Marl Lake

Waushara County, Wisconsin

Comprehensive Management Plan

June 2013



Sponsored by:

Marl Lake District

WDNR Grant Program

LPL-1379-10 & LPL-1380-10

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Onterra, LLC
Lake Management Planning

Marl Lake

Waushara County, Wisconsin

Comprehensive Management Plan

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TABLE OF CONTENTS

1.0 Introduction 3
2.0 Stakeholder Participation 5
3.0 Results & Discussion 9
3.1 Lake Water Quality 9
3.2 Watershed Assessment 23
3.3 Shoreland Condition Assessment 27
3.4 Aquatic Plants 37
3.5 Fisheries Data Integration 60
4.0 Summary and Conclusions 63
5.0 Implementation Plan 65
6.0 Methods 71
7.0 Literature Cited 73

FIGURES

2.0-1 Select survey responses from the Marl Lake Stakeholder Survey 7
2.0-2 Select survey responses from the Marl Lake Stakeholder Survey, continued 8
3.1-1 Wisconsin Lake Classifications 13
3.1-2 Location of Marl Lake within the ecoregions of Wisconsin 13
3.1-3 Marl Lake, state-wide deep seepage lakes, and regional total phosphorus concentrations 15
3.1-4 Marl Lake, state-wide class 6 lakes, and regional chlorophyll-*a* concentrations 16
3.1-5 Marl Lake, state-wide class 6 lakes, and regional Secchi disk clarity values 16
3.1-6 Marl Lake total phosphorus, chlorophyll-*a*, and Secchi disk clarity values 18
3.1-7 Marl Lake, state-wide deep seepage lakes, and regional Trophic State Index Values 19
3.1-8 Marl Lake dissolved oxygen and temperature profiles 20
3.2-1 Marl Lake watershed land cover types in acres 25
3.2-2 Marl Lake watershed phosphorus loading in pounds 25
3.3-1 Shoreline assessment category descriptions 34
3.3-2 Marl Lake shoreland categories and total lengths 35
3.4-1 Spread of Eurasian water milfoil within WI counties 50
3.4-2 Marl Lake proportion of substrate types within littoral areas 51
3.4-3 Marl Lake aquatic plant littoral occurrence analysis 53
3.4-4 Marl Lake Floristic Quality Assessment 55
3.4-5 Marl Lake species diversity index 55
3.4-6 Marl Lake aquatic plant relative occurrence analysis 56
3.5-1 Aquatic food chain 60

TABLES

3.4-1 Aquatic plant species located in Marl Lake during July 2010 surveys 52
3.4-2 Marl Lake acres of emergent and floating leaf plant communities from the 2002 NES Ecological Services and 2010 Onterra community mapping services 57
3.5-1 Gamefish present in Marl Lake with corresponding biological information 61
6.0-1 Water Quality Sample Parameters and Timing 71

PHOTOS

1.0-1 Marl Lake, Waushara County 3
3.3-1 Example of a biolog restoration site 31
3.4-1 Marl Lake CLP Hand-harvesting 58

MAPS

1. Project Location and Lake Boundaries ..... Inserted Before Appendices
2. Watershed Boundary & Land Cover Types ..... Inserted Before Appendices
3. 2010 Shoreline Condition ..... Inserted Before Appendices
4. PI Survey: Substrate Types ..... Inserted Before Appendices
5. PI Survey: Aquatic Plant Distribution ..... Inserted Before Appendices
6. Emergent & Floating-leaf Aquatic Plant Communities ..... Inserted Before Appendices
7. 2010 CLP Locations ..... Inserted Before Appendices
8. 2011 CLP Locations ..... Inserted Before Appendices
9. 2012 CLP Locations ..... Inserted Before Appendices
10. 2011 EWM Locations ..... Inserted Before Appendices
11. 2012 EWM Locations ..... Inserted Before Appendices

APPENDICES

A. Public Participation Materials
B. Stakeholder Survey Response Charts and Comments
C. Water Quality Data
D. Watershed Analysis WiLMS Results
E. Aquatic Plant Survey Data

1.0 INTRODUCTION

Marl Lake, Waushara County, is a 41-acre seepage lake with a maximum depth of 35 feet and a mean depth of 16 feet (Map 1). This mesotrophic lake contains 20 native plant species, of which Fries' pondweed (*Potamogeton freisii*) is the most common plant. Curly-leaf pondweed and Eurasian water milfoil (hybrid) were discovered in Marl Lake during this project.

