Mirror Lake

Sauk County, Wisconsin

Comprehensive Management Plan

August 2014

Sponsored by:

Mirror Lake Management District

WDNR Grant Program

LPL-1460-12

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Onterra LLC
Lake Management Planning

Mirror Lake

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

Mirror Lake Planning Committee

Mark Blakeslee
Jerry Collins
Brent Gasser
Becky Green
Paul Kropp
R. Waldo Peterson
Cheryl Weston

Wisconsin Dept. of Natural Resources

Susan Graham

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1.0 INTRODUCTION

Mirror Lake, Sauk County, is an approximate 137-acre impoundment of Dell Creek upstream of Lake Delton and has a maximum depth of 19 feet and an average depth of 8 feet (Map 1). This highly eutrophic system has a watershed that encompasses approximately 67 square miles within the Driftless Area of Wisconsin in both Sauk and Juneau Counties, yielding a watershed to lake area ratio of 304:1. In 2012, 30 native aquatic plant species were documented, of which common waterweed (*Elodea canadensis*) was the most abundant. Five non-native plant species were located in 2012, and include Eurasian water milfoil, curly-leaf pondweed, purple loosestrife, Japanese knotweed, and sweetflag.

Field Survey Notes

Large, contiguous mats of duckweed (Lemna turionifera) and watermeel (Wolffia spp.) were a frequent scene during 2012 surveys in Upper Mirror Lake. A number of birds, including sandhill cranes, were often observed during surveys in areas of wild rice. Despite eutrophic and often turbid conditions, high-quality aquatic plant species including ribbon-leaf pondweed and stiff pondweed were located.

Photo 1.0-1. Mirror Lake, Sauk County, Wisconsin.

Lake at a Glance - Mirror Lake

Morphology	
Acreage	137
Maximum Depth (ft)	19
Mean Depth (ft)	8
Watershed to Lake Area Ratio	304:1
Vegetation	
Curly-leaf Survey Date	May 23, 2012
Comprehensive Survey Date	June 25 & August 27, 2012
Number of Native Species	30
Threatened/Special Concern Species	-
Exotic Plant Species	5
Simpson's Diversity	0.88
Average Conservatism	6.0
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus (may transition to nitrogen occasionally)
Water Acidity (pH)	7.9 – 9.1
Sensitivity to Acid Rain	Low

Mirror Lake is located just west of Lake Delton within the Wisconsin River drainage basin, and is fed via numerous tributaries, of which Dell Creek is the largest. From Mirror Lake, water flows over the Delton Dam through Dell Creek and into Lake Delton and finally the Wisconsin River.

In 1986, Mirror Lake stakeholders formed the Mirror Lake Association (MLA), and soon thereafter worked with the Townships of Delton and Dellona to adopt a slow, no wake ordinance for the entire lake to reduce erosion of the picturesque sandstone cliffs that create the Mirror Lake Gorge. The MLA also initiated an aquatic plant harvesting program to remove excessive growth of aquatic plants, primarily duckweed, to improve navigation and recreation around the lake.

In 2006, members of the MLA voted to create the Mirror Lake Management District (MLMD) to aid in funding the lake's harvesting program and other activities. Since the creation of the MLA and MMLD, numerous studies have been conducted on Mirror Lake and within the Dell Creek watershed to reduce the amount of nutrients entering the lake. In 2008, a one million dollar grant was received from the State of Wisconsin to conduct dredging within the western portion of the lake to improve navigation and trap incoming sediments. Similarly, in 2010, studies were initiated on Mirror Lake to mitigate erosion and subsequent sediment deposition from gullies immediately surrounding the lake.

The MLMD was interested in developing a lake management plan for Mirror Lake for several reasons. First, they wanted to know the extent of non-native aquatic plant species within their lake (Eurasian water milfoil and curly-leaf pondweed). Secondly, they also wanted to develop a Wisconsin Department of Natural Resources (WDNR)-approved aquatic plant harvesting plan which the MLMD would be responsible for implementing. And finally, they wanted to understand and learn more about Mirror Lake as a whole and manage it as an ecosystem, not just a recreational resource.

This report discusses the shoreline, watershed, water quality, aquatic plants, and Mirror Lake stakeholder studies that were conducted in Mirror Lake in 2012/2013. Also included is the Implementation Plan, which includes goals and actions specific to Mirror Lake's current and future management that were developed by both members of the Mirror Lake Planning Committee and Onterra ecologists.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa.

The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee, the completion of a stakeholder survey, and updates within the lake group's newsletter. The highlights of this component are described below. Materials used during the planning process can be found in Appendix A.

Kick-off Meeting

On August 18, 2012, a project kick-off meeting was held at the Marshall Memorial Hall in Lake Delton to introduce the project to the general public. The meeting was announced through a mailing and personal contact by Mirror Lake Management District board members. Thirty-four attendees observed a presentation given by Brenton Butterfield, an aquatic ecologist with Onterra. His presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Introduction to Onterra Planning Process

Prior to the Kick-off Meeting held in August 2012, Brenton Butterfield met with members of the Mirror Lake Planning Committee to introduce them to the process Onterra uses to create a lake management plan. During this meeting, Mr. Butterfield started with an overview of how Onterra combines the technical and sociological aspects of lake management to create a plan that is acceptable and implementable by the lake group. During this meeting, the committee's role in that process was also described, along with how their time is recorded and reflected for the grant reimbursement at the end of the project.

Planning Committee Meeting I

On June 20, 2013, Onterra ecologists Brenton Butterfield and Tim Hoyman met with members of the Mirror Lake Planning Committee and WDNR Water Resources Management Specialist, Susan Graham. In advance of this meeting, a draft copy of the Results and Discussion Sections (Section 3.0) was provided to attendees. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including the aquatic plant inventories, water quality analyses, and watershed modeling were presented and discussed.

Planning Committee Meeting II

On August 19, 2013, Onterra ecologists Brenton Butterfield and Tim Hoyman met with members of the Mirror Lake Planning Committee and WDNR Water Resources Management Specialist, Susan Graham to discuss the stakeholder survey results and begin developing management goals and actions for the Mirror Lake Management District's Comprehensive Lake Management Plan. One of the major topics of discussion was related to mechanical harvesting of aquatic plants and the excessive growth of duckweed within the lake.

Project Wrap-up Meeting

On June 21, 2014, Brenton Butterfield met with the general membership of the MLMD and MLA at their annual meeting, which also functioned as this project's Wrap-up meeting. During this meeting, highlights of the study were presented and discussed by Mr. Butterfield, with emphasis placed upon nutrient levels in the lake, plant and algae growth as well as aquatic invasive species. The presentation concluded with a discussion of the Management Goals and Actions as they are presented within the Implementation Plan. A question and answer session followed the presentation.

Management Plan Review and Adoption Process

Prior to the first planning meeting, the Planning Committee received copies of the Results Section of this report (Section 3.0). Their comments were addressed at this meeting and appropriate changes were incorporated within the management plan. Following creation of the Implementation Plan, the Mirror Lake Planning Committee approved of the draft management plan for Mirror Lake. A draft of the plan was also sent to the WDNR for review. The WDNR provided comments on the plan in June of 2014. In July of 2014, Onterra staff discussed and then addressed the WDNR comments. The plan was ultimately approved in August of 2014.

Stakeholder Survey

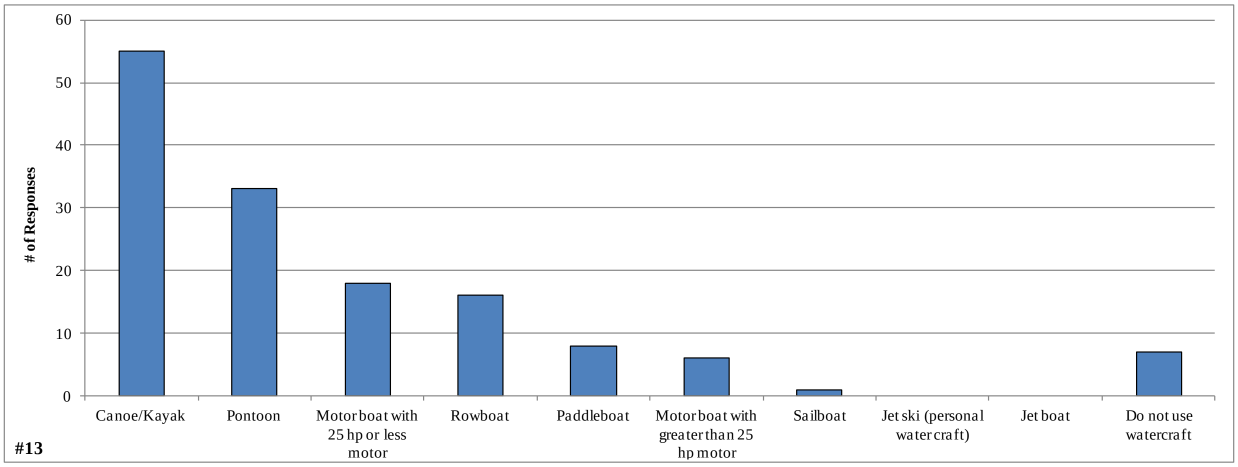
During the winter of 2012/2013, the Mirror Lake Planning Committee and Onterra staff developed an anonymous stakeholder survey that would be distributed to Mirror Lake Association and Mirror Lake Management District members. During February of 2013, the survey was completed and then reviewed by a WDNR social scientist. Following WDNR approval, the seven-page, 29-question survey was mailed to 237 households. Thirty-three percent of the surveys were returned and those results were entered into a spreadsheet by members of the Mirror Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan 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 Mirror Lake. The majority of stakeholders (22%) are seasonal residents or visit on weekends throughout the year, while 15% of respondents reside near Mirror Lake during the entire year (Appendix B, Question #1). Fifty-five percent of stakeholders have owned their property for over 15 years, while 49% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a canoe/kayak on Mirror Lake, while pontoon boats, small motor boats and rowboats were also popular options (Question #13). On a relatively small lake with narrow channels such as Mirror Lake, the importance of responsible boating activities is increased. The need for responsible boating increases further during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question #14, several of the top recreational activities on the lake involve boat use.

Throughout the stakeholder survey, respondents identified concerns regarding excessive aquatic plant growth, algae blooms, water quality degradation and aquatic invasive species (Question #20 & #21; stakeholder survey comments). These topics are discussed at length within the Water Quality and Aquatic Plants section, as well as within the Summary & Conclusions section and Implementation Plan.

Question #13: What types of watercraft do you currently use on the lake?



Question #14: Please rank up to three activities that are important reasons for owning your property on or near the lake.

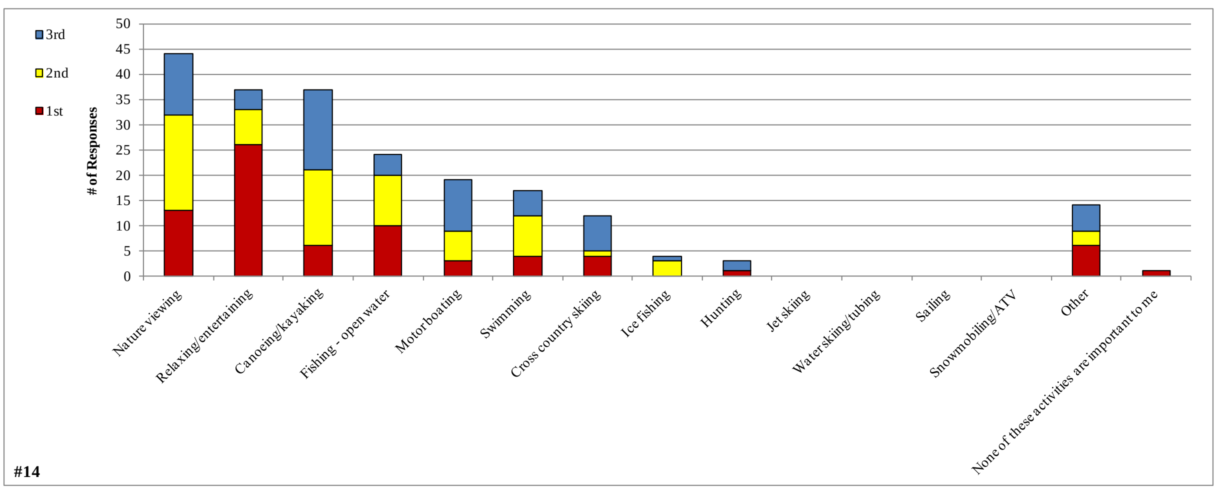


Figure 2.0-1. Select survey responses from the Mirror Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

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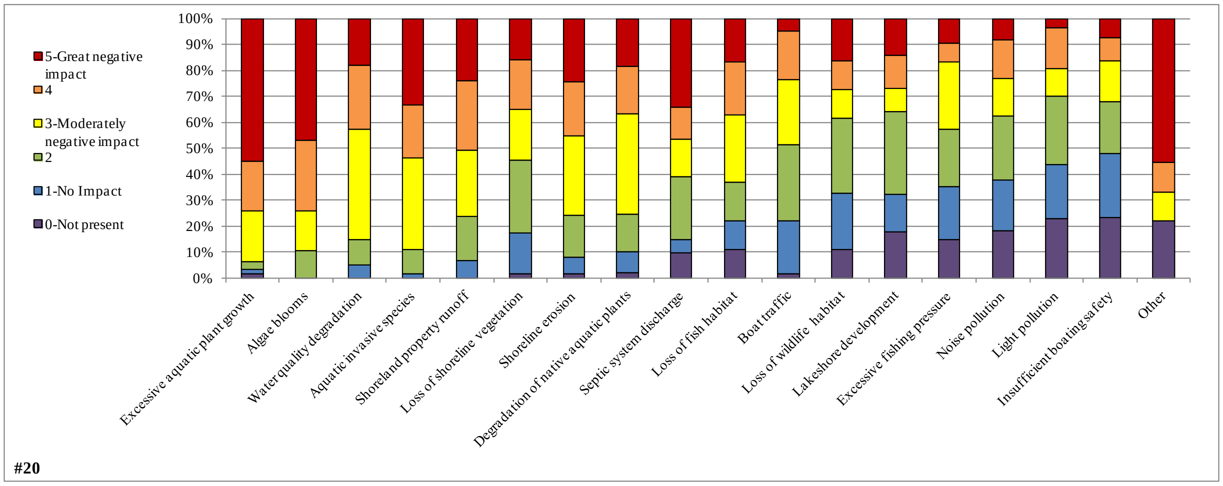
Question #20: To what level do you believe each of these factors may be negatively impacting Mirror Lake?



Question #21: Please rank your top three concerns regarding Mirror Lake.

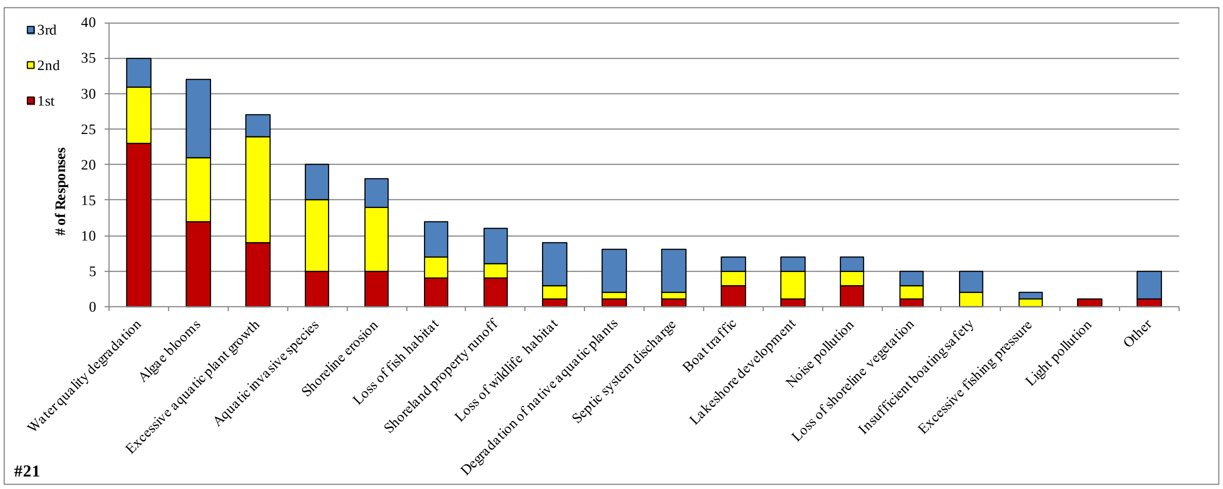


Figure 2.0-2. Select survey responses from the Mirror Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

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 Mirror Lake is compared to other lakes in the state with similar characteristics (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 Mirror Lake's water quality analysis:

> **Phosphorus** is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term plants includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.
>
> **Chlorophyll-*a*** is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.
>
> **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and the average of the depths at which it disappears and then reappears is recorded.

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.

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

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

Internal Nutrient Loading

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

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

Non-Candidate Lakes

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

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations exceeding 200 μg/L.
- Lakes with epilimnetic phosphorus concentrations that cannot be accounted for in watershed phosphorus load modeling.

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

Comparisons with Other Datasets

The WDNR publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) 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 Mirror Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

First, the lakes are classified into two main groups: **shallow (mixed)** or **deep (stratified)**. Shallow lakes tend to mix throughout or periodically during the growing season and as a result, remain well-oxygenated. Further, shallow lakes often support aquatic plant growth across most or the entire lake bottom. Deep lakes tend to stratify during the growing season and have the potential to have low oxygen levels in the bottom layer of water (hypolimnion). Aquatic plants are usually restricted to the shallower areas around the perimeter of the lake (littoral zone). An equation developed by Lathrop and Lillie (1980) incorporates the maximum depth of the lake and the lake's surface area and 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.

