.6215)	Nonprofit organization that covers central WI	Once a year, or more as issues arise.	Provide information on conservation and natural resource preservation
Waupaca County Highway Department	Commissioner (Casey Beyersdorf, casey.beyersdorf@co.waupaca.wi.us or 715.258.7152)	Maintains STH 49 & 161.	As needed	Contact to discuss debris management in Hwy 49 & 161 culverts
Waupaca County Land Conservation Department/Committee	County Conservationist (Brian Haase - Brian.Haase@co.waupaca.wi.us or 715.258.6482)	Oversees conservation efforts for land and water projects.	Continuous as it relates to lake and watershed activities	Can aid with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Jason Breeggemann – 920.420.4619)	Manages the fishery of Lake Iola.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery and fish structure
	Lakes Coordinator (Ted Johnson – TedM.Johnson@wisconsin.gov 920.424.2104)	Oversees management plans, grants, all lake activities.	Continuous as it relates to lake management activities	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues including AIS management.
	Citizens Lake Monitoring Network contact (Ted Johnson – 920.424.2104)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Early spring: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
University of Wisconsin – Extension Lakes Program	Eric Olson, Director and Lakes Specialist (715.346.2192) Paul Skawinski, Citizens Lake Monitoring Network Educator (715.346.4853)	Provide general information regarding lakes and lake districts. Assist in CLMN training and education.	As needed.	The UW-Ext Lakes Program is a resource for educational materials and guidance regarding lakes, lake monitoring, and the operations of lake management districts.
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.	LILD members may attend WL's annual conference to keep up-to-date on lake issues.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Lake Iola (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) only, except for spring where a subsurface (S) and bottom (B) sample were taken. Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

	Spring		June	July	August	Fall	Winter
Parameter	**S**	**B**	**S**	**S**	**S**	**S**	**S**
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 Lake Iola'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

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Lake Iola during a May 31, 2017 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Lake Iola 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 on July 25-26, 2017. A point spacing of 40 meters was used resulting in approximately 550 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Lake Iola (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.

Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium.

7.0 LITERATURE CITED

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

Canter, L.W., D.I. Nelson, and J.W. Everett. 1994. Public Perception of Water Quality Risks – Influencing Factors and Enhancement Opportunities. Journal of Environmental Systems. 22(2).

Carpenter, S.R., Kitchell, J.F., and J.R. Hodgson. 1985. Cascading Trophic Interactions and Lake Productivity. BioScience, Vol. 35 (10) pp. 634-639.

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

Christensen, D.L., B.J. Herwig, D.E. Schindler and S.R. Carpenter. 1996. Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. Ecological Applications. Vol. 6, pp 1143-1149.

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

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

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

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

Garrison, P., Jennings, M., Mikulyuk, A., Lyons, J., Rasmussen, P., Hauxwell, J., Wong, D., Brandt, J. and G. Hatzenbeler. 2008. Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest. Pub-SS-1044.

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

Gettys, L.A., W.T. Haller, & M. Bellaud (eds). 2009. *Biology and Control of Aquatic Plants: A Best Management Handbook.* Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp. Available at http://www.aquatics.org/bmp.htm.

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

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

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

Lathrop, R.D., and R.A. Lillie. 1980. Thermal Stratification of Wisconsin Lakes. Wisconsin Academy of Sciences, Arts and Letters. Vol. 68.

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

Lutze, Kay. 2015. 2015 Wisconsin Act 55 and Shoreland Zoning. State of Wisconsin Department of Natural Resources

Netherland, M.D. 2009. Chapter 11, "Chemical Control of Aquatic Weeds." Pp. 65-77 in *Biology and Control of Aquatic Plants: A Best Management Handbook*, L.A. Gettys, W.T. Haller, & M. Bellaud (eds.) Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp

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

Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2): 133-141

Panuska, J.C., and J.C. Kreider. 2003. Wisconsin Lake Modeling Suite Program Documentation and User's Manual Version 3.3. WDNR Publication PUBL-WR-363-94.

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

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

Sass, G.G. 2009. Coarse Woody Debris in Lakes and Streams. In: Gene E. Likens, (Editor) Encyclopedia of Inland Waters. Vol. 1, pp. 60-69 Oxford: Elsevier.

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

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

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

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

United States Environmental Protection Agency. 2009. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. EPA 841-R-09-001. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

Vander Zanden, M.J. and J.D. Olden. 2008. A management framework for preventing the secondary spread of aquatic invasive species. Canadian Journal of Fisheries and Aquatic Sciences 65 (7): 1512-22.

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

Wisconsin Department of Natural Resources – Bureau of Science Services. 2008. Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest. PUB-SS-1044.

Wisconsin Department of Natural Resources – Bureau of Fisheries Management. 2014. Fish sticks: Improving lake habitat with woody structure. Available at: http://dnr.wi.gov/topic/fishing/documents/outreach/FishSticksBestPractices.pdf

Wisconsin Department of Natural Resources – Bureau of Fisheries Management. 2017. Fish data summarized by the Bureau of Fisheries Management. Available at: http://infotrek.er.usgs.gov/wdnr_public. Last accessed January 2018.

Wisconsin Department of Natural Resources (WDNR). 2017. Wisconsin 2018 Consolidated Assessment and Listing Methodology (WisCALM). Bureau of Water Quality Program Guidance.

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