Field Survey Notes

Marl Lake's water levels are down significantly since the last management planning studies were completed in 2002 and 2003. Still, this is a beautiful lake with high water clarity.



Photograph 1.0-1 Marl Lake, Waushara County

Lake at a Glance - Marl Lake

Morphology	
Acreage	41 at ordinary high water mark; 27 in 2010
Maximum Depth (ft)	35 (30 in 2010)
Mean Depth (ft)	16 (11 in 2010)
Shoreline Complexity	1.65
Vegetation	
Curly-leaf Pondweed Survey Dates	June 9, 2010; May 5, 18, & 31, 2011
Comprehensive Survey Date	July 9, 2010
Number of Native Species	20
Threatened/Special Concern Species	None
Exotic Plant Species	CLP, EWM (Hybrid), Reed canary grass
Simpson's Diversity	0.80
Average Conservatism	5.9
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	8.4 – 8.9
Sensitivity to Acid Rain	Not Sensitive
Watershed to Lake Area Ratio	14:1

In 1988 a group of Marl Lake residents successfully petitioned Waushara County to form the Marl Lake District. The initial motivation for the formation of the district was brought about by concerns over animal waste pollution entering the lake from a nearby dairy operation.

Since the creation of the Marl Lake District, its members have worked hard on their own and though partnerships with the Wisconsin Department of Natural Resources (WDNR), Waushara County, and private landowners to not only minimize the effects of the aforementioned dairy operation, but also to protect and enhance the health of the lake via multiple avenues. For instance, the district understands that in the last 25 years, Eurasian water-milfoil (*Myriophyllum spicatum*) has been introduced to 21 nearby lakes within Waushara County, increasing the probability of introduction to Marl Lake. Being proactive, the district posted signage at the lake's sole boat landing warning users about aquatic invasive species and reminding them to thoroughly inspect their watercraft and trailers before and after leaving the lake. The Marl Lake District also sponsored the development of an aquatic plant management plan in 1996 and the completion of a comprehensive lake management plan in 2003 by NES Ecological Services through a WDNR Lake Planning Grant.

The main purpose of this project is to serve as an update to the 2003 plan. Specifically, the district wants to assure that their management efforts are effective in maintaining the health of Marl Lake. This project aims to detect any possible changes (natural or anthropogenic) that have occurred since 2003 in terms of the lake's water quality and aquatic plant community, and to determine if any non-native aquatic plant species have since become established in the lake.

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting
On June 19, 2010, a project kick-off meeting was held at the Marl Lake Pavilion to introduce the project to the general public. The meeting was announced through a mailing and personal contact by Marl Lake District board members. The approximately 25 attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Mr. Hoyman's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting I
On October 5, 2012, Tim Hoyman and Brenton Butterfield of Onterra met with members of the Marl Lake District Planning Committee and Ted Johnson with the Wisconsin Department of Natural Resources for over three hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including curly-leaf pondweed and Eurasian water milfoil surveys and potential control strategies, water quality analyses, watershed assessments, and aquatic plant community inventories were presented and discussed. The major concerns raised by the committee included curly-leaf pondweed and Eurasian water milfoil as well as the declining water levels observed over the past decade.

Project Wrap-up Meeting
To be determined.