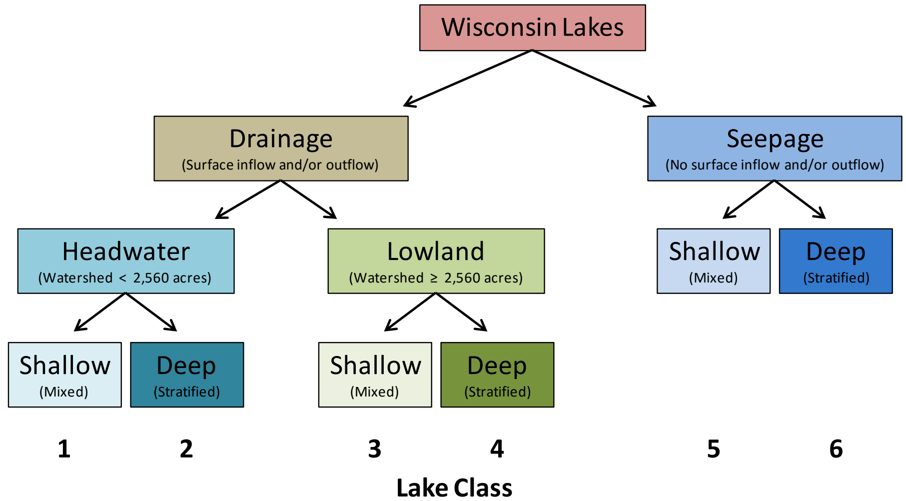


Figure 3.1-1. Wisconsin Lake Classifications. Mirror Lake is classified as a shallow (mixed), lowland drainage lake (Class 3). Adapted from WDNR PUB-SS-1044 2008.

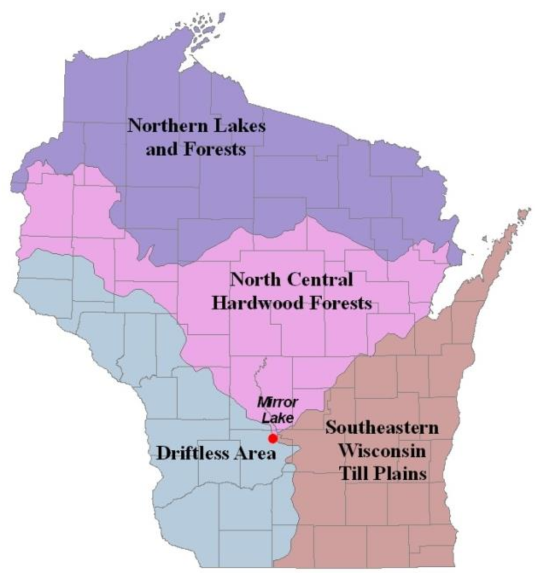


Figure 3.1-2. Location of Mirror Lake within the ecoregions of Wisconsin. After Nichols 1999.

While Mirror Lake is classified as a shallow, lowland drainage lake within this classification system, it is technically defined as a flowage or impoundment because greater than 50% of its water volume can be attributed to a control structure or dam. However, regional and state-wide water quality data sets for impounded waters are not yet available, and impoundments most closely resemble shallow, lowland drainage lakes. The WDNR developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for each of the six 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.

Mirror Lake itself is located at the boundaries of the North Central Hardwood Forests, Southeastern Wisconsin Till Plains, and Driftless Area Ecoregions (Figure 3.1-2). However, the majority of its watershed is located within the Driftless Area Ecoregion. Unfortunately, an insufficient amount of data from lakes within the Driftless Area were collected to create ecoregional median values; therefore, Mirror Lake's water quality will only be compared to other shallow, lowland drainage lakes throughout the State of Wisconsin.

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is another useful tool in helping lake stakeholders understand the health of their lake compared to others 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, they 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 Mirror Lake are displayed in the following section. 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 near surface samples. Near 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.

Mirror Lake Water Quality Analysis

Mirror Lake Long-term Trends

The historical water quality data that exists for Mirror Lake is minimal and has been collected sporadically, making it difficult to complete a reliable long-term trend analysis. Having an understanding of how a lake's water quality has changed (or not changed) over time is always beneficial and leads to sounder management decisions. It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year to year based upon environmental conditions, such as weather, and b) differences in observation and perception of water quality can differ greatly from person to person. It is best to analyze the water quality of a lake through measurable parameters as these provide a scientific basis behind anecdotal claims.

Public perception of water quality, while not useful to guide management decisions, is nonetheless interesting to examine. In the stakeholder survey distributed through this project, the majority of Mirror Lake stakeholders (83%) indicated they believe the water quality in the lake is *Fair* or *Good* (Appendix B – Question #15). The majority of survey respondents (34%), however, indicated that they believe the water quality has degraded somewhat since they first visited the lake (Question #16). Roughly 40% of survey respondents believe the water quality has remained the same or somewhat improved. Water quality degradation was ranked 1st on a list of top concerns respondents have regarding Mirror Lake (Question #21).

Since the early 1990s, the Mirror Lake Management District (MLMD) and Mirror Lake Association (MLA) have initiated a number of studies on Mirror Lake investigating the impacts of nutrient and sediment inputs to the lake's water quality. In 1992, the MLA received a WDNR Lake Management Planning Grant to conduct an assessment of Mirror Lake's water quality and to identify sources of nutrient pollution to the lake. Woodward-Clyde Consultants (1994), a firm hired by the MLA to conduct the studies, concluded that Mirror Lake was a nutrient-rich, eutrophic system that produces nuisance levels of rooted aquatic plant growth, algal growth, and duckweed growth. They also concluded that the majority of the sediments and nutrients being delivered to Mirror Lake were from agricultural sources.

Following recommendations from the Woodward-Clyde study and recognizing the importance of Mirror Lake and Lake Delton as nationally-recognized tourist destinations, the Dell Creek watershed, which includes Mirror Lake, was designated as a priority watershed by the WDNR's Nonpoint Source Abatement Program in 1994. The Dell Creek Watershed Project's (DCWP) primary purpose was to protect and enhance surface and groundwater throughout the watershed by controlling nonpoint sources of nutrient and sediment pollution (Sauk and Juneau County Land Conservation Departments 2010).

The project's goals were to reduce sediment delivery by 25%, reduce streambank erosion by 120 tons/year, reduce gully erosion, reduce barnyard phosphorus runoff, and restore wetlands to achieve sediment reduction. By 2009, the project had surpassed its sediment reduction goal by 1,000 tons, and thus also reduced the amount of phosphorus entering the lake. The DCWP also reduced nutrient runoff from the spreading of animal wastes on agricultural fields by limiting applications to appropriate times and only where needed. In addition, efforts were also focused on reducing the amount of nutrient runoff from barnyards within the watershed. Erosion from multiple gullies within the immediate watershed of Mirror Lake was also reduced via the construction of control structures and sedimentation basins by an environmental engineering firm hired by the MLMD. In addition to controlling sediment and nutrient runoff within the Dell Creek watershed, dredging of lake sediments occurred in Mirror Lake's western basin and upstream into Dell Creek in 2008 to improve navigation and trap sediment before it could travel downstream. Approximately 70,000 cubic yards of sediment were removed.

As mentioned, the historical water quality data that exist for Mirror Lake are sporadic and relatively limited. The data that are available have been collected from two locations within the lake: one is located in the upstream-most portion of the lake (Upper Mirror Lake), while the other is located downstream near the Ishnala Restaurant (Lower Mirror Lake) (Map 1). In general, data collected from the most downstream sampling location, in this case the Lower Mirror Lake site, provides the most accurate representation of the lake as a whole. Data were collected from the Upper Mirror Lake site because this area of the lake has exhibited the highest levels of aquatic plant growth and is where the dredging project occurred.

Near-surface total phosphorus data are available from the Upper Mirror Lake sampling site from 1975-1977, 1993-1994, 2004, and 2012. All of the total phosphorus concentrations measured over these time periods fall within the *Fair* and *Poor* categories for shallow, lowland drainage lakes (Figure 3.1-3). Growing season and summer total phosphorus concentrations measured in 2012 were the highest recorded at this sampling location, averaging approximately 200 µg/L and falling within the *Poor* category. The weighted average summer near-surface total phosphorus concentrations for all years at the Upper Mirror Lake sampling site fall within the *Poor* category, and is nearly four times higher than the state-wide median total phosphorus concentration for shallow, lowland drainage lakes. Total phosphorus concentrations measured from water near the lake bottom were similar to near-surface concentrations, indicating internal nutrient loading from bottom sediments is likely not occurring within Upper Mirror Lake. Because the total phosphorus data available from Upper Mirror Lake are limited and temporally sporadic, it is not possible to determine if trends (positive or negative) are occurring over time.

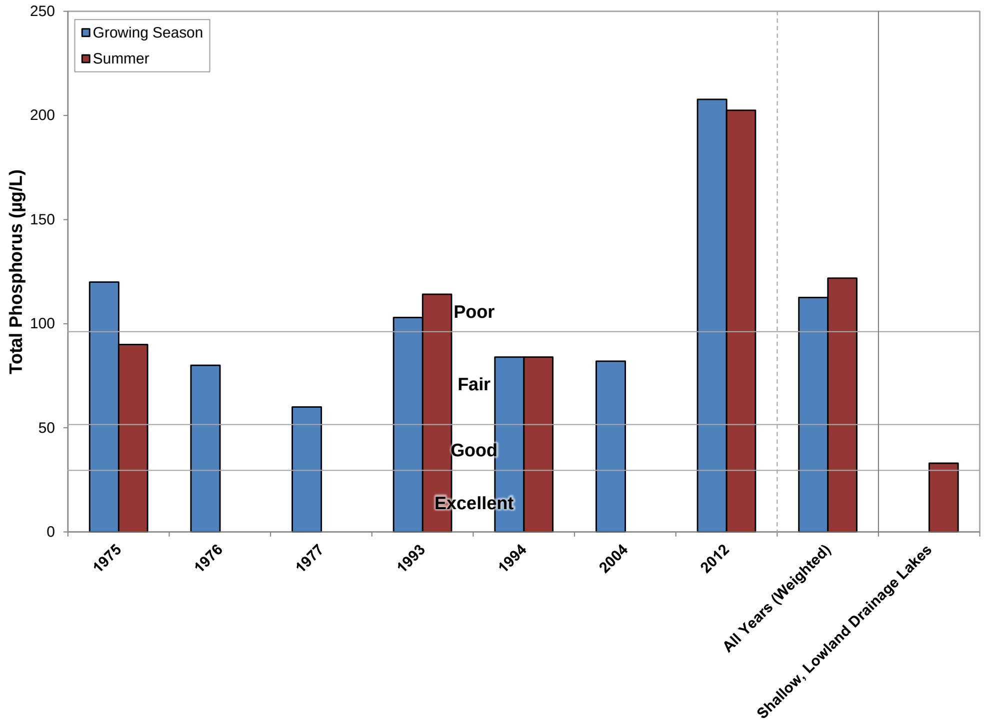


Figure 3.1-3. Upper Mirror Lake annual and state-wide shallow, lowland drainage lakes median total phosphorus concentrations. State-wide median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Unfortunately, near-surface total phosphorus data are only available for three years from the Lower Mirror Lake sampling location: 1993, 1994, and 2012. Total phosphorus concentrations collected in 1993 and 1994 were relatively similar and fell in the *Poor* category for shallow, lowland drainage lakes (Figure 3.1-4). Growing season and summer total phosphorus concentrations from Lower Mirror Lake in 2012 were approximately half of what was measured in 1993 and 1994, falling into the *Fair* category. The weighted average summer total phosphorus concentration from these three years falls into the *Poor* category, and exceeds the state-wide median total phosphorus concentration for shallow, lowland drainage lakes. Near-bottom total phosphorus concentrations collected from Lower Mirror Lake indicate that internal nutrient loading from bottom sediments is likely not occurring. Comparing Figures 3.1-3 and 3.1-4 indicates that near-surface total phosphorus concentrations within Upper Mirror Lake were significantly higher than those measured in Lower Mirror Lake; possible explanations for this difference are discussed later in this section.

While the previously described efforts have been made within the watershed of Mirror Lake and within the lake itself to reduce sediment and nutrient loads, given the limited amount of data taken before and after these implementations, a determination cannot be made as to whether or not the lower near-surface total phosphorus concentrations measured in Lower Mirror Lake in 2012 are a result of these efforts. As is discussed in the Watershed Section, Mirror Lake has an incredibly large watershed when compared to the size of the lake itself, and the concentrations of nutrients in the lake at any given time are largely dependent on the amount of precipitation that fell within its watershed. Figure 3.1-5 displays the average rainfall in Wisconsin Dells from

April-September, 1990-2012, and may explain why total phosphorus concentrations in Lower Mirror Lake were lower than in 1993 and 1994. As illustrated, total growing season rainfall in 1993 was above average at 31 inches, while rainfall in 1994 was slightly below average at 24 inches. Rainfall in 2011 and 2012 was well below the average for this two-decade period at approximately 18 inches. Less precipitation means that less sediment and nutrients are being delivered to Mirror Lake from its watershed and is a plausible explanation for the reduced total phosphorus concentrations observed in 2012.

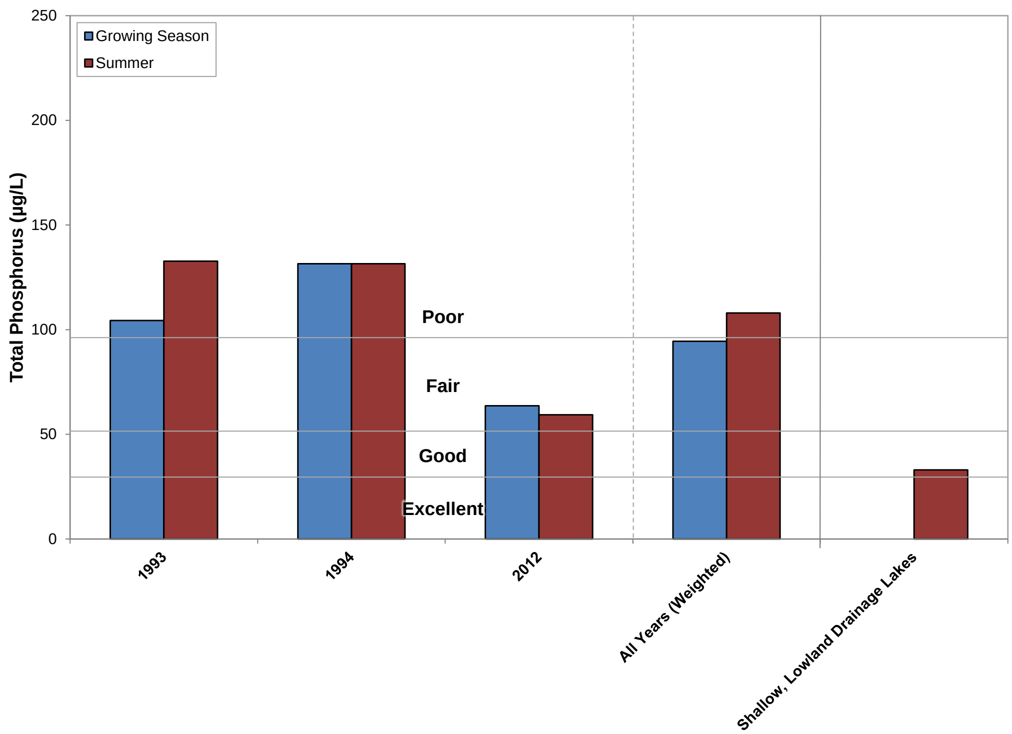


Figure 3.1-4. Lower Mirror Lake annual and state-wide shallow, lowland drainage lakes median total phosphorus concentrations. State-wide median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

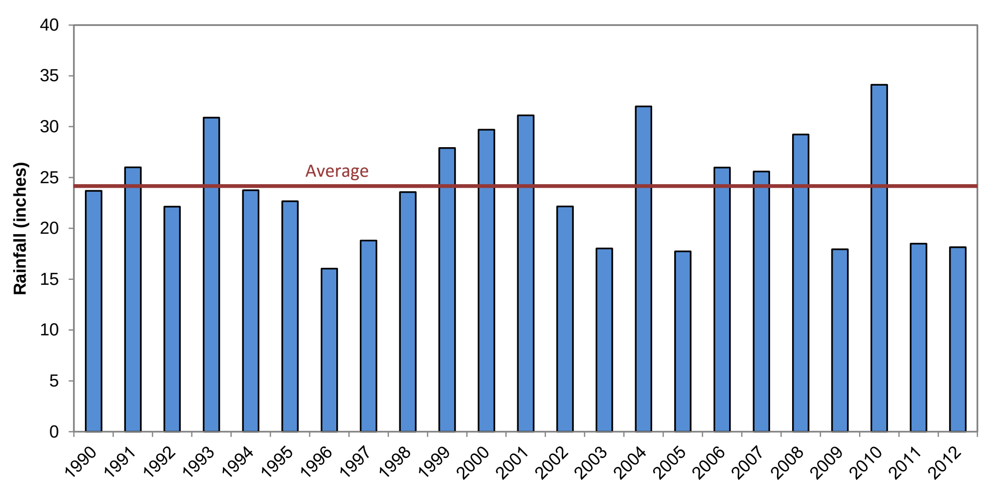


Figure 3.1-5. Total April-September rainfall from 1990-2012 in Wisconsin Dells. Data obtained from NOAA National Climate Data Center, 2012, station name: Wisconsin Dells, WI US.

Like total phosphorus, chlorophyll-*a* data from Mirror Lake are also limited and temporally sporadic. Most of the historical chlorophyll-*a* data are from the sampling location in Upper Mirror Lake, and are available from 1980, 1992-1994, 2001, 2004, and 2012 (Figure 3.1-6). The data collected from 1980 through 2004 are relatively consistent and fell within the *Excellent* or *Good* categories, with the exception of 2001 which fell in the *Fair* category. Average chlorophyll-*a* concentrations for 2012 were significantly higher than what has been recorded in the past, falling into the *Poor* category. However, the 2012 growing season and summer averages are being skewed by a single sampling event that occurred on August 28, 2012 and yielded a chlorophyll-*a* concentration of 229 µg/L. The chlorophyll-*a* concentration measured in August 2012 is not believed to due to an analysis error, as it correlates with a significant increase in total phosphorus. If the August 2012 sampling event is removed, the 2012 average growing season chlorophyll-*a* concentration straddles the *Good-Fair* threshold, while the average summer concentration falls within the *Fair* category.