Management Plan Review and Adoption Process
Yet to occur

Stakeholders of Marl Lake

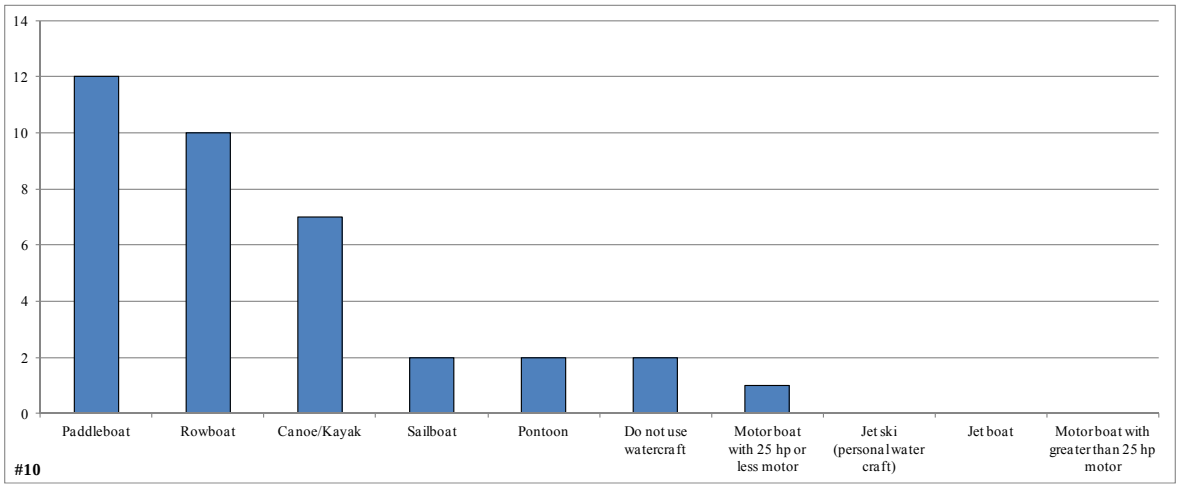
During September of 2010, a seven-page, 28-question survey was mailed to 32 riparian property owners in the Marl Lake watershed. Fifty-nine percent of the surveys were returned and those results were entered into a spreadsheet by members of the Marl Lake Planning Committee. The data were summarized and 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 Marl Lake. The majority of stakeholders (47%) are year-round residents, while 29% visit on weekends through the year and 18% live on the lake during the summer months only. Fifty-three percent of stakeholders have owned their property for over 15 years, and 29% 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. Below, Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. Most survey respondents indicate that they use a paddle boat, rowboat, a canoe/kayak, or a combination of these three vessels on Marl Lake (Question 10). On a small lake such as Marl, the importance of responsible boating activities is elevated. Marl Lake is a slow-no-wake lake; therefore, safety is increased while impacts to the lake are minimized.

A concern of stakeholders noted throughout the stakeholder survey (see Question 17, Question 18 and survey comments – Appendix B) was water levels within Marl Lake, excessive fishing pressure, and loss of fish habitat. However, at the time that this survey was distributed, the extent of curly-leaf pondweed was not entirely understood by riparian property owners as this was a recent discovery within Marl Lake. Further, the occurrence of hybrid milfoil within the lake had not yet been confirmed. Therefore, these significant discoveries may have changed the concerns of Marl Lake stakeholders. The topics of low water levels and habitat are touched upon in the Watershed Section, and discussion of aquatic invasive species within Marl Lake takes place in the Aquatic Plant Section. These topics are discussed at length in the Summary & Conclusions Section and Implementation Plan as well.

Question 10: What types of watercraft do you currently use on the lake?



Question 11: Please rank up to three activities that are important reasons for owning your property on or near the lake.