As discussed previously, precipitation was well below average in 2012. This reduced precipitation decreases the rate at which water travels through Mirror Lake, or increases the water's residence time. With reduced water flow, algae have more time to grow and multiply. In addition, the growing season began earlier in 2012 and temperatures where higher, all which contributed to increased amounts of algae. However, the weighted averages from all years available for chlorophyll-*a* in Upper Mirror Lake (minus the August 2012 data) fall within the *Good* category and are slightly higher than the median for shallow, lowland drainage lakes in Wisconsin.

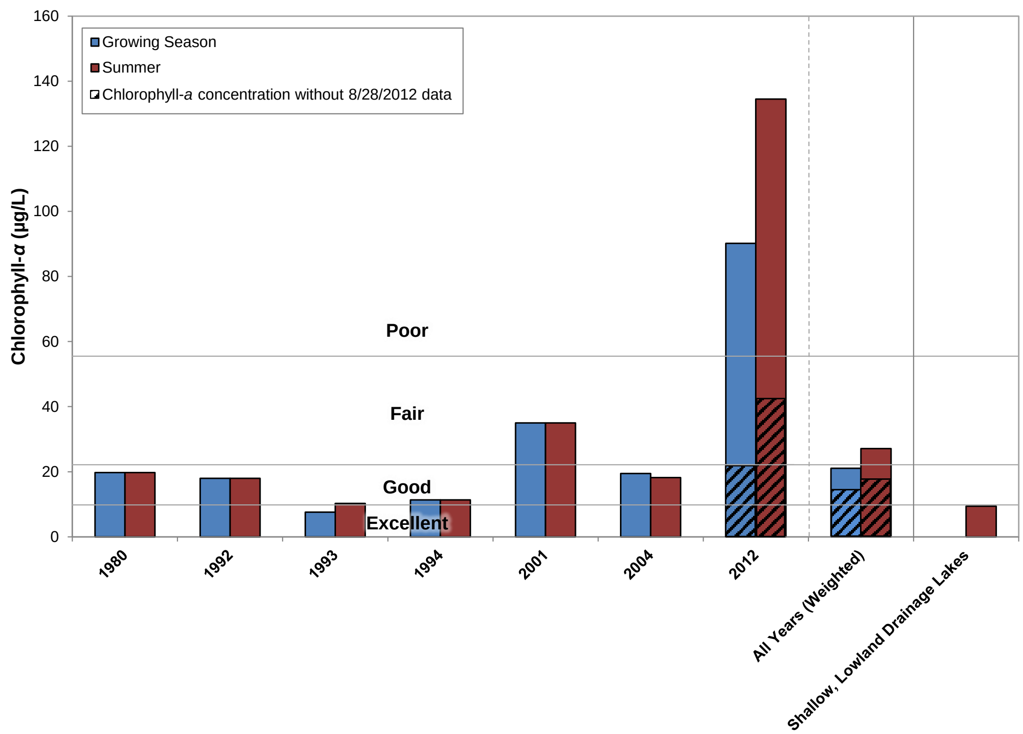


Figure 3.1-6. Upper Mirror Lake annual and state-wide shallow, lowland drainage lakes median chlorophyll-*α* concentrations. State-wide median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-*a* concentrations from Lower Mirror Lake are only available from two years: 1994 and 2012 (Figure 3.1-7). The chlorophyll-*a* data collected in 1994 is from a single sampling event in June; however, despite the 18-year gap between sampling events, is comparable to the growing season average from 2012 which fell into the *Fair* category. Data collected during the summer months of 2012 indicate that chlorophyll-*a* concentrations were low, falling into the *Excellent* category. The weighted average for summer chlorophyll-*a* concentrations in Lower Mirror Lake straddles the *Excellent-Good* threshold, and is comparable to other shallow, lowland drainage lakes in Wisconsin.

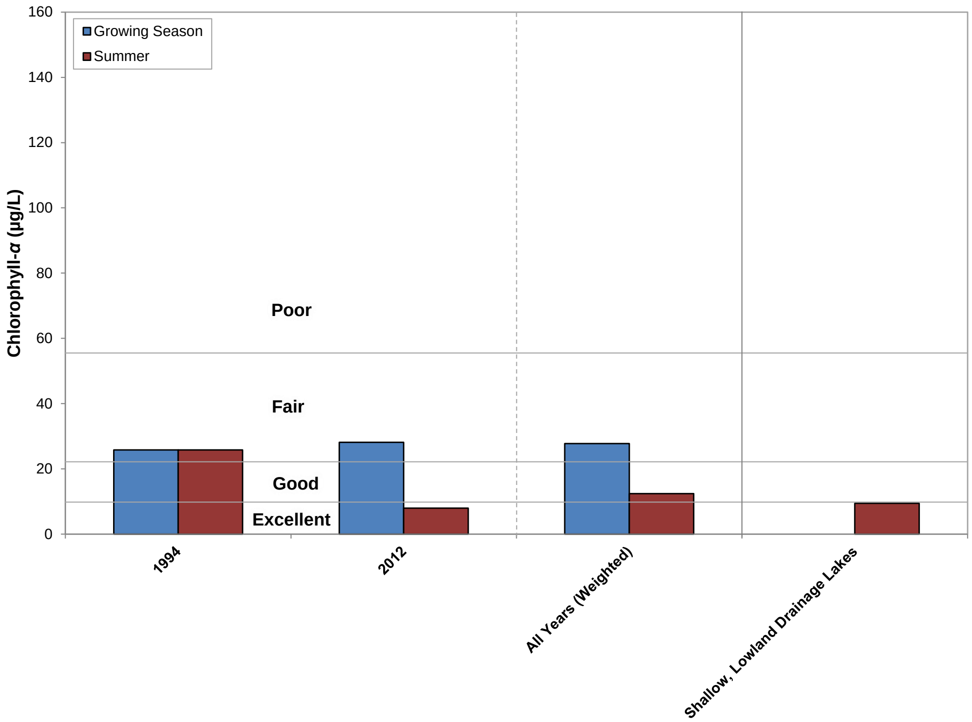


Figure 3.1-7. Lower Mirror Lake annual and state-wide shallow, lowland drainage lakes median chlorophyll-*a* concentrations. State-wide median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Despite having high nutrient concentrations, Mirror Lake has relatively low algal abundance, for which there are likely two main reasons. First, as mentioned, Mirror Lake has a very large watershed when compared to the size of the lake. Modeling (discussed in Watershed Section) indicates that Mirror Lake has a high flushing rate, as the water in the lake is estimated to be completely replaced on average every seven days. With a flushing rate this high, algae do not have enough time to grow and multiply before being carried downstream. On the other hand, WiLMS modeling of downstream Lake Delton which is larger and has a greater water volume than Mirror Lake, has an estimated flushing rate of approximately three weeks, which provides algae plenty of time to grow and multiply. Secondly, Mirror Lake has abundant growth of aquatic vascular plants (macrophytes) which remove nutrients from the water and make them unavailable to free-floating algae. With the limited chlorophyll-*a* data available from Mirror Lake, a determination as to whether or not a trend (positive or negative) in algal abundance is occurring over time cannot be made.

Of the historical water quality data that are available from Mirror Lake, Secchi disk transparency data are the most abundant. In Upper Mirror Lake, data are available from 1975-1977, 1980, 1993-1994, 2001, 2007-2009, and 2012 (Figure 3.1-8). As illustrated, water clarity from 1975-1980 ranged from 3.0 to 4.2 feet. From 1993 to 2012, water clarity measurements were slightly higher, with the exception of 2008 which was the year of a significant flooding event that drained Lake Delton. Water clarity measurements recorded in 2012 were similar to what was recorded in the most recent years, with the growing season average falling in the *Good* category and summer averages falling in the *Excellent* category. The weighted average for all years places Upper Mirror Lake in the *Good* category for shallow, lowland drainage lakes in Wisconsin.

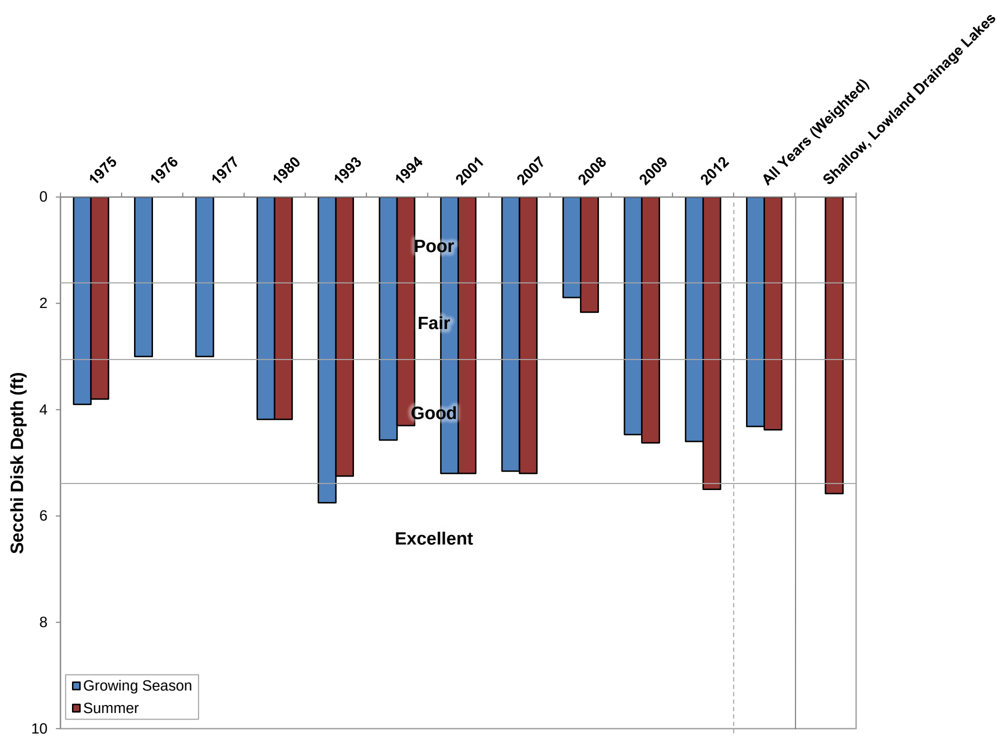


Figure 3.1-8. Upper Mirror Lake annual and state-wide shallow, lowland drainage lakes median Secchi disk transparency values. State-wide median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

In Lower Mirror Lake, Secchi disk transparency data are available from 1987, 1993-1994, 2007-2009, and 2012 (Figure 3.1-9). Secchi disk transparency was relatively consistent in measured years from 1987-2007 falling into the *Good* category, while transparencies were lower in 2008 and 2009 falling into the *Fair* category. Water clarity measured in 2012 in Lower Mirror Lake was the highest on record, with both growing season and summer averages falling into the *Excellent* category and exceeding the median value for shallow, lowland drainage lakes. The weighted average for all years available in Lower Mirror Lake falls in the *Good* category. For reasons discussed previously, Mirror Lake has a lower abundance of free-floating algae; this in turn allows light to penetrate deeper into the water column and increases water clarity and rooted aquatic plant growth. In addition, the abundant rooted macrophyte growth decreases resuspension of bottom sediments and slows down incoming water allowing particulate matter to settle out.

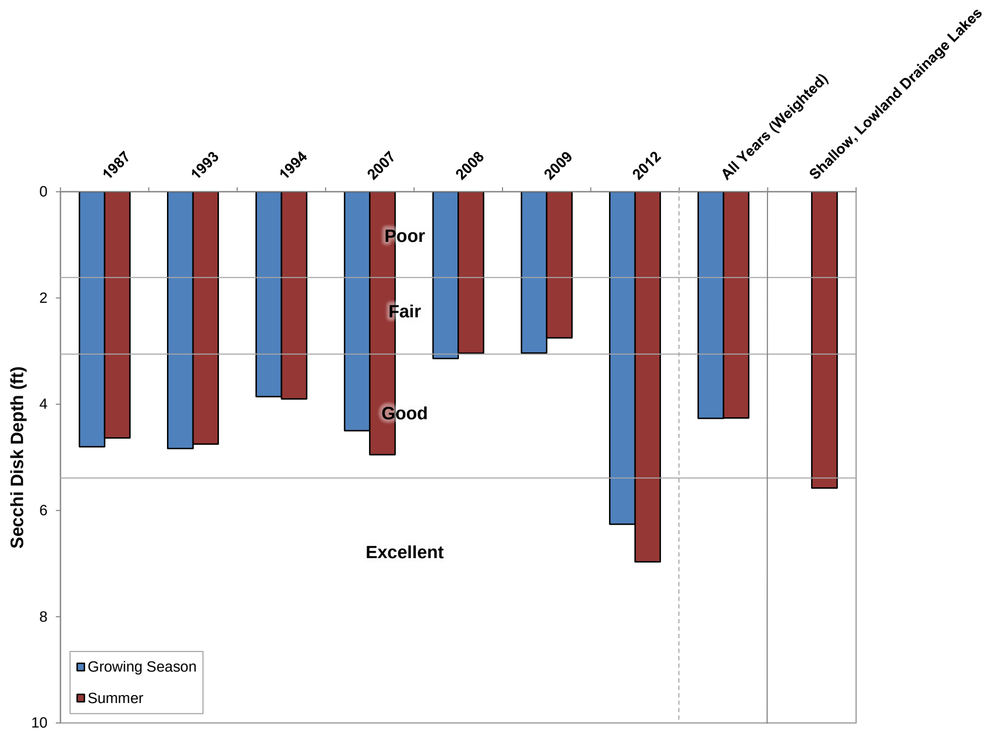


Figure 3.1-9. Lower Mirror Lake annual and state-wide shallow, lowland drainage lakes median Secchi disk transparency values. State-wide median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed within the Water Quality Primer Section, water clarity is determined by the amount of suspended particular matter (sediment and algae) within the water as well as dissolved compounds. Total suspended solids (TSS) are a measure of inorganic and organic particles suspended in the water and include everything from algae to clay particles. High TSS creates low water clarity and prevents light from penetrating into the water to support aquatic plant growth. TSS was measured in both Upper and Lower Mirror Lake in 2012, and the data indicate that TSS is relatively low in Mirror Lake, ranging from undetectable to 13.0 mg/L. TSS likely increases in Mirror Lake during storm events when large amounts of water and thus sediments are delivered to the lake.

Another measure of water clarity once suspended material has been removed is called true color. Many lakes have natural dissolved organic materials from decomposing plant material delivered from wetlands within the watershed. These compounds turn the water a tannish-brown and may decrease water clarity. In 2012, Mirror Lake had true color values of 10.0 and 12.5 SU, which fall in the low category for Wisconsin Lakes (Lillie and Mason 1983). This means that the water clarity in Mirror Lake is mainly dictated by algae and suspended sediment.

As mentioned previously, water quality parameters collected in 2012 differed, sometimes greatly, between the Upper and Lower Mirror Lake sampling locations. Figure 3.1-10 displays the 2012 total phosphorus, chlorophyll-*a*, and Secchi disk transparency values collected from these two sites throughout the growing season. Near-surface total phosphorus concentrations remained relatively consistent throughout the growing season in Lower Mirror Lake. In contrast, total phosphorus concentrations increased five-fold from July to August in Upper Mirror Lake.

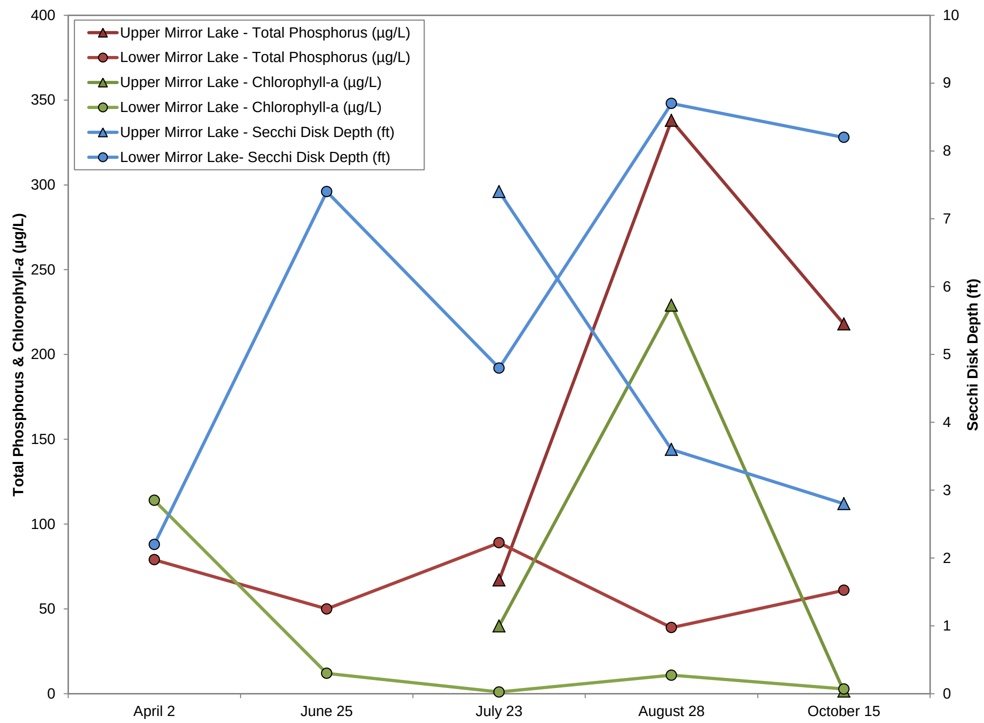


Figure 3.1-10. 2012 growing season near-surface total phosphorus, chlorophyll-α, and Secchi disk transparency values from Upper and Lower Mirror Lake.