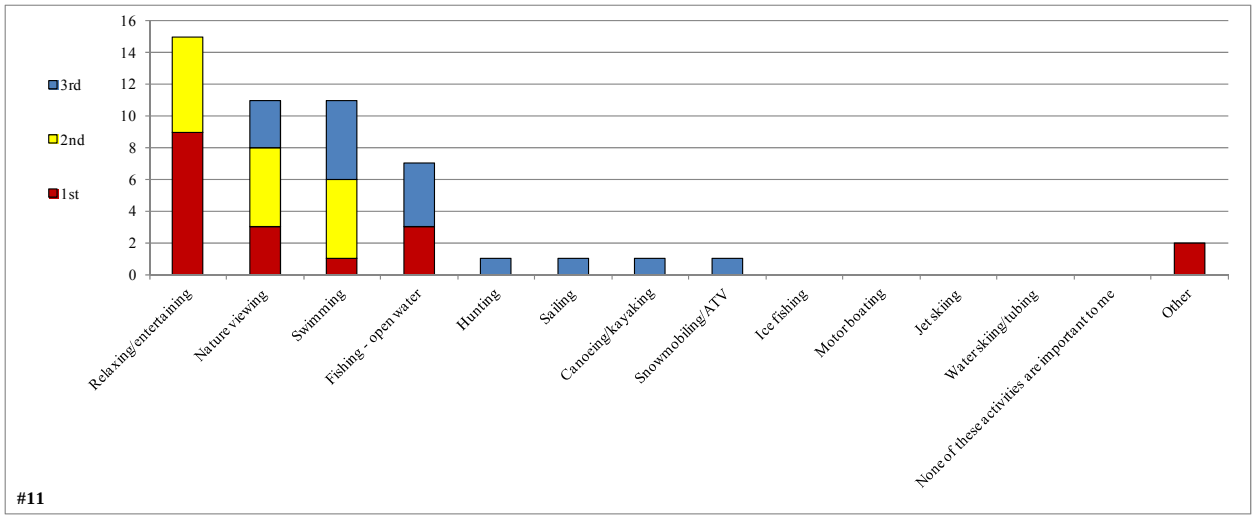
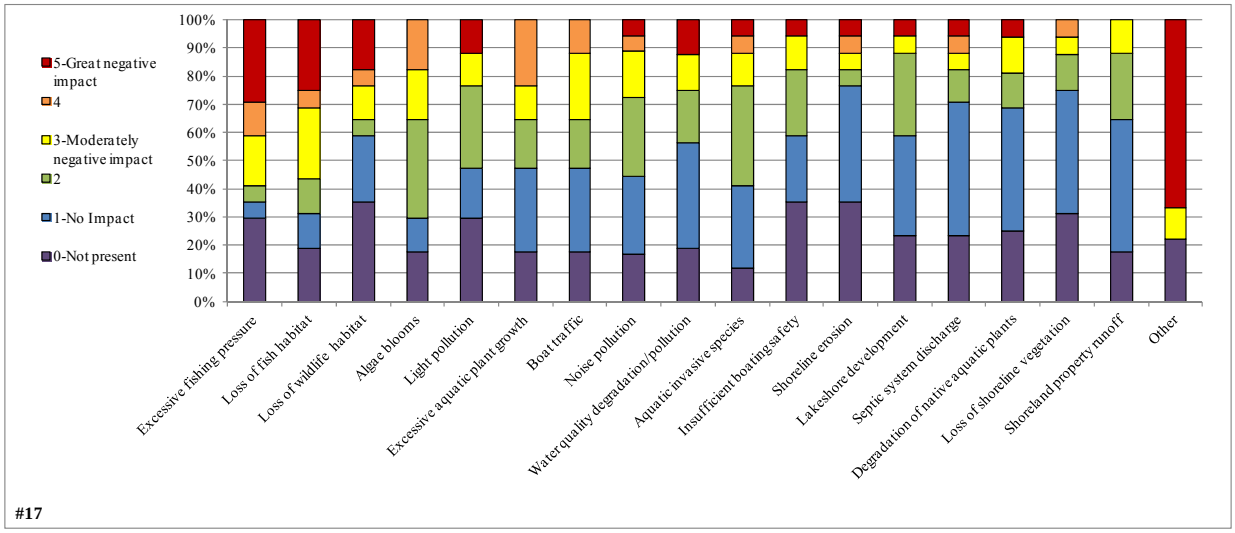


Figure 2.0-1. Select survey responses from the Marl Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 17: To what level do you believe these factors may be negatively impacting Marl Lake?



Question 18: Please rank your top three concerns regarding Marl Lake.