The large increase in total phosphorus recorded in Upper Mirror Lake in August is believed to be a result of a precipitation event occurring over the course of two days prior to the sampling event that totaled 0.6 inches (NOAA National Climate Data Center). This large pulse of phosphorus delivered to the lake also created a significant increase in algal abundance, as recorded by chlorophyll-*a* and a decrease in Secchi disk transparency (Figure 3.1-9). However, this pulse of phosphorus and subsequent increase in chlorophyll-*a* were not detected in Lower Mirror Lake.

As mentioned earlier, the water residence time of Mirror Lake is estimated to be approximately seven days and it is likely that the phosphorus pulse had not yet reached lower Mirror Lake at the time of sampling. In addition, dilution of phosphorus may also occur as it travels downstream from Upper to Lower Mirror Lake as Upper Mirror Lake is relatively shallow and is approximately one-tenth the volume of Lower Mirror Lake. However, if dilution was the sole reason for the discrepancy in total phosphorus concentrations recorded in 2012 between Upper and Lower Mirror Lake, it would be expected that the total phosphorus concentrations in Upper Mirror Lake would always be higher. But as the July 2012 data indicates, total phosphorus concentrations in Upper Mirror Lake were lower than those measured in Lower Mirror Lake at that time.

A similar situation occurred during the October 2012 sampling event, where total phosphorus concentrations were significantly higher in Upper Mirror Lake than in Lower Mirror Lake.

Precipitation data indicates that a total of 2.7 inches of rain fell for two days prior and up to the morning of the October sampling event (NOAA National Climate Data Center). Onterra ecologists on the water noted water levels had increased and the current was moving swiftly through the Dell Creek inlet. However, as illustrated on Figure 3.1-10, there was very little algae content detected in the water during this sampling event. Water temperatures at this time of year were likely too cold to support algae growth, and in addition, the flushing rate of Mirror Lake likely increased following this large rainfall event. While there was little algae content in the water, water clarity was relatively low. The reduced water clarity was likely a result from suspended sediments in the water as well as an increase in dissolved organic compounds from wetlands and forests within the lake's watershed.

Limiting Plant Nutrient of Mirror Lake

Using midsummer nitrogen and phosphorus concentrations from Upper and Lower Mirror Lake, a nitrogen:phosphorus ratio of 18:1 was calculated. This finding indicates that Mirror Lake is phosphorus limited, as are the vast majority of Wisconsin lakes. However, this ratio is close to the 15:1 threshold, indicating that Mirror Lake at times may transition between phosphorus and nitrogen limitation. Very limited data from 2012 were used to calculate the nitrogen to phosphorus ratio, and ratios calculated over time will provide more information as to whether or not Mirror Lake may be nitrogen-limited at times. In lakes that are phosphorus-limited, reducing the amount of phosphorus entering the lake generally leads to reduced levels of algae and macrophytes. However, in lakes that have phosphorus levels that meet or exceed production rates, nitrogen may become limiting.

One of the major concerns on Mirror Lake is the excessive growth of the free-floating plants duckweed (*Lemna*) and watermeal (*Wolffia*). As is discussed in the Aquatic Plant Section, duckweeds receive all of their nutrients directly from the water, and thus require water with sufficient amounts of nutrients to grow and reproduce. Research has shown that nitrogen rather than phosphorus is the primary nutrient limiting the growth of duckweeds, and that duckweeds will preferentially remove ammonia nitrogen (NH_4-N) as a nitrogen source even when nitrate (NO_3^-) is abundant (Luond 1980). Data collected from Upper and Lower Mirror Lake support these findings. Average ammonia nitrogen recorded from Upper Mirror Lake in 2012 where duckweed growth is abundant was 41.0 µg/L compared to an average of 135.0 µg/L measured from Lower Mirror Lake. These data indicate that the ammonia nitrogen within Upper Mirror Lake is likely being removed from the water by excessive growth of duckweed. The higher levels of ammonia nitrogen recorded in Lower Mirror Lake indicate that nitrogen may be entering the lake from sources somewhere within the direct watershed of Lower Mirror Lake. Ammonia nitrogen in lakes primarily comes from organic wastes within the lake's watershed.

Mirror Lake Trophic State

Figure 3.1-11 contains the Trophic State Index (TSI) values calculated from data collected from Lower Mirror Lake. The TSI values are calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values. In general, the best values to use in judging a lake's trophic state are ones relative to biological activity. Because water clarity can be influenced by other parameters other than algae, total phosphorus and chlorophyll-*a* are the best values to use. Using these parameters, it can be concluded that Mirror Lake is in a upper-eutrophic state. While Mirror Lake's chlorophyll-*a* levels fall within the eutrophic level, much of Mirror Lake's production is within the aquatic plant community, primarily the excessive growth of duckweed. In addition, most of the total phosphorus concentrations fall within the hypereutrophic level.

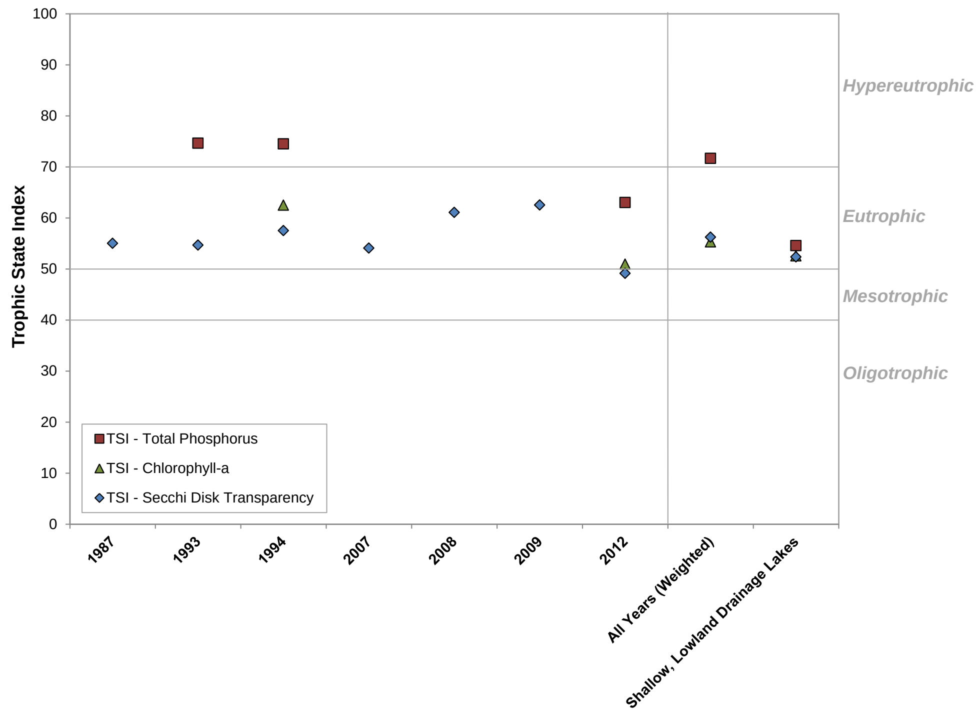


Figure 3.1-11. Mirror Lake, state-wide class 3 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Mirror Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Mirror Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-12. In flowage systems such as Mirror Lake, it is not uncommon to see little difference in the temperature and dissolved oxygen from the top to the bottom of the water column. This is due to the constant flow of water, which mixes the water column completely. In lakes where this riverine type flow is not present, a gradient of warmer water/higher dissolved oxygen on the surface and colder water/lower dissolved oxygen near the bottom may develop. Without replenishment from overlying, well oxygenated waters from the surface, water near the bottom of the lake may become depleted of dissolved oxygen due to the presence of bacteria decomposing organic material. All profiles in Figure 3.1-12 indicate that the water in Mirror Lake is oxygenated sufficiently for warm-water fish species that are found in Wisconsin.

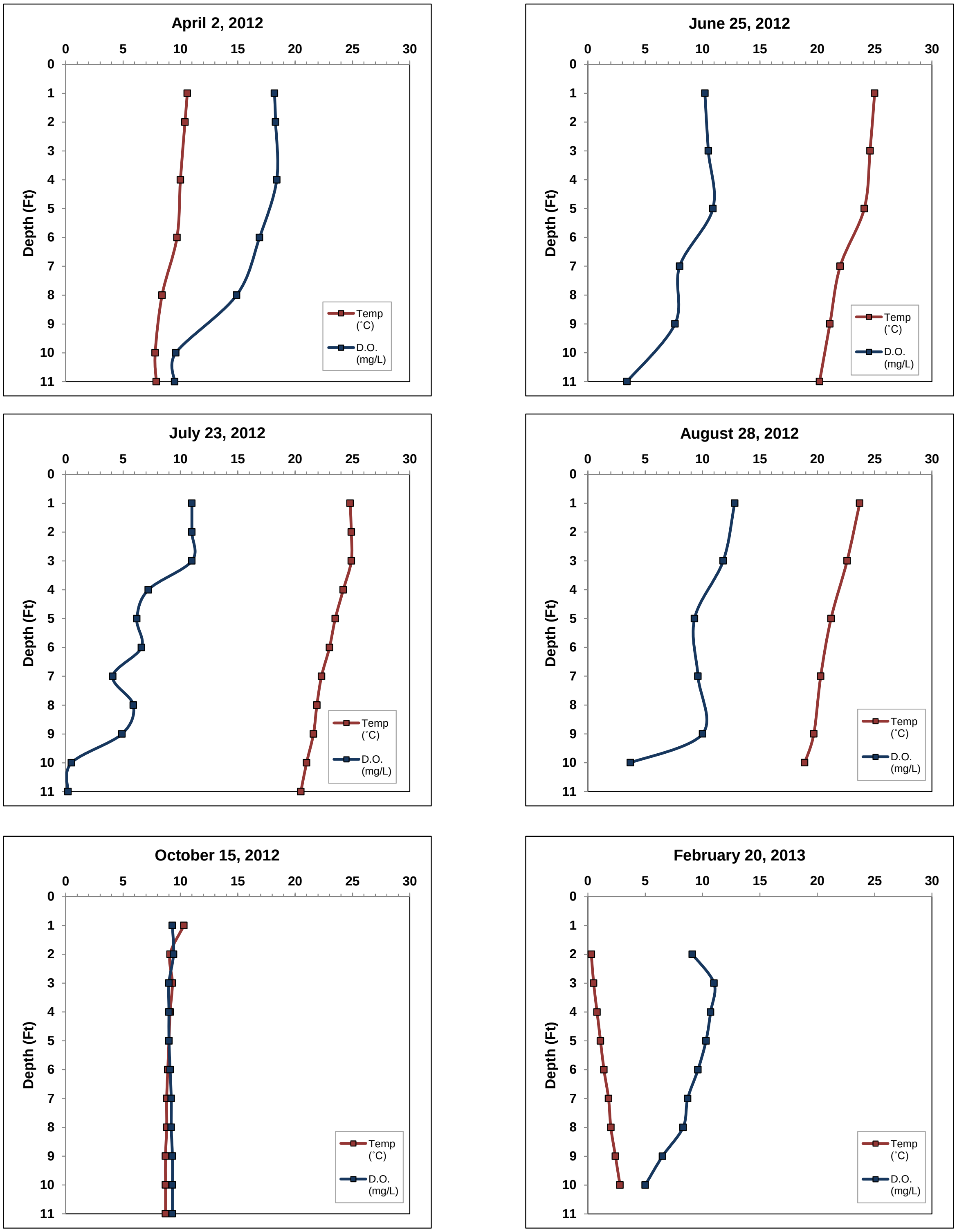


Figure 3.1-12. Temperature and dissolved oxygen profiles collected from Lower Mirror Lake in 2012/2013.

Additional Water Quality Data Collected at Mirror Lake

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw et al. 2004). The pH of the near-surface water in Mirror Lake was found to be alkaline ranging from 7.9 to 9.1.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in 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 Mirror Lake was measured at 108 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity 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 Mirror Lake's pH falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Mirror Lake was found to be 26.1 mg/L, indicating Mirror Lake is moderately susceptible to zebra mussel establishment if they are ever introduced.

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, Mirror Lake was considered to be suitable for mussel establishment. Plankton tows were completed by Onterra staff during the summer of 2012 and these samples were processed by the WDNR for larval zebra mussels. These samples were analyzed by the WDNR and they did not record any zebra mussel veligers.

3.2 Watershed Assessment

Watershed Modeling

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.

> 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.

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

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

In systems with high WS:LA ratios, like those exceeding 10-15:1, the impact of land cover may be tempered by the sheer amount of land draining to the lake. Situations do 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 lower. However, in that same lake, because of its low flushing rate (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. On the contrary, a lake with a higher flushing rate (low residence time, i.e., days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

A reliable and cost-efficient method of creating a general picture of a watershed's 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.

The Mirror Lake watershed drains approximately 42,726 acres (67 square miles) of land in Sauk and Juneau Counties (Map 2). The watershed is immense when compared to the size of the lake and results in a watershed to lake area ratio of 302:1. With this amount of land draining into Mirror Lake, WiLMS estimated that the lake is able to completely exchange its volume of water every 7-9 days (lake flushing rate). The majority (42.9%) of Mirror Lake's watershed is comprised of forests, 35.9% is comprised of row crop agriculture, 17.0% is comprised of pasture/grassland, 2.6% is comprised of wetlands, 1.0% is comprised of rural residential areas, 0.3% is comprised of the lake's surface itself, 0.1% is comprised of high-density urban areas, and the remaining 0.1% is comprised of medium-density urban areas (Figure 3.2-2).

It is difficult to accurately model lakes with watersheds as immense as Mirror Lake's. However, the WiLMS modeling program may be used to give managers a general idea of the amount of phosphorus that is delivered to Mirror Lake on an annual basis. Additionally, in-field measurements of the lake's water quality may be used to calibrate the model and ensure accuracy. Because some water quality data are available from Lower Mirror Lake, these calibrations were able to be made. Using the land cover types and their acreages within Mirror Lake's watershed, WiLMS predicted an annual phosphorus load to Mirror Lake of approximately 17,379 pounds (Figure 3.2-2). Despite comprising 35.9% of the lake's watershed, row crop agriculture accounts for approximately 78.8% (13,693 lbs) of the phosphorus loaded to the lake on an annual basis. Pasture/grass accounts for 11.2% (1,938 lbs), forests account for 8.5% (1,473 lbs), wetlands account for 0.6% (101 lbs), high-density urban areas account for 0.4% (75 lbs), rural residential areas and atmospheric deposition to the lake's surface account for 0.2% (37 lbs) each, and medium-density urban areas account for 0.1% (24 lbs).

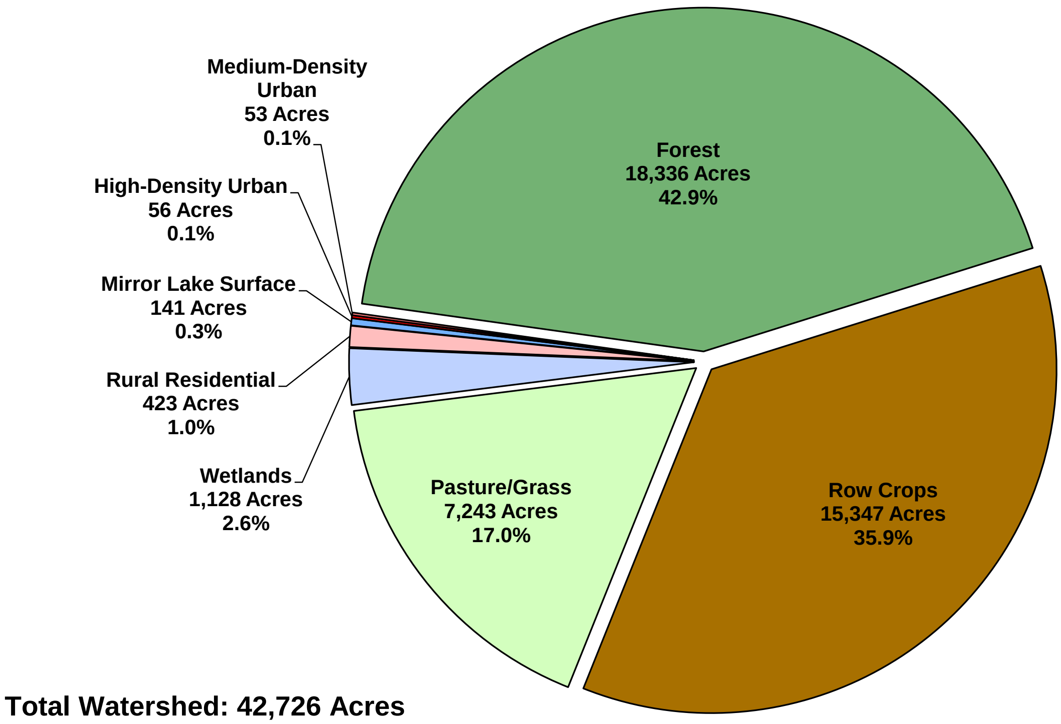


Figure 3.2-1. Mirror Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

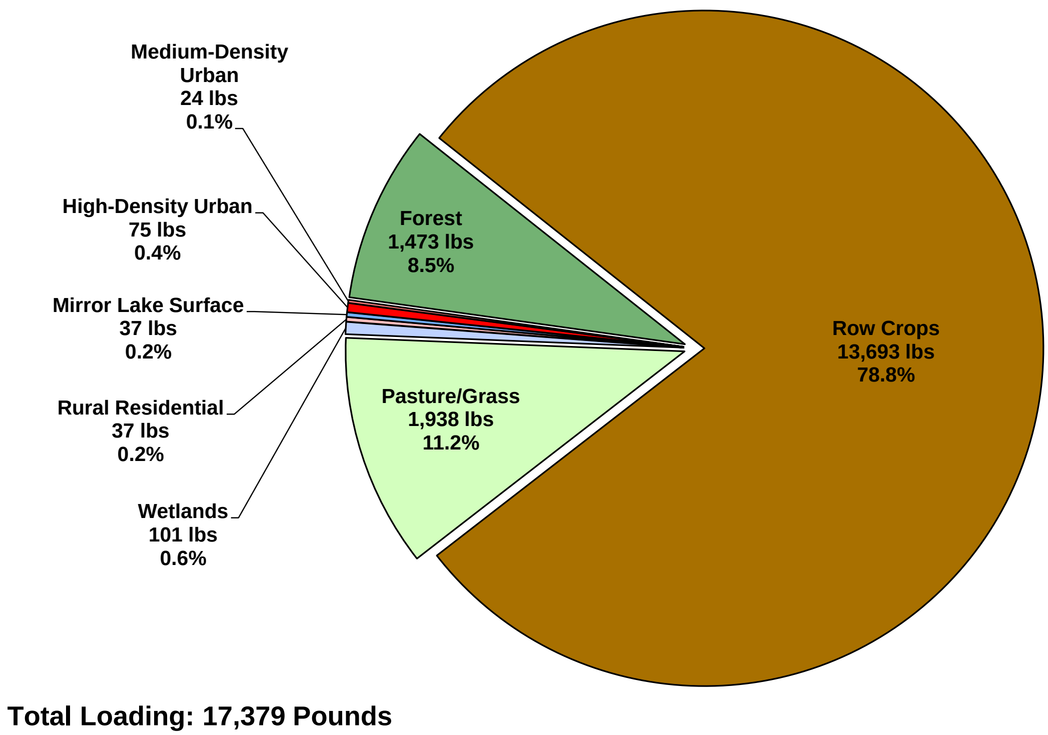


Figure 3.2-2. Mirror Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

During modeling procedures, WiLMS compares observed (measured in the field) and predicted (model-calculated) growing season mean and spring overturn phosphorus concentrations to determine the accuracy of the model. The growing season mean phosphorus concentration is defined as the mean of all surface water data collected from March 31-November 1. The spring overturn phosphorus concentration is defined as the concentration of phosphorus that is collected while the lake is completely mixed, as it was during the April 2012 water quality visit by Onterra staff. This value is a good representation of the phosphorus content of the lake, because during this time, the water is thoroughly mixed which means phosphorus is fairly similar within the entire water column.