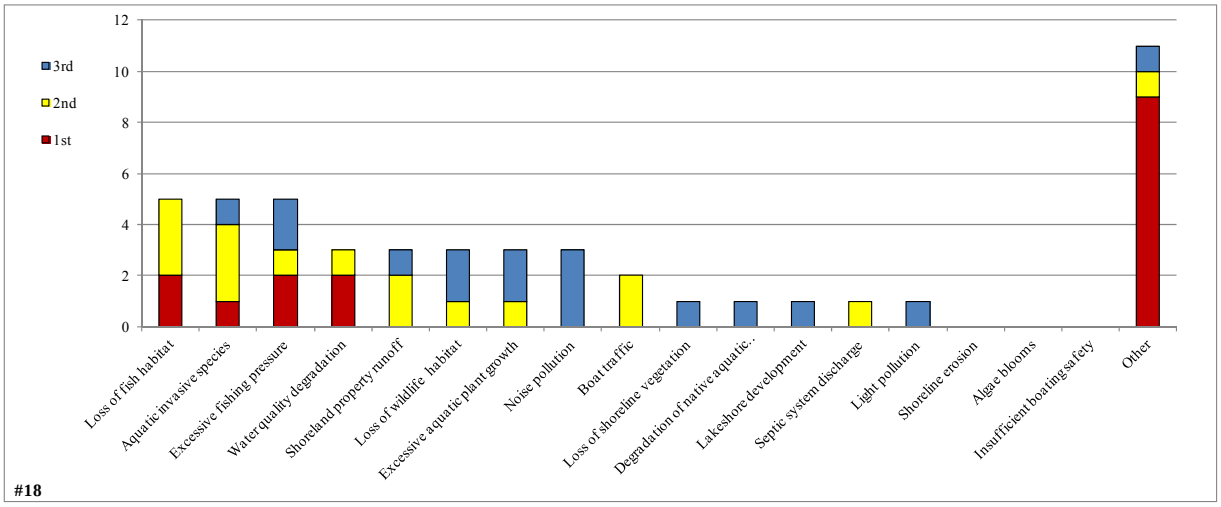


Figure 2.0-2. Select survey responses from the Marl Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Marl Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Marl Lake's water quality analysis:

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

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

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

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

Trophic State

Total phosphorus, chlorophyll-*a*, and water clarity values are directly related to the trophic state of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: oligotrophic, mesotrophic, and finally eutrophic. Every lake will naturally progress through these states and under natural conditions (i.e. not influenced by the activities of humans) this progress can take tens of thousands of years. Unfortunately, human influence has accelerated this natural aging process in many Wisconsin lakes. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the productivity of their lake over time. Yet, classifying a lake into one of three trophic states often does not give clear indication of where a lake really exists in its trophic progression because each trophic state represents a range of productivity. Therefore, two lakes classified in the same trophic state can actually have very different levels of production.

Trophic states describe the lake's ability to produce plant matter (production) and include three continuous classifications: Oligotrophic lakes are the least productive lakes and are characterized by being deep, having cold water, and few plants. Eutrophic lakes are the most productive and normally have shallow depths, warm water, and high plant biomass. Mesotrophic lakes fall between these two categories.

However, through the use of a trophic state index (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake's position within the eutrophication process. This allows for a more clear understanding of the lake's trophic state while facilitating clearer long-term tracking. Carlson (1977) presented a trophic state index that gained great acceptance among lake managers.

Limiting Nutrient

The limiting nutrient is the nutrient which is in shortest supply and controls the growth rate of algae and some macrophytes within the lake. This is analogous to baking a cake that requires four eggs, and four cups each of water, flour, and sugar. If the baker would like to make four cakes, he needs 16 of each ingredient. If he is short two eggs, he will only be able to make three cakes even if he has sufficient amounts of the other ingredients. In this scenario, the eggs are the limiting nutrient (ingredient).

In most Wisconsin lakes, phosphorus is the limiting nutrient controlling the production of plant biomass. As a result, phosphorus is often the target for management actions aimed at controlling plants, especially algae. The limiting nutrient is determined by calculating the nitrogen to phosphorus ratio within the lake. Normally, total nitrogen and total phosphorus values from the surface samples taken during the summer months are used to determine the ratio. Results of this

ratio indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 15:1, the lake is considered phosphorus limited; if it is less than 10:1, it is considered nitrogen limited. Values between these ratios indicate a transitional limitation between nitrogen and phosphorus.

Temperature and Dissolved Oxygen Profiles

Temperature and dissolved oxygen profiles are created simply by taking readings at different water depths within a lake. Although it is a simple procedure, the completion of several profiles over the course of a year or more provides a great deal of information about the lake. Much of this information relates to whether the lake thermally stratifies or not, which is determined primarily through the temperature profiles. Lakes that show strong stratification during the summer and winter months need to be managed differently than lakes that do not. Normally, deep lakes stratify to some extent, while shallow lakes (less than 17 feet deep) do not.

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

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, 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.

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 Marl 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) that incorporates the maximum depth of the lake and the lake's surface area is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

Seepage Lakes have no surface water inflow or outflow in the form of rivers and/or streams.

Drainage Lakes have surface water inflow and/or outflow in the form of rivers and/or streams.