Utilizing the acreages of land cover types within Mirror Lake's watershed and hydrologic data, WiLMS was able to estimate the annual growing season total phosphorus concentration within the lake. A predictive equation within WiLMS (Canfield-Bachmann, 1981) estimated that the growing season mean should most likely be 140 µg/L in Mirror Lake. Comparatively, Mirror Lake's actual growing season mean phosphorus concentration was found to be 94.4 µg/L. Because of the sheer size of Mirror Lake's watershed, total phosphorus concentrations throughout the year are relatively variable and fluctuate with precipitation events, making modeling of impoundments like Mirror Lake difficult. However, the model is indicating that given the land cover types within the lake's watershed, total phosphorus concentrations are lower than predicted, indicating that the efforts to control sediment and nutrient runoff within the watershed are likely having a positive impact on the lake's water quality.

The remediation that has taken place within the Dell Creek watershed is certainly beneficial for the ecological and recreational health of Mirror Lake, as well as waters downstream including Lake Delton and the Wisconsin River, and ultimately the Mississippi River and the Gulf of Mexico. However, it is important to realize that no matter how much remediation to the lake's watershed takes place, Mirror Lake will always be a eutrophic, productive system. Mirror Lake is an unnatural system that would not exist without the manmade dam built to create it; naturally it would be a riverine system. Mirror Lake drains an immense area of land relative to its size, funneling nutrients from the watershed into a relatively small volume of water.

Using WiLMS, the predicted growing season mean (GSM) phosphorus was predicted if all of the developed land cover (e.g. row crops, urban, pasture/grass) within the lake's watershed was converted to forest and existing wetlands were left in place. Even if Mirror Lake's watershed was in a completely natural condition, the predicted GSM phosphorus would be 36 µg/L, still placing Mirror Lake in a eutrophic state. Despite having completely natural land cover within the watershed that exports minimal amounts of phosphorus, the sheer size of the watershed cumulatively would deliver enough phosphorus to Mirror Lake to make it eutrophic. Figure 3.2-3 illustrates the trophic state index (TSI) values for the predicted GSM total phosphorus based on Mirror Lake's current watershed, the TSI for the actual total phosphorus measured in Mirror Lake, and the TSI for the scenario just described where Mirror Lake's watershed was converted to a completely natural state.

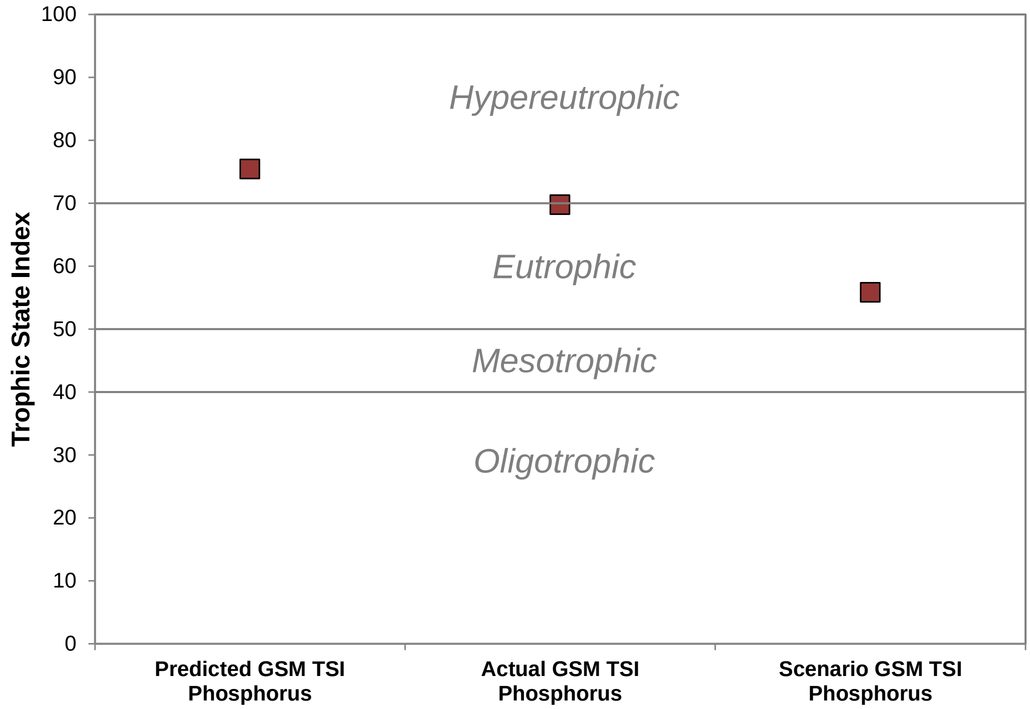


Figure 3.2-3. Mirror Lake total phosphorus TSI index values for predicted GSM total phosphorus for the lake's current watershed, the actual GSM total phosphorus measured in the lake, and predicted GSM total phosphorus for a completely natural watershed.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to 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. Along with this, the immediate shoreland area is often one of the easiest areas to restore.

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. 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 more strict 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 of their own. County ordinances may be more restrictive than NR 115, but not less so. These policy regulations require each county to amend ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows:

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for access/viewing corridors, shoreline restoration and invasive species removal, and sound forestry practices larger pieces of land.

- 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. A county may allow more than 15% impervious surface (but not more than 30%) on a lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner.

- 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. New 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
    - Complete reconstruction allowed from 35-75 feet if no portion of the structure is closer than 35 feet
    - Construction may occur if no other build-able location exists on the lot
    - Construction may occur if mitigation measures are included
    - Vertical expansion cannot exceed 35 feet

- Mitigation requirements: New 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 count as 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. Ground-water 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 debris provides shoreland erosion control, a carbon source for the lake, prevents suspension of sediments and provides a surface for algal growth which important for aquatic macroinvertebrates (Sass 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area as well as spawning habitat (Hanchin et al 2003). In one study, researchers observed 16 different species occupying coarse woody habitat areas in a Wisconsin lake (Newbrey et al. 2005). Bluegill and bass species in particular are attracted to this habitat type; largemouth bass stalk bluegill in these areas while the bluegill hide amongst the debris and often feed upon in many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface.

With development of a lake's shoreland zone, much of the coarse woody debris 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).

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).

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

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

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

Mirror Lake Shoreland Zone Condition

Shoreland Development

Mirror Lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.3-1 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state.

On Mirror Lake, the development stage of the entire shoreland was surveyed during the fall of 2012 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 3.3-1.

Urbanized: This type of shoreland 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 shorelands 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 shoreland 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 shoreland that was restored would likely be included here, also.

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

Figure 3.3-1. Shoreland assessment category descriptions.

Mirror Lake has stretches of shoreland that fit all of the five shoreland assessment categories (Figure 3.3-2). In all, 7.4 miles (89%) of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-2). Most of these areas were located along shorelines that are part of the Mirror Lake State Park. These shoreland types provide the most benefit to the lake and should remain in their natural state. During the survey, 0.4 miles (4%) of urbanized and developed–unnatural shoreland were observed. If restoration of the Mirror Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

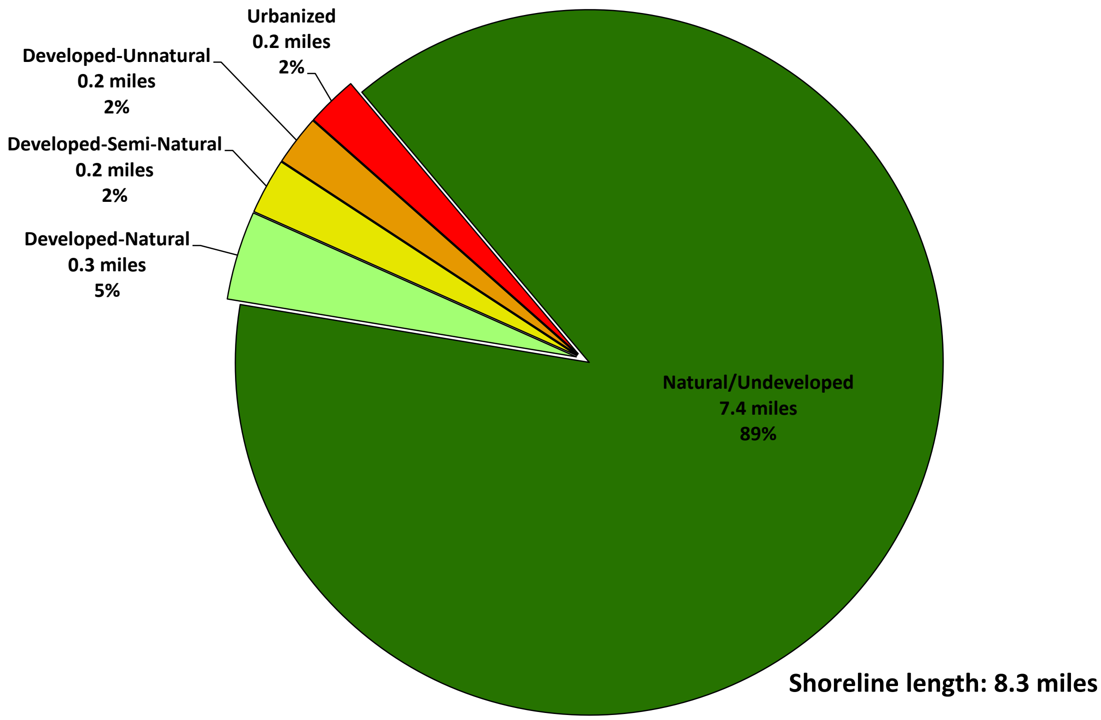


Figure 3.3-2. Mirror Lake shoreland categories and total lengths. Based upon a fall 2012 survey. Locations of these categorized shorelands can be found on Map 3.

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. Locating lawns on flat, unsloped 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

Mirror Lake was also surveyed in the fall of 2012 to determine the extent of its coarse woody habitat. This survey was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) 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.

During this survey, 174 total pieces of coarse woody habitat were observed along 8.3 miles of shoreline, which gives Mirror Lake a coarse woody habitat to shoreline mile ratio of 21:1. Locations of coarse woody habitat are displayed on Map 4. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

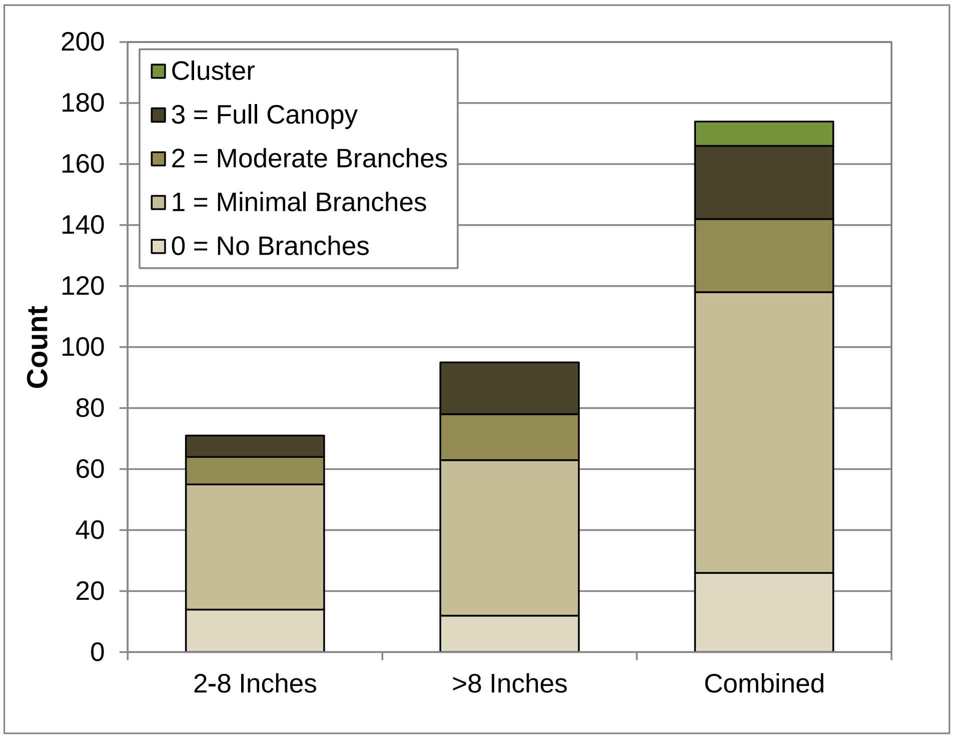


Figure 3.3-3. Mirror Lake coarse woody habitat survey results. Based upon a fall 2012 survey. Locations of Mirror Lake coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

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 water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

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

Aquatic Plant Management and Protection

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

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

Permits

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

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. This 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 and required by law 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 and require a permit.

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

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

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

Water Level Drawdown

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

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

Advantages	Disadvantages
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian water-milfoil for a few years. • Allows some loose sediment to consolidate, increasing water depth. • May enhance growth of desirable emergent species. • Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.	• May be cost prohibitive if pumping is required to lower water levels. • Has the potential to upset the lake ecosystem and have significant 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

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, and the interior surface is not easy to disinfect. • Bottom sediments may be re-suspended leading to increased turbidity and water column nutrient levels.

Herbicide Treatment

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

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

Applying herbicides in the aquatic environment requires special considerations compared with terrestrial applications. WDNR administrative code states that a permit is required. 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, trageted 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 water-milfoil. • 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 fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many 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 water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

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

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

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

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

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

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

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, such as variable water levels or negative, 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 Mirror Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

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

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of Mirror Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

Species Diversity and Richness

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

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

Simpson's diversity index is used to determine this diversity in a lake ecosystem. Simpson's diversity (1-D) is calculated as:

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

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. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Mirror Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-2) and in the state.

Box Plot or box-and-whisker diagram graphically shows data through five-number summaries: minimum, lower quartile, median, upper quartile, and maximum. Just as the median divides the data into upper and lower halves, quartiles further divide the data by calculating the median of each half of the dataset.

As previously stated, species diversity is not the same as species richness. One factor that influences species richness is the "development factor" of the shoreland. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreland may hold. This value is referred to as the shoreland complexity. It specifically analyzes the characteristics of the shoreland and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreland complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreland complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind.

Floristic Quality Assessment

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

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

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

Community Mapping

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

Exotic Plants

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

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 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 water-milfoil, curly-leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.

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

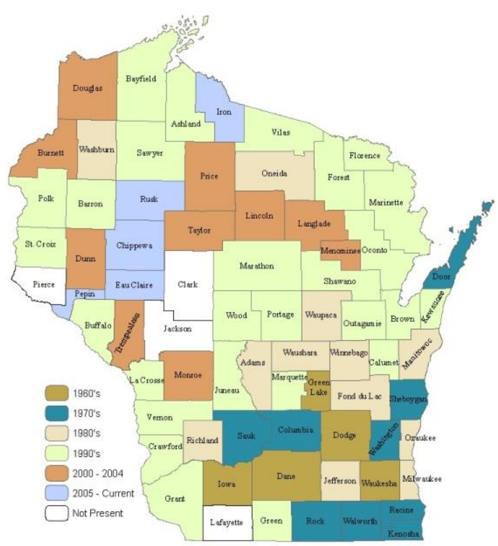


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

Aquatic Plant Survey Results

> **Littoral Zone** is the area of a lake where sunlight is able to penetrate down to the sediment and support aquatic plant growth.

As mentioned earlier, numerous aquatic plant surveys were completed as a part of this project. On May 23, 2012 Onterra ecologist conducted an early-season aquatic invasive species (AIS) survey on Mirror Lake. While this survey's intent is to locate any potential non-native species, its main focus is locating occurrences of curly-leaf pondweed. As discussed earlier, curly-leaf pondweed is at or near its peak growth early in the summer and dies back by early July. During this meander-based survey of the lake's *littoral zone*, Onterra ecologists located numerous large colonies of curly-leaf pondweed, mainly located in the western portion of the lake. Because of the ecological and recreational implications this species presents, the curly-leaf pondweed population within Mirror Lake will be discussed in the following Non-native Plants Section.

The comprehensive aquatic plant point-intercept and community mapping surveys were conducted by Onterra on June 25 and August 27, 2012, respectively. During these surveys, a total of 35 aquatic plant species were located in Mirror Lake, five of which are considered to be non-native: curly-leaf pondweed, Eurasian water milfoil, pale-yellow iris, Japanese knotweed, and sweetflag (Table 3.4-1). Curly-leaf pondweed, Eurasian water milfoil, pale-yellow iris, and Japanese knotweed are considered to be invasive species as they spread rapidly and displace valuable native species and alter native ecosystems. While sweetflag is a non-native species, it is not considered to be invasive, but naturalized. Naturalized plants do not aggressively take over native plant communities and form large monotypic stands, but instead integrate themselves into the native community and pose little if any ecological threats. Because of their importance, the four invasive species found in Mirror Lake will be discussed in the following Non-native Plants Section.

Sediment data gathered during the 2012 point-intercept survey indicates that approximately 70% of the 314 locations sampled contain soft sediments (muck), 28% contain sand, and 2% contain rock (Figure 3.4-2a). Map 4 illustrates that most of the points containing sand were located within the narrow channels and near-shore areas in the eastern portion of the lake, while areas of muck were prevalent in deeper areas and throughout the western side of the lake. Like terrestrial plants, most aquatic plants prefer to grow in soft, nutrient-rich sediments; the substrates present in Mirror Lake are very conducive for supporting a lush aquatic plant community.

Map 5 shows that Mirror Lake is highly vegetated, with approximately 69% of the point-intercept sampling locations that fell within the maximum depth of plant growth (14 feet) contained aquatic vegetation. The majority of aquatic plant growth occurs in the western and southeastern portions of the lake (Map 5). The density of aquatic plant growth within Mirror Lake is also relatively high, with 41% of the point-intercept sampling locations having aquatic plant density ratings of 2 or 3 (Figure 3.4-2b).

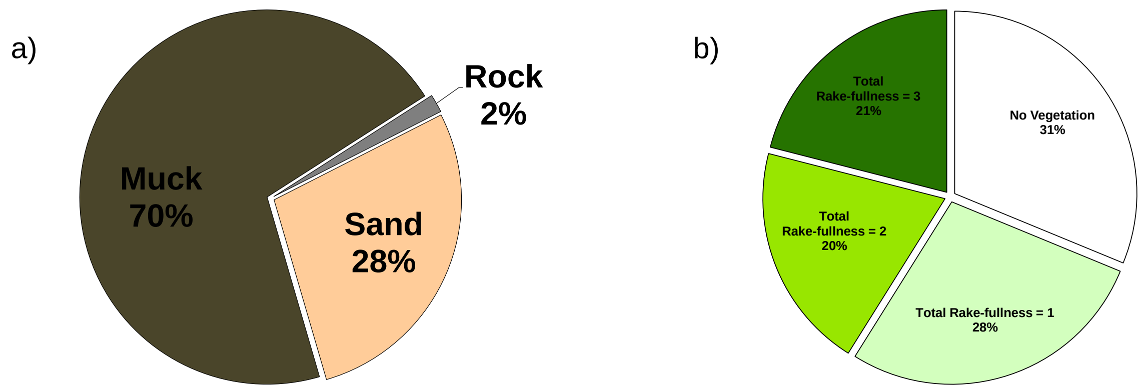


Figure 3.4-2. a) Mirror Lake proportion of substrate types within littoral areas. b) Mirror Lake aquatic vegetation rake-fullness ratings. Created using data from June 2012 aquatic plant point-intercept survey.

Table 3.4-1. Aquatic plant species located in Mirror Lake during 2012 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2012 (Onterra)
Emergent	*Acorus calamus*	Sweetflag	Exotic (Naturalized)	I
	Calla palustris	Water arum	9	X
	Carex comosa	Bristly sedge	5	I
	Carex lurida	Shallow sedge	8	I
	Eleocharis obtusa	Blunt spikerush	3	I
	Fallopia japonica	Japanese knotweed	Exotic (Invasive)	I
	Iris pseudacorus	Pale-yellow iris	Exotic (Invasive)	I
	Juncus effusus	Soft rush	4	I
	Sagittaria latifolia	Common arrowhead	3	X
	Sagittaria rigida	Stiff arrowhead	8	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Scirpus atrovirens	Black bulrush	3	I
	Scirpus cyperinus	Wool grass	4	I
	Sparganium sp. (sterile)	Bur-reed species (sterile)	N/A	I
FL	*Nymphaea odorata*	White water lily	6	I
Submergent	*Callitriche palustris*	Common water starwort	8	I
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Elodea nuttallii	Slender waterweed	7	X
	Heteranthera dubia	Water stargrass	6	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic (Invasive)	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic (Invasive)	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton nodosus	Long-leaf pondweed	7	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Ranunculus aquatilis	White water-crowfoot	8	X
	Stuckenia pectinata	Sago pondweed	3	X
FF	*Lemna turionifera*	Turion duckweed	2	X
	Spirodela polyrhiza	Greater duckweed	5	X
	Wolffia spp.	Watermeal species	N/A	X

FL = Floating Leaf; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species

Data gathered during the 2012 aquatic plant point-intercept survey indicates that common waterweed, coontail, turion duckweed, and watermeal species were the four-most abundant aquatic plant species encountered (Figure 3.4-3). As its name suggests, common waterweed is an aquatic plant species with a wide distribution across North America. While common waterweed can be found growing in many of Wisconsin's waterbodies, excessive growth of common waterweed is often observed in waterbodies which receive excessive amounts of nutrients. As discussed in within the Water Quality and Watershed Sections, Mirror Lake is a productive system that receives a large amount of nutrients. While common waterweed does produce roots to hold itself in place, it can obtain many of its essential nutrients directly from the water. In addition, it can tolerate the low light conditions found in eutrophic systems better than many other aquatic plant species. For these reasons, common waterweed has competitive advantages over other aquatic plant species that favor its growth in highly eutrophic systems such as Mirror Lake.

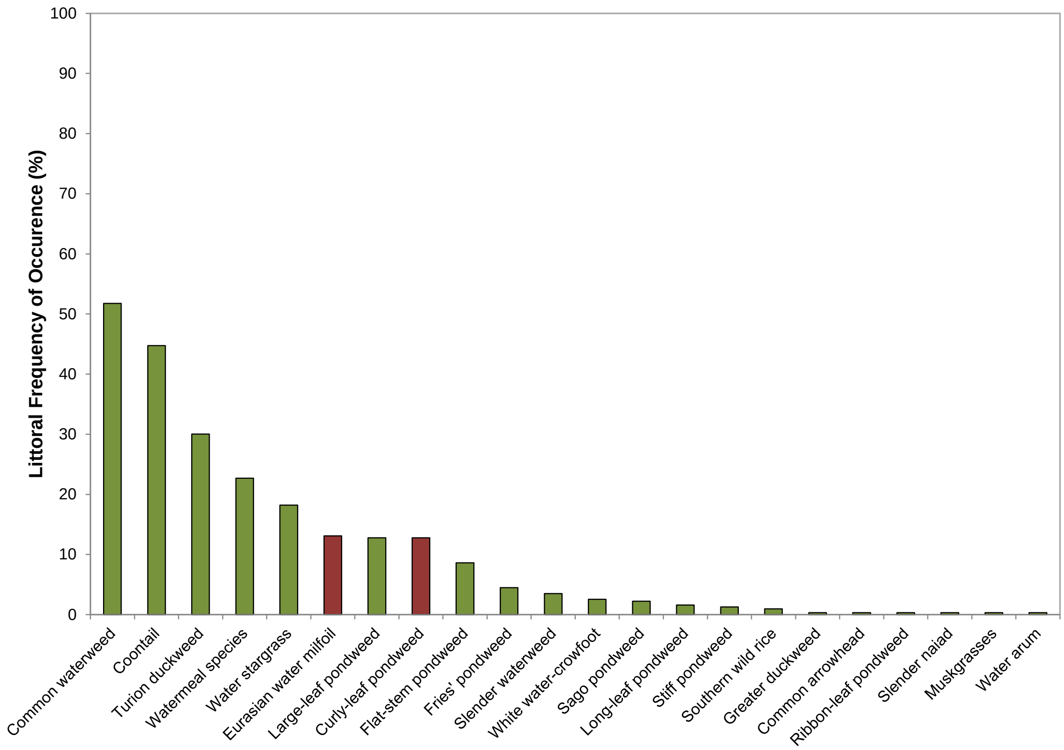


Figure 3.4-3. Mirror Lake aquatic plant littoral frequency of occurrence. Created using data from 313 locations sampled during June 2012 point-intercept survey. Non-native species are indicated in red.

Coontail was the second-most frequently encountered aquatic plant species during the 2012 point-intercept survey. Like common waterweed, coontail is an abundant and widespread species throughout North America. And like common waterweed, coontail can obtain most of its essential nutrients directly from the water and tolerate lower light levels, and thus can grow prolifically in high-nutrient systems. Unlike common waterweed, coontail does not produce any roots, and often grows free-floating within the water or entangled among other aquatic plants.

Three species of the duckweed family (*Lemnacea*) were located in Mirror Lake in 2012, and include turion duckweed, watermeal species, and greater duckweed. While turion duckweed and watermeal were found in great abundance, greater duckweed was very infrequent (Figure 3.4-3). Unlike most other aquatic plants, duckweed and watermeal are free-floating, unattached from the sediment and obtain all of their nutrients directly from the water (Huebert and Shay 1991). While these plants are flowering plants, they mainly reproduce vegetatively via budding. Under optimal conditions, they can double their population every 16 hours (Hasan and Chakrabarti 2009), allowing them to completely cover areas of waterbodies in a very short time. These plants cannot grow and reproduce in fast-moving water, and require areas of still or slow-moving water that is relatively protected from wind.

According to Hasan and Chakrabarti (2009), only a minimal amount of phosphorus within the water is required to support duckweed growth, and once this level has been reached, the concentration of nitrogen, specifically ammonia nitrogen, is main nutrient controlling the growth of duckweeds. If adequate nutrients and light are present, the remaining important factor in determining the growth rate of duckweeds is temperature (van der Heide et al. 2006). The growth rate of duckweeds is positively correlated with water temperature, and their maximum growth rate is achieved when water temperature is at 78.8°F (van der Heide et al. 2006). However, if their density or the thickness of the mat becomes too great, their growth rates decline due to self-shading (Driever et al. 2005).

During the 2012 surveys on Mirror Lake, vast blanket-like mats of duckweed and watermeal were observed within the western basin (Upper Mirror Lake) (Photo 3.4-1). The amount of duckweed present within Mirror Lake is an indicator of high nutrient levels within the water, particularly ammonia nitrogen. Sources of ammonia nitrogen to lakes include fertilizers and animal wastes. As discussed in the Watershed Section, lower levels of ammonia nitrogen were detected in Upper Mirror Lake than Lower Mirror Lake, possibly indicating its uptake by the duckweed growth in that area. Mirror Lake has an immense drainage basin much of which is comprised of agricultural land cover. The composition and size of Mirror Lake's watershed is the reason why high levels of ammonia nitrogen are present within the lake.

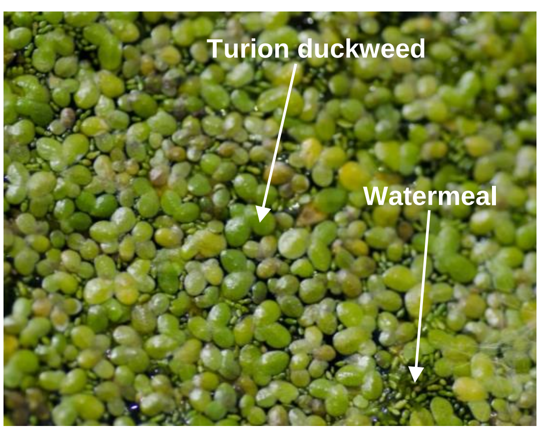


Photo 3.4-1. Close-up (left) and large blanket-like mat (right) of turion duckweed (*Lemna turionifera*) and watermeal (*Wolffia spp.*) in the western basin of Mirror Lake. Photos taken during 2012 aquatic plant surveys.

All of the conditions necessary for producing excessive growth of duckweed within Upper Mirror Lake are present: 1) high levels of nutrients, particularly ammonia nitrogen within the water, 2) the western basin contains slower-moving water with surface-matted vegetation that provides habitat for the duckweed to grow, 3) adequate sunlight, and 4) especially in 2012, warm surface water temperatures to facilitate a rapid growth rate. Most of the duckweed present within Mirror Lake is produced within Upper Mirror Lake and is delivered via current and wind to other areas of the system.

While there is abundant, and in some areas excessive aquatic plant growth in Mirror Lake, the plants that are present are very adept at obtaining nutrients from the water. By removing these nutrients and incorporating them into their tissues, they are making those nutrients unavailable to often troublesome free-floating and filamentous algae. However, the level of aquatic plant growth, particularly in the western basin of the lake, grows to levels that hinder watercraft navigation and other recreational activities. These levels could be considered nuisance levels of aquatic plant growth. As mentioned earlier, Mirror Lake has ideal conditions for supporting a high level of aquatic plant growth.

Climatic factors in 2012 greatly favored vigorous aquatic plant growth across Wisconsin's lakes with the early ice-out, higher-than-normal temperatures, and little rain which lowered water levels. It is unrealistic to quantitatively define the term "nuisance", as this designation is subjective by nature. However, WDNR Science Services researchers indicate that nuisance levels of a certain plant species likely occur when its littoral frequency of occurrence exceeds 35% (Alison Mikulyuk, personal comm.). Plants that can potentially cause nuisance conditions are those that grow to and/or near the surface or float on the water's surface and contain a high biomass. In Mirror Lake, common waterweed and coontail exceed this relatively arbitrary benchmark while turion duckweed falls just below this threshold (Figure 3.4-4). Coontail, common waterweed, and turion duckweed have the potential to impact navigation at these levels, especially when the plants grow in dense surface mats. In early summer, curly-leaf pondweed is also a likely contributor to the nuisance levels of aquatic plants within Upper Mirror Lake. A mechanical harvesting plan for Mirror Lake to alleviate areas of nuisance aquatic plant growth is discussed within the Implementation Plan Section.

While only the four-most frequently encountered aquatic plant species in Mirror Lake have been discussed above, all of the native aquatic plant species encountered on the rake during the 2012 point-intercept survey are used to calculate the lake's Floristic Quality Index (FQI). These calculations do not include species that were located incidentally during the 2012 surveys. For example, while a total of 31 native aquatic plant species were located in Mirror Lake during the 2012 surveys, only 20 were encountered on the rake during the point-intercept survey. The conservatism values of these 20 native species were used to calculate the FQI of Mirror Lake's aquatic plant community (equation shown below).

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

Figure 3.4-5 compares the FQI components from Mirror Lake calculated from the 2012 point-intercept survey to median values of lakes within the Driftless Area and Mississippi Backwater Lakes and Flowages (DMR) Ecoregion and to other lakes and flowages within the entire state of Wisconsin. As displayed in Figure 3.4-5, the native species richness (20) falls within the top 25% for lakes within the DMR Ecoregion and for flowages throughout Wisconsin. The average conservatism value for the 20 native plant species (6.0) falls within the top 25% for lakes within the DMR Ecoregion and is the same as the median value for lakes in the state (Figure 3.4-5). Combining Mirror Lake's native species richness and average conservatism values yields a high

FQI value of 26.8, falling in the top 25% for lakes in the DMR ecoregion and the top 50% for lakes in Wisconsin (Figure 3.4-5).

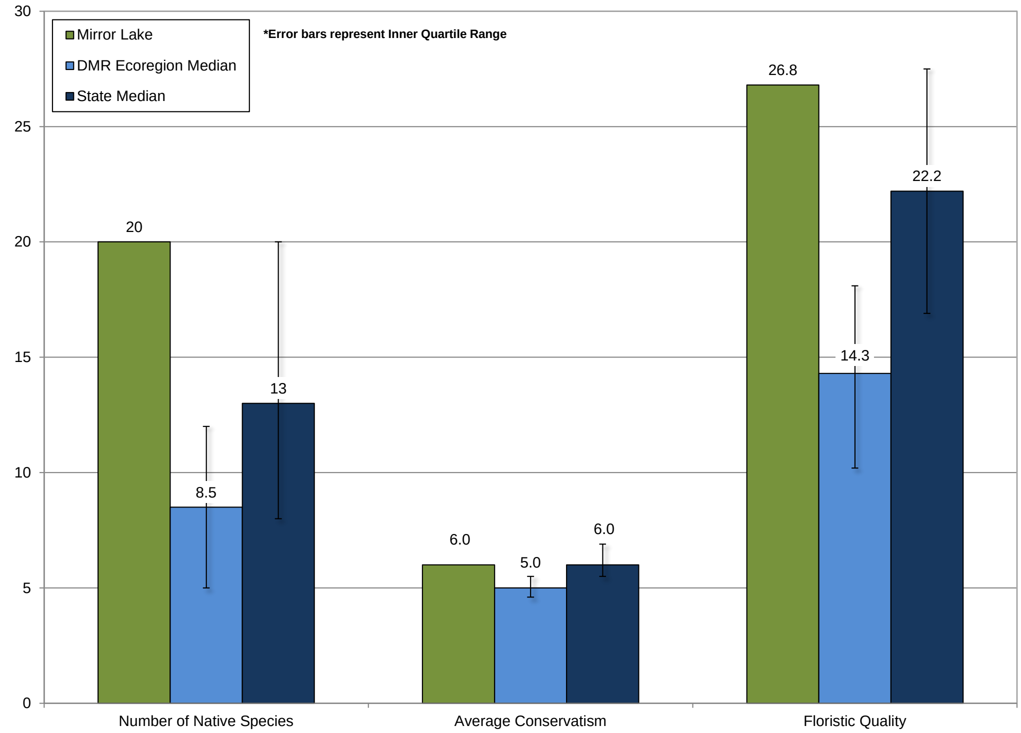


Figure 3.4-5. Mirror Lake Floristic Quality Assessment. Created using data from 2012 aquatic plant point-intercept survey.