Headwater drainage lakes have a watershed of less than 4 square miles.

Lowland drainage lakes have a watershed of greater than 4 square miles.

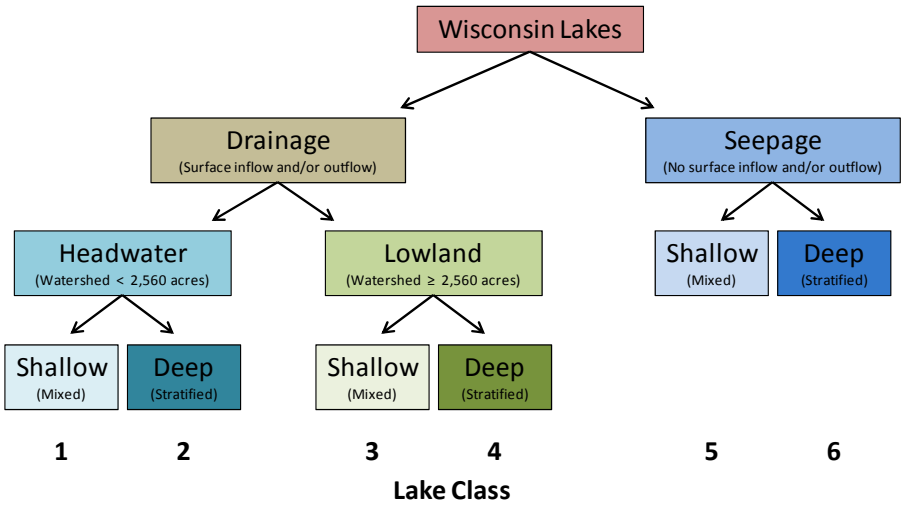


Figure 3.1-1. Wisconsin Lake Classifications. Marl Lake is classified as a deep (stratified), seepage lake (Class 6). Adapted from WDNR PUB-SS-1044 2008.

Marl Lake is classified as a deep (stratified), seepage lake (Class 6) (Figure 3.1-1). 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. 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. Marl Lake is within the North Central Hardwood Forests (NCHF) ecoregion (Figure 3.1-2).

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.

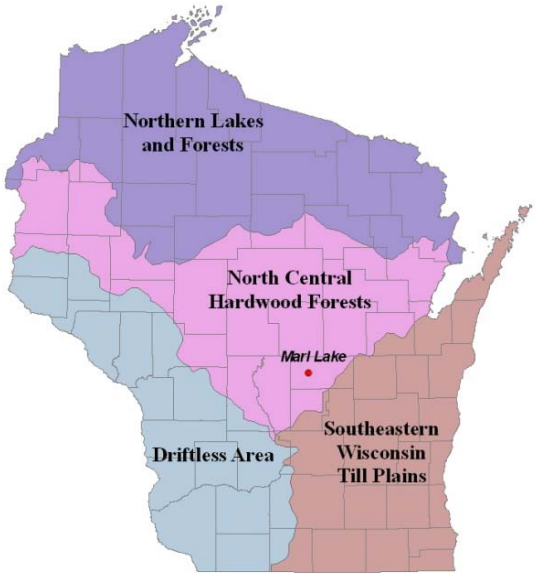


Figure 3.1-2. Location of Marl Lake within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Marl Lake are displayed

in Figures 3.1-3 - 3.1-7. Please note that the data in these graphs represent concentrations taken only during the growing season (April-October). Since state and regional medians were calculated using summer (June, July, August) data, summer data for Marl Lake has also been displayed. Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Marl Lake Water Quality Analysis

Marl Lake Long-term Trends

Perception of water quality often varies greatly from person to person. This variance is due to differences in the tolerance and past experiences of people. In short, the water quality of a given lake might be poor to one person, but rather good to another person who has spent considerable time on other lakes that have poor water clarity, algae problems, or other water quality issues. When asked how they would describe the current water quality of Marl Lake, the majority of survey respondents answered positively, with 67% selecting good or excellent (Appendix B, Question #12). Respondents were divided when asked how the water quality had changed since they obtained their property. Thirty-nine percent believe the water quality has degraded somewhat, 22% believe the water quality has improved somewhat, and 33% believe the water quality on Marl Lake has remained the same (Question #13). Water quality degradation was not a primary concern of lake stakeholders, as indicated on Questions #17 and #18. By using factual, scientific data regarding water quality, we are able to say with certainty what the water quality of a lake is, and by comparing to historic data, learn for certain if the water quality has changed over time.