While the FQI analysis indicates that Mirror Lake's aquatic plant community is of higher quality than most lakes within the DMR Ecoregion and comparable to other lakes within the state, this analysis does not take into account the abundance of each the plant species within the lake. Mirror lake does contain more sensitive aquatic plant species (C-values of 7 and 8), but they are in low abundance. Figure 3.4-6 displays the relative frequency of occurrence of aquatic plant species in Mirror Lake from the 2012 point-intercept survey and illustrates that the vast majority of the lake's plant community is comprised of species with lower conservatism values (i.e. common waterweed and coontail). High abundances of common waterweed, coontail, duckweed, and watermeal are indicative of an over-nutrified, disturbed system.

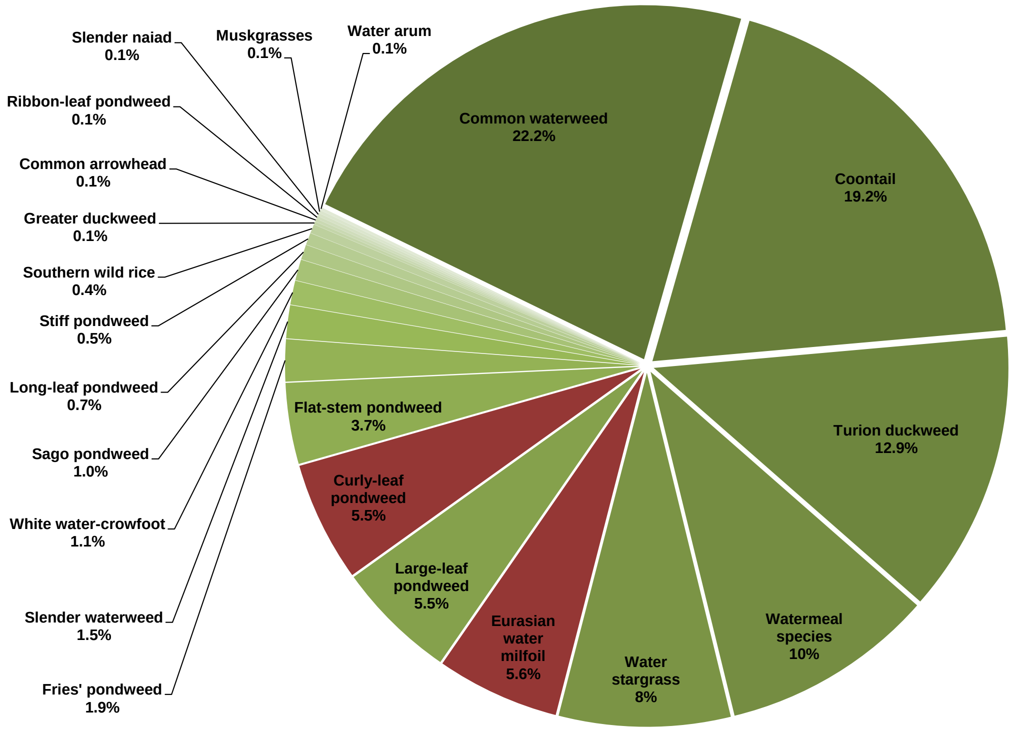


Figure 3.4-6. Mirror Lake aquatic plant relative frequency of occurrence. Created using data from 313 locations sampled during June 2012 point-intercept survey. Non-native species are indicated in red.

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 Mirror Lake contains a relatively 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 Mirror Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for four lakes within the DMR Ecoregion and 252 lakes within the state (Figure 3.3-7). Using the data collected from the 2012 point-intercept survey, Mirror Lake's aquatic plant

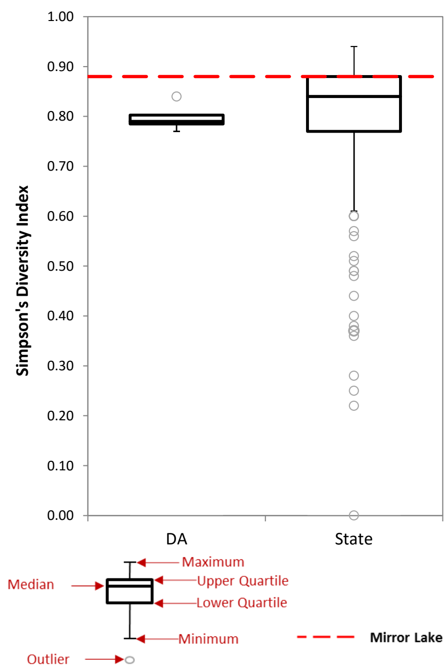


Figure 3.4-7. Mirror Lake species diversity index. Created using data from 2012 aquatic plant point-intercept survey.

community was shown to have moderate species diversity with a Simpson's diversity value of 0.88. This value indicates that if two individual aquatic plants were randomly sampled from Mirror Lake, there would be an 88% probability that they would be different species. The DMR Ecoregion's sample size of four is very small, but Mirror Lake's diversity value does fall above the upper quartile of the four lakes sampled. A better comparison is with diversity values from lakes around the state, with Mirror Lake's diversity falling even with the upper quartile value (75^{th} percentile) for lakes statewide (Figure 3.4-7).

The emergent and floating-leaf aquatic plant communities were also assessed in Mirror Lake in 2012. The 2012 community map (Map 6) indicate that approximately 21.3 acres (15.5%) of the 137-acre lake contain these types of plant communities (Table 3.4-2). Twelve floating-leaf and emergent native species were located in Mirror Lake (Table 3.4-1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. Map 6 also displays adjacent wetland habitat to Mirror Lake. While not included in the table below, these wetland areas are extremely beneficial to Mirror Lake's water quality and ecology by absorbing nutrients, filtering sediments, and providing valuable habitat for aquatic and terrestrial wildlife.

Table 3.4-2. Mirror Lake acres of floating-leaf and emergent plant communities. Created from the 2012 community mapping survey.

Plant Community	Acres
Floating-leaf	0.7
Emergent	20.5
Mixed Floating-leaf & Emergent	0.1
Total	**21.3**

Southern wild rice (*Zizania aquatic*a) dominates the emergent plant communities within Mirror Lake (Photo 3.4-2, Map 6). Wild rice is an emergent aquatic grass that grows in shallow water of lakes and slow-moving rivers. Wild rice has cultural significance to the Chippewa Tribal Communities where the grain historically was an important component of Native American diets. It is also an important diet component for waterfowl, muskrats, deer, and many other species. Established wild rice plant communities can provide valuable nursery and brooding habitat for wetland bird and amphibian species as well as spawning habitat for various fish. Perhaps one of the most overlooked benefits of having established wild rice communities is their ability to utilize excessive plant nutrients, stabilize soils, and form natural wave breaks to protect shoreland areas.

Photo 3.4-2. Southern wild rice in Mirror Lake.

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

Non-native Plants in Mirror Lake

Curly-leaf pondweed

The Wisconsin Department of Natural Resources (WDNR) does not have a documented year of when the non-native plant curly-leaf pondweed (*Potamogeton crispus*) was first discovered in Mirror Lake; however, given its wide-spread occurrence it has likely been present within the lake for some time. During the 2012 early-season AIS survey, approximately 12 acres of colonized curly-leaf pondweed with a density rating of dominant or higher was mapped in Mirror Lake, while approximately 28 acres of the lake were classified as having scattered or highly scattered curly-leaf pondweed occurrences (Map 7). The majority of the curly-leaf pondweed was found growing in Upper Mirror Lake.

Eurasian water milfoil

Eurasian water milfoil (*Myriophyllum spicatum*) was first documented in Mirror Lake in 1994. No areas of dominant Eurasian water milfoil were observed during the 2012 surveys, though approximately 39 acres of Mirror Lake contains Eurasian water milfoil classified as either *scattered* or *highly-scattered* (Map 9) and is more widespread throughout the system than curly-leaf pondweed (Map 8). Most of Upper Mirror Lake contains highly scattered Eurasian water milfoil while the southeastern portion of the lake contains areas of *scattered* and *highly scattered* Eurasian water milfoil. *Single or Few Plant* occurrences were also documented throughout other areas of the lake.

Pale-yellow iris

One occurrence of pale-yellow iris (*Iris pseudacorus*) was located growing on Mirror Lake's shoreline during the community mapping survey (Map 7). Pale-yellow iris a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. At the time of this report, it appears that the only means of control are continual hand removal and monitoring.

Japanese knotweed

A relatively large patch of Japanese knotweed (*Fallopia japonica*) was located growing along the southern shore of Upper Mirror Lake during the community mapping survey (Map 7). Like many other invasive species, Japanese knotweed was introduced to the United States as an ornamental plant. This perennial produces large, hollow stems that have the appearance of bamboo, and it is able to thrive in many different habitats where it out-competes native species. At this time, the best method of control through a combination of cutting followed by an application of herbicide once in late spring and again in early fall. Often, several years of cutting/herbicide applications will be required to eradicate areas of this invasive plant.

3.5 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 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 numerous fisheries biologists overseeing Mirror Lake. The goal of this section is to provide an incomplete overview of some of the data that exists, particularly in regards to specific issues (e.g. fish stocking, angling regulations, etc) that were brought forth by the MLMD stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR (WDNR 2011).

Mirror Lake Fishery

Mirror Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was ranked as the fourth most important reason for owning property near Mirror Lake (Question #14). Approximately 74% of these same respondents believed that the quality of fishing on the lake is Fair or Good (Question #11); and approximately 35% believe that the quality of fishing has remained while 39% believe the fishing has gotten either somewhat or much worse since they have obtained their property (Question #12).

Table 3.5-1 shows the popular game fish that are present in the system. 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 Mirror Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous 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 3.5-1.

Table 3.5-1. Gamefish present in the Mirror Lake with corresponding biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
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
Common Carp	*Cyprinus carpio*	47	April - August	Shallow, weedy areas from 3 - 6 ft	Insect larvae, crustaceans, mollusks, some fish and fish eggs
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)
Walleye	*Sander vitreus*	18	Mid April - early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Warmouth	*Lepomis gulosus*	13	Mid May - Early July	Shallow water 0.6 - 0.8 m, with rubble slightly covered with silt	Crayfish, small fish, odonata, and other invertebrates
White Crappie	*Pomoxis annularis*	13	May - June	Within 10 m from shore, over hard clay, gravel, or roots	Crustaceans, insects, small fish
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates
Yellow Bullhead	*Ameiurus natalis*	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae

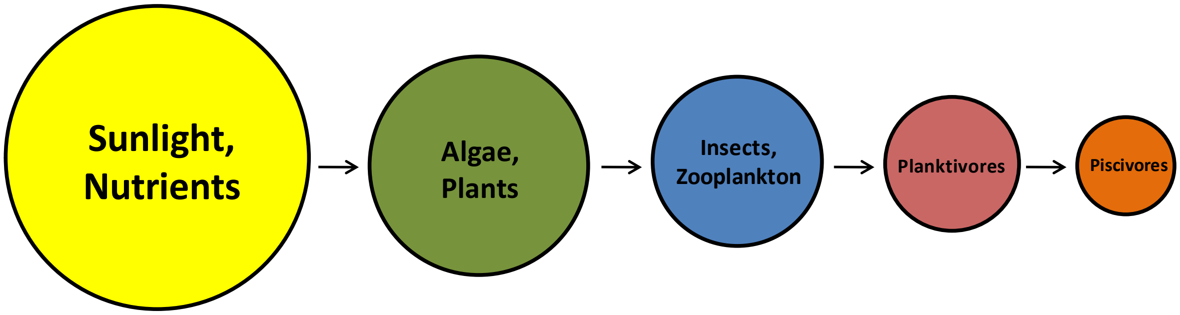


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Mirror Lake is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Mirror Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust.

Mirror Lake Fish Stocking

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

Table 3.5-2. Walleye stocking data available from the WDNR from 1986 to 2009 (WDNR 2013).

Year	Age Class	# Stocked	Avg. Length (inches)
1986	Fingerling	8,473	3
1987	Fingerling	33,000	5.5
1988	Fingerling	5,772	2
1989	Fingerling	11,300	3
1991	Fingerling	6,750	2
1992	Fingerling	5,763	5.5
1995	Fingerling	1,435	4.5
1996	Fingerling	2,500	6.5
1998	Large Fingerling	1,020	5.7
1998	Small Fingerling	13,700	1.4
1999	Fry	246,600	0.4
2000	Fry	246,000	0.5
2000	Large Fingerling	3,204	6.4
2000	Small Fingerling	18,756	1.4
2001	Fry	246,000	0.5
2002	Large Fingerling	3,780	7.7
2003	Small Fingerling	6,850	1.4
2004	Small Fingerling	6,850	1.5
2005	Large Fingerling	1,375	7.4
2005	Small Fingerling	6,870	1.8
2006	Small Fingerling	8,520	1.4
2007	Large Fingerling	4,250	7
2008	Small Fingerling	2,466	1.3
2009	Small Fingerling	2,466	1.4

Mirror Lake Substrate and Near Shore Habitat

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

According to the point-intercept survey conducted by Onterra, 70% of the substrate sampled in the littoral zone on Mirror Lake was muck, with 28% being classified as sand and 2% being classified as rock (Map 5). Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. 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 is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

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.

Mirror Lake Regulations and Management

Because Mirror Lake is located within the southern region of Wisconsin, special regulations may occur that differ from those in other areas of the state. For example, Mirror Lake is in the southern large and smallmouth bass management zone as well as the southern muskellunge and northern pike management zone so regulations here may differ from those set for northern Wisconsin lakes. Table 3.5-3 displays the 2013-2014 regulations for species that may be found in Mirror Lake. Please note that this table is intended to be for reference purposes only, and that anglers should visit the WDNR website (see end of paragraph) anglers should visit the WDNR website for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.
(www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html)

Table 3.5-3. WDNR fishing regulations for Mirror Lake, 2013-2014.

Species	Season	Regulation
Catfish	Open All Year	No minimum length limit and the daily bag limit is 10.
Panfish	Open All Year	No minimum length limit and the daily bag limit is 25.
Largemouth and smallmouth bass	May 4, 2013 to March 2, 2014	The minimum length limit is 14" and the daily bag limit is 5.
Muskellunge and hybrids	May 4, 2013 to December 331, 2013	The minimum length limit is 40" and the daily bag limit is 1.
Northern pike	May 4, 2013 to March 2, 2014	The minimum length limit is 26" and the daily bag limit is 2.
Walleye	May 4, 2013 to March 2, 2014	The minimum length limit is 15" and the daily bag limit is 5.
Bullheads	Open All Year	No minimum length limit and the daily bag limit is unlimited.
Rock, yellow, and white bass	Open All Year	No minimum length limit and the daily bag limit is unlimited.
Catfish	Open All Year	No minimum length limit and the daily bag limit is 10.

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

These three objectives were fulfilled during the project and have led to a good understanding of the Mirror Lake ecosystem, the people who care about the lake, and what needs to be completed to protect and enhance it.

The studies conducted on Mirror Lake indicate that the system receives a high amount of nutrients (phosphorus and nitrogen) which fuel excessive growth of free-floating duckweed and watermeal, as well as rooted aquatic plants. Not only does Mirror Lake have a very large watershed relative to the size of the lake itself (302:1), a large portion of its watershed is comprised of agricultural lands which deliver higher amounts of nutrients to waterways. However, while Mirror Lake is currently highly eutrophic and bordering hypereutrophic, watershed modeling and predictive analyses indicated that the mitigation that has taken place within the Dell Creek watershed is having a detectable effect at reducing the level of total phosphorus entering the lake; even if Mirror Lake's entire watershed were converted to natural land cover (e.g. forest and wetlands) the system would still be eutrophic due to the sheer size of the watershed and cumulative levels of phosphorus delivered to the lake.

While near-surface total phosphorus values in Mirror Lake fall within the *Fair* and *Poor* categories for shallow lowland drainage lakes in Wisconsin, chlorophyll-*a* levels were lower, falling in the *Good* and *Fair* categories. This is likely a result of Mirror Lake's high flushing rate (water exchange rate) which does not give algae a sufficient amount of time to grow and multiply within the lake before being carried downstream. In addition, Mirror Lake has abundant rooted aquatic plant and free-floating duckweed growth, which consume a large amount of nutrients making them unavailable to free-floating algae. As a result of lower chlorophyll-*a* levels, water transparency fell within the *Good* and *Excellent* categories for shallow, lowland drainage lakes in Wisconsin.

A lake's water quality is largely a reflection of its drainage basin, or watershed. As discussed, Mirror Lake has a large watershed, encompassing approximately 67 square miles. The majority of the watershed is comprised of intact forested land cover; however, approximately 36% is comprised of row crop agriculture, which modeling indicated is the largest contributor of phosphorus to Mirror Lake. The mitigation efforts that have taken place within the Dell Creek watershed to reduce nutrient and sediment inputs appear to have had a detectable effect on Mirror Lake's water quality. Total phosphorus concentrations measured from Mirror Lake were significantly lower than what the model predicted based upon the land cover types within its watershed.

The shoreland assessment revealed that the vast majority of Mirror Lake's shoreline is in a completely undeveloped, natural state. Most of the shoreline falls within Mirror Lake State Park, and in regards to protecting Mirror Lake, conserving this existing natural shoreline and potentially restoring the smaller areas of disturbed shoreline may be one of the best options at this time. This survey also revealed that Mirror Lake has high amounts of course woody habitat, with approximately 27 pieces observed per shoreline mile. Course woody habitat is valuable for maintaining a healthy lake ecosystem, and management of this habitat is discussed further within the Implementation Plan.

The 2012 whole-lake point-intercept survey revealed that the native aquatic plant community of Mirror Lake is of higher quality than most of the lakes and impoundments within the Driftless Area of Wisconsin, and contains a number of species that considered more sensitive to environmental degradation. While aquatic plant growth, particularly of duckweed, can grow to nuisance levels in certain areas of the lake, these plants are consuming nutrients that would otherwise be available to free-floating algae. These aquatic plants also aid in maintaining water clarity by stabilizing bottom sediments, and also provide competition against non-native plants like Eurasian water milfoil and curly-leaf pondweed. While Mirror Lake contains populations of both Eurasian water milfoil and curly-leaf pondweed, the 2012 surveys revealed that their populations are relatively small, and with members of the Mirror Lake Planning Committee, it was determined control of these plants was not currently warranted. Strategies for monitoring Eurasian water milfoil and curly-leaf pondweed in the future can be found within the Implementation Plan.

Through the process of this lake management planning effort, the MLMD has learned much about their lake, both in terms of its positive and negative attributes. It is now the MLMD's responsibility to maximize the positive attributes while minimizing the negative attributes as much as possible. The Implementation Plan that follows this section stems from discussions between Onterra ecologists and the MLMD Planning Committee on which action items the district may implement to properly maintain and care for this resource.

5.0 IMPLEMENTATION PLAN

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

Management Goal 1: Maintain and Enhance the Overall Ecological Health of Mirror Lake

Management Action: Update the Mirror Lake Management Plan in 2018.

Timeframe: Begin summer of 2016 or winter of 2017

Facilitator: Mirror Lake Management District Board of Directors

Description: The studies conducted on Mirror Lake in 2012/2013 focused on the lake's water quality, watershed condition and impacts, shoreland condition, aquatic plant community, stakeholder perceptions, and an updated mechanical harvesting plan. The data collected during these studies created a baseline for future studies and provided a snapshot of Mirror Lake's condition in 2012/2013. Continual monitoring and reassessments of certain aspects of Mirror Lake are necessary to ensure that its ecological integrity is being maintained. One way to reassess the health of Mirror Lake is to update the lake management plan five years following its completion.

One of the primary reasons the MLMD wanted to complete a lake management plan was to understand the extent of non-native, invasive species (Eurasian water milfoil and curly-leaf pondweed) within the lake. The surveys revealed that while both Eurasian water milfoil and curly-leaf pondweed are established and relatively widespread throughout littoral areas of Mirror Lake, they do not constitute a large proportion of the lake's aquatic plant community. Together, the MLMD Planning Committee and Onterra ecologists determined that chemical control of these non-native plants was not yet warranted. However, it was recommended that their populations be reassessed in 2017 as part of the lake management plan update. Aquatic plants, native and non-native, vary in their occurrence from year to year for reasons that are not yet well understood. Control of EWM or CLP within Mirror Lake should be considered if large, dense monotypic stands of the plants begin to develop, where they may start to displace valuable native aquatic plant species.

Mirror Lake's native aquatic plant community would also be reassessed in 2017 in the form of another whole-lake point-intercept survey and community mapping survey. As discussed in the Aquatic Plant Section, Mirror Lake was found to have a high-quality native aquatic plant community, with high species richness and diversity. Comparing the 2017 data to the date collected in 2012 will allow for an understanding of any potential impacts annual mechanical harvesting may have on the native aquatic plant community, and allow for changes to the plan to be made to minimize negative impacts. The southern wild rice population in Mirror Lake was also a concern to stakeholders, as many believed the population was expanding and may soon interfere with navigation in Upper Mirror Lake. In 2012, approximately 21 acres of emergent aquatic plant communities contained southern wild rice. A reassessment of the wild rice population in Mirror Lake in 2017 will determine if this population is expanding.

The update of the Mirror Lake Management Plan would also include updated water quality analyses. These analyses would allow for a determination of any potential trends in water quality had occurred over this five-year period. Monitoring of water quality over time is important as an early discovery of negative trends may more easily lead to the reason as to why the trend is developing.

Action Steps:

1. Retain qualified professional assistance to aid in the development of an updated lake management plan to coordinate the studies listed previously.
2. In the summer of 2016 or winter of 2017, the MLMD will apply for a WDNR Lake Management Planning Grant to aid in funding the studies to be conducted in 2018 to update the Mirror Lake Management Plan.

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

Timeframe: Continuation of current effort

Facilitator: Mirror Lake Planning Committee

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.

The Citizen Lake Monitoring Network (CLMN) is a WDNR/UW-Extension program in which volunteers are trained to collect data on Wisconsin's lakes and rivers. One aspect of the CLMN is the collection of water quality data This program involves volunteers taking Secchi disk readings and water chemistry samples three times during the summer and once during the spring at the lake's deep hole. While the MLMD is enrolled in this program, water quality data have not been collected on a regular basis due to the inability to find a volunteer to regularly collect these data.

It is the responsibility of the current Mirror Lake Planning Committee to coordinate a volunteer(s) to regularly collect these data as needed. According to the stakeholder survey, 34% of respondents indicated they would be willing to participate in water quality monitoring (Appendix B, Question #28). When a volunteer(s) has been selected, Rachel Sabre (262-574-2133) or the appropriate WDNR/UW Extension staff should be contacted to ensure the proper training occurs and the necessary sampling materials are received by the volunteer(s). It is also 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) by the volunteer.

Action Steps:

1. The Mirror Lake Planning Committee appoints a volunteer(s) to collect water quality samples four times per year on Mirror Lake.
2. Trained CLMN volunteer(s) collects data and report results to WDNR and to district members during annual meeting.
3. Volunteer(s) contacts Rachel Sabre (262-574-2133) to acquire necessary materials and training for new volunteer(s).

Management Action: The MLMD contracts with an environmental engineering firm to reassess the previously-dredged sedimentation basin in Upper Mirror Lake, the sedimentation basins created above the gullies around Mirror Lake, and to quantify the growth and potential removal of sand deltas at the mouths of the gullies.

Timeframe: Begin summer of 2016 or winter of 2017

Facilitator: Mirror Lake Planning Committee

Description: In 2008, the MLMD contracted with Vierbicher Associates, Inc., an environmental engineering firm, to undertake a lake improvement project to reduce sediments and nutrients entering the lake. That project resulted in navigational dredging and the creation of a sediment/nutrient trap in Upper Mirror Lake. Following that project, in 2010, the MLMD initiated another project with Veirbicher that identified highly developed, steep areas of shoreline that were contributing significant amounts of sediment/nutrients to the lake. As a result of this study, best management practices (BMPs) were implemented in four gullies around Mirror Lake. In addition, sediment surveys of the deltas at the mouths of the gullies were also completed, and estimates for dredging this material were provided to the MLMD; however, the sediments comprising these deltas were not removed.

The goal of the 2008 dredging in Upper Mirror Lake in 2008 was to improve navigation and create a sediment/nutrient trap in the upstream-most area of the lake. The intent of the sediment/nutrient trap is to slow incoming water and allow particulate matter (sediment) which carries nutrients (phosphorus) to settle to the bottom and not be carried downstream. The 2012 studies conducted as part of the Mirror Lake Management Plan did not collect the information necessary to quantify the effectiveness of this sediment/nutrient trap. If it is working as designed, this dredged area will eventually fill will sediment over time. Since it was created in 2008, it is recommended that the MLMD contract with Vierbicher Associates, Inc. to reassess the sediment/nutrient trap in 2018 to determine 1) if it is functioning as intended, and 2) when it will likely need to be re-dredged.

In addition to reassessing the sediment/nutrient trap in Upper Mirror Lake, it is also recommended that the BMPs implemented on the four gullies be reassessed at that time to ensure they are functioning properly. During the Planning Committee Meetings, Mirror Lake stakeholders expressed concerns that the deltas forming at the base of the gullies were growing and may soon hinder navigation in the areas they occur. These deltas and other areas (i.e. Pickerel Slough) should also be reassessed in 2018 to determine if they have grown in size/volume since their assessment in 2010. Depending on this assessment, the MLMD may want to investigate potential methods for delta removal and more efficient erosion control.

Action Steps:

1. In the summer of 2016 or winter of 2017, the MLMD will contact Vierbicher Associates, Inc., and/or other firms offering similar services, to investigate the initiation of a study to reassess the sediment/nutrient trap, gully BMPs, and gully deltas in Mirror Lake.
2. If the MLMD decides to move forward with the above-mentioned reassessment project, the MLMD will apply for WDNR Lake Protection and Classification Grant to aid in funding this reassessment project.

Management Goal 2: Assure and Enhance the Communication of the Mirror Lake Management District with Lake Stakeholders

Management Action: The MLMD and Mirror Lake Association (MLA) will create and support a joint education committee comprised of both MLMD and MLA members to promote safe boating, water quality, public safety, and quality of life on Mirror Lake.

Timeframe: Begin summer of 2014

Facilitator: MLMD and MLA Board of Directors

Description: Education is an effective tool to address issues that impact water quality such as lake shore development, lawn fertilization, and other issues such as air quality, noise pollution, and boating safety. Within the 2012 Mirror Lake stakeholder survey, 40% of respondents indicated that they were members of both the MLA and the MLMD. To facilitate better communication between these two management entities and greater outreach to both association and district members, a joint Education Committee comprised of members from both the MLA and MLMD will be created to promote lake protection through a variety of educational efforts.

Currently, the MLA distributes at least one to three newsletters per year to association members, as well as special mailings as appropriate. The MLA also maintains a website (www.mirrorlakeassociation.com). This level of communication is important within a management group because it builds a sense of community while facilitating the spread of important association/district news, educational topics, and even social happenings. This is exemplified by 69% of stakeholder respondents indicating that the MLA and MLMD have kept them either fairly well or highly informed regarding lake-related issues (Appendix B, Question #27). This level of communication also provides a medium for the recruitment and recognition of volunteers. Perhaps most importantly, the dispersal of a well written newsletter can be used as a tool to increase awareness of many aspects of lake ecology and management among association and district members. By doing this, meetings can often be conducted more efficiently and misunderstandings based upon misinformation can be avoided. Educational pieces within the association newsletter may contain monitoring results, association management history, as well as other educational topics listed below.

In addition to creating regularly published association newsletter a variety of educational efforts will be initiated by the joint Education Committee. These may include educational materials, awareness events and demonstrations for lake users as well as activities which solicit local and state government support.

Example Educational Topics:

- Aquatic invasive species monitoring updates
- Boating safety and ordinances (slow-no-wake zones and hours)
- Catch and release fishing
- Littering (particularly on ice)
- Noise, air, and light pollution
- Shoreland restoration and protection

- Septic system maintenance
- Fishing Rules
- Specific topics brought forth in other management actions

Action Steps:

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

Management Goal 3: Control Aquatic Invasive Species in Mirror Lake and Prevent Future Introductions to and Spread from Mirror Lake

Management Action: Initiate volunteer-based monitoring of Eurasian water milfoil and curly-leaf pondweed and other non-native species in Mirror Lake.

Timeframe: Begin 2014

Facilitator: MLMD Board of Directors

Description: As discussed in the Aquatic Plant Section, the 2012 surveys on Mirror Lake indicated that the Eurasian water milfoil and curly-leaf pondweed populations in Mirror Lake do not require chemical methods of control at this time. However, monitoring of the Eurasian water milfoil and curly-leaf pondweed populations on an annual basis and reporting the findings to resource managers will yield an understanding of their dynamics from year to year and if potential action needs to be taken to initiate control strategies. It is proposed that this monitoring be conducted via Mirror Lake volunteers. In addition to reporting on the levels of Eurasian water milfoil and curly-leaf pondweed within the lake, these volunteers will also survey the lake for other potential invasive species.

The Citizen Lake Monitoring Network (CLMN) is a program that coordinates citizen-based data collection. Along with water quality data collection programs, the CLMN also has developed an AIS Monitoring plan. The goals of the CLMN aquatic invasive monitoring program are as follows:

- Help you become familiar with some of the more common native aquatic plants and animals in your lake.
- Help you monitor for the more common aquatic invasive species.
- Help you to communicate information to others.

Mirror Lake volunteers will conduct AIS surveillance monitoring on Mirror Lake with coordination from the South Central Region CLMN

Coordinator (Rachel Sabre – 262.574.2133) and following CLMN protocols, which are outlined within the AIS Monitoring Handbook and can be found at the CLMN website:

www4.uwsp.edu/cnr/uwexlakes/clmn

In order for accurate data to be collected during these surveys, volunteers must be able to identify non-native species such as Eurasian water milfoil and curly-leaf pondweed. Distinguishing these plants from native look-a-likes is very important. Mirror Lake volunteers can attend Citizen Lake Monitoring Network workshops to gain this training. The MLMD would also encourage its volunteer monitors to purchase a field guide to aquatic plants, such as *Through the Looking Glass* (Borman et al. 1997) which can be purchased through the CLMN website under 'publications.'

In 2014, Mirror Lake volunteers will conduct monitoring of the Eurasian water milfoil and curly-leaf pondweed around Mirror Lake, as discussed in the previous management action. The information gathered by the volunteers will be transferred to professional consultants. Professional monitoring will occur in these areas under one of two scenarios: 1) the MLMD believed that the amount of Eurasian water milfoil and/or curly-leaf pondweed found warrants control action (e.g. large, colonized areas of *dominant* or greater Eurasian water milfoil and/or curly-leaf pondweed), or 2) a period of five years has passed from the previous professional survey (2012).

Action Steps:

1. MLMD Board recruits volunteer AIS monitors.
2. Volunteers from Mirror Lake are trained on CLMN Aquatic Invasive Species Monitoring protocols (Rachel Sabre – 262.574.2133).
3. Volunteer monitors report findings to MLMD, WDNR, and consultant (as necessary).

<u>Management Action:</u> Initiate Clean Boats Clean Waters watercraft inspections at Mirror Lake public boat landings.

Timeframe: Begin 2014

Facilitator: MLMD Board of Directors

Description: Although Mirror Lake already contains Eurasian water milfoil and curly-leaf pondweed, and the non-native Chinese mystery snail, it is still important to minimize the chance that additional AIS be introduced into the system and that AIS are not transported from Mirror Lake to other waterbodies. To that end, the MLMD will initiate a WDNR Clean Boats Clean Waters (CBCW) watercraft inspection program at the two Mirror Lake public accesses.

Members of the MLMD and MLA will be trained on the CBCW protocols and complete boat inspections at the public landing on a regular basis. The goal would be to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts AIS exert on Wisconsin's lakes and educating people about how they are the primary vector of their spread.

Action Steps:

1. Members of the MLMD and MLA attend Clean Boats Clean Waters training session during the spring or summer of 2014.
2. MLMD and MLA members trained will train other volunteers in 2014.
3. Begin watercraft inspections during busy, high-use weekends.
4. Report results to the WDNR and MLMD.
5. Promote enlistment and training of new volunteers to keep the program fresh.

Management Goal 4: Maintain Navigation in Open Water and Near-shore Areas on Mirror Lake

<u>Management Action:</u> Use district-owned mechanical harvester to maintain reasonable navigation on Mirror Lake.

Timeframe: Ongoing

Facilitator: Mirror Lake Management District Board of Directors

Description: The purpose of mechanical harvesting is to allow navigation in certain areas of the lake that contain dense, nuisance levels of native and non-native aquatic plants. Map 10 displays the mechanical harvesting plan that was developed in conjunction with Onterra ecologists, WDNR staff, and district members. The map illustrates four types of harvesting areas; the primary harvest area which encompasses approximately 30 acres in Upper Mirror Lake, 50 and 30-foot wide navigational lanes which extend into Dell Creek, and a 30-foot duckweed harvesting lane in the narrows between Upper and Lower Mirror Lake.

The district has conducted harvesting operations in the past. The stakeholder survey results indicate that the vast majority of respondents have navigation issues involving excessive plants and believe that control is warranted. However as brought forth earlier, other alternatives to harvesting, such as dredging and herbicides, are not feasible for numerous reasons at the scale required to manage aquatic plants on Mirror Lake.

The district will follow the cutting plan displayed on Map 10. The following conditions would apply to the cutting:

1. Mechanical harvesting of lanes (or segments of lanes) should

only occur on an as-needed basis, as determined by the MLMD.

2. The harvesting map (Map 10) is a guide; therefore, the harvester operator should use it as such in determining the placement of lanes. Ultimately, the navigation lanes should be cut as close to the piers as possible, though cutting shall not occur shallower than 3 feet of water.

Action Steps:

1. District reapplies for a multiyear harvesting permit in 2017 (5 year).
2. District harvests in areas shown on Map 10 while following the plan listed above and restrictions indicated on the WDNR permit.
3. Harvest summary report is provided to the WDNR annually after each harvesting season.

<u>Management Action:</u> Selectively remove course woody habitat that inhibits reasonable navigation and recreational safety on Mirror Lake.

Timeframe: Ongoing

Facilitator: Mirror Lake Management District Board of Directors and Mirror Lake State Park

Description: As discussed in the Shoreline Condition Section, the majority of Mirror Lake's shoreline resides in the Mirror Lake State Park and is comprised of undeveloped, forested land. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. The 2012 course woody habitat survey revealed that Mirror Lake has a relatively high density of course woody habitat, with approximately 27 pieces of course woody habitat per shoreline mile. However, some trees that fall into the lake can impede navigation and present a recreational safety hazard for lake users, particularly in section of the lake locally known as the "Narrows" between Upper and Lower Mirror Lake. Trees that fall into or across the lake in this area often totally restrict navigation until the tree can be removed.

Since 2008, the MLMD has contracted with a local company to remove trees that impede navigation within the lake. Each year, members of the MLMD and employees from Mirror Lake State Park select trees for removal. The MLMD understands the ecological importance of maintaining course woody habitat within the lake, and together with the Mirror Lake State Park, will only select trees for removal if they restrict reasonable navigation within the lake and/or present a safety hazard to lake users.

Action Steps:

1. Members of the MLMD and employees from Mirror Lake State Park survey the lake annually and select pieces of course woody habitat for removal if they inhibit reasonable navigation and/or present a safety hazard to lake users.

2. The MLMD contracts with a tree removal service to remove the selected trees.

6.0 METHODS

Lake Water Quality

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

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

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

Watershed Analysis

The watershed analysis began with an accurate delineation of Mirror Lake’s drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – Fry et. al 2011) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR’s Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Mirror Lake during a May 23, 2012 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 Mirror Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on June 25, 2012. A point spacing of 37 meters was used resulting in approximately 400 points.

Community Mapping

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

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. A set of samples was also provided to the Mirror Lake Management District.

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