As previously stated, there are three primary parameters that are analyzed when assessing the water quality of a lake: total phosphorus, chlorophyll-*a*, and Secchi disk clarity. These three parameters yield a great deal of information about the lake's water quality and are closely correlated with one another. As discussed earlier, phosphorus is the limiting nutrient in the majority of Wisconsin's lakes, and increases in this plant nutrient often increases the growth and abundance of free-floating algae (measured by chlorophyll-*a*). The increase in free-floating algae decreases sunlight penetration into the water and lowers water clarity (measure by Secchi disk transparency). So, as phosphorus concentrations increase, algae (chlorophyll-*a*) increases, and water clarity (Secchi disk transparency) decreases. However, examining these data is not always this simple or straightforward as there are often other factors influencing the chemistry and clarity of a lake's water.

Total phosphorus and chlorophyll-*a* data from Marl Lake are somewhat limited and temporally sporadic. The data that are available indicate that total phosphorus values have remained relatively constant in Marl Lake, with the exception of the growing season mean in 1989 and 1990; both of these values represent a single sampling event in early spring (Figure 3.1-3). It is possible that these may represent phosphorus pulses from the nearby dairy farm prior to mitigation. In addition, the growing season and summer mean phosphorus concentrations for 2010 were also elevated (Figure 3.1-3). However, the high average total phosphorus values for 2010 are being skewed by a very high (121µg/L) phosphorus concentration measured during the August sampling period. The possible reasons for this abnormally high phosphorus value will be discussed later in this section. When this August value is removed, 2010 average total

phosphorus concentrations fall more in line with what has been measured on Marl Lake (Figure 3.1-3). The weighted average for total phosphorus concentrations on Marl Lake straddles the *Good-Excellent* threshold and is comparable to the median phosphorus concentration of other deep seepage lakes within the State of Wisconsin and much lower than the median value for lakes within the North Central Hardwood Forests (NCHF) Ecoregion.

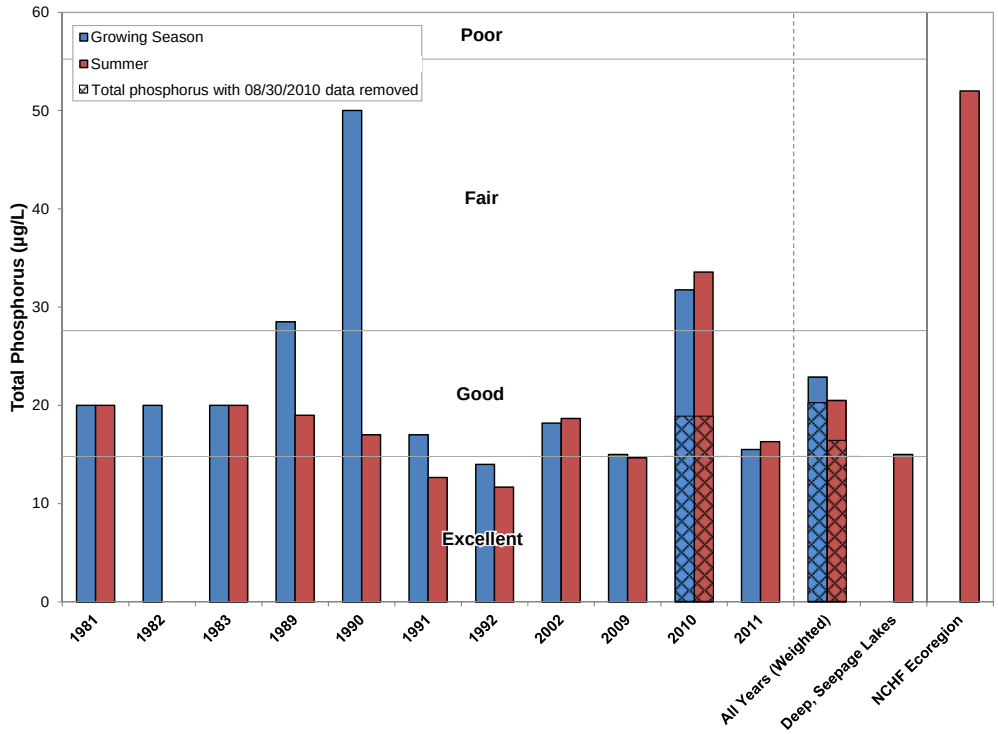


Figure 3.1-3. Marl Lake, state-wide deep seepage lakes, and regional total phosphorus concentrations. Mean values calculated with surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Like total phosphorus, available chlorophyll-*a* concentrations for Marl Lake are relatively constant over time with the exception of 1989 and 1990 (Figure 3.2-4). In addition, abnormally high chlorophyll-*a* concentrations were measured during the August 2010 sampling event which skewed the annual average. Removing the August 2010 data indicates that the weighted average for summer chlorophyll-*a* concentrations falls within the *Excellent* category for deep seepage lakes and is significantly lower than other lakes within the NCHF Ecoregion (Figure 3.1-4).

Secchi disk transparency data is the most prevalent form of water quality data available for Marl Lake. While Figure 3.3-4 shows that there is slight variation in average water clarity values for Marl Lake, there is no apparent positive or negative trend in water clarity over time. For every year that data are available, Secchi disk transparency values have fallen in the *excellent* category for Wisconsin's deep seepage lakes (Figure 3.3-4). The weighted average across all years shows that Marl Lake's water clarity is higher than most other deep seepage lakes in the state as well as most lakes within the region. Due to the phosphorus spike measured in August of 2010, chlorophyll-*a* levels also increased and thus, water clarity also declined. Removing the Secchi disk transparency data collected in August in 2010 slightly increases the 2010 annual averages, but only minimally increased the overall weighted averages.

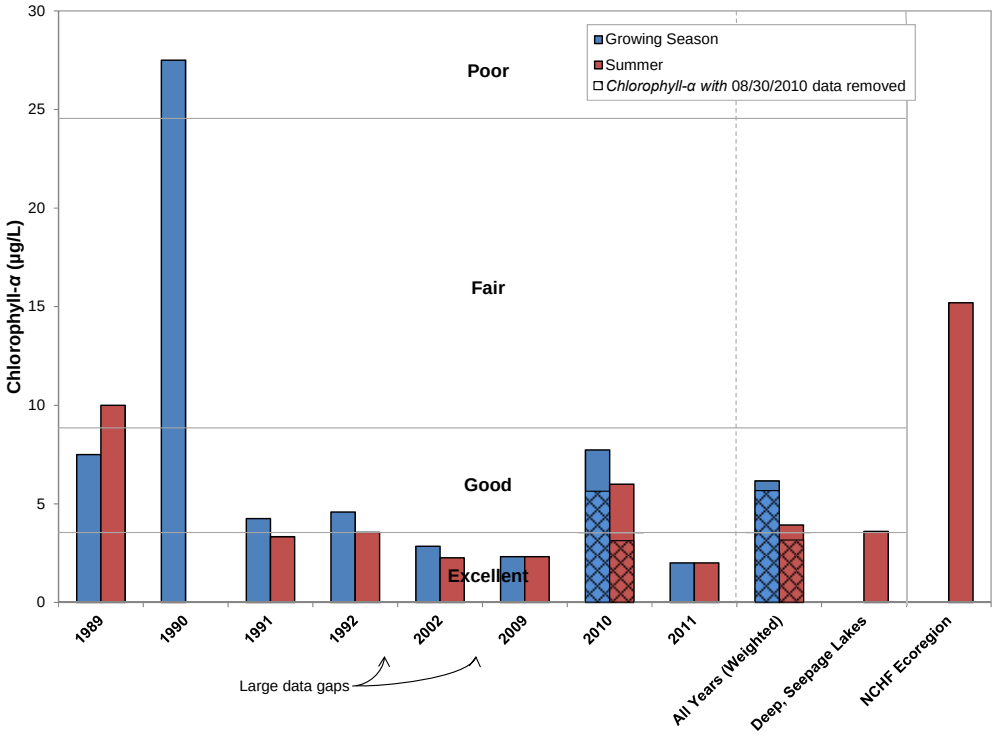


Figure 3.1-4. Marl Lake, state-wide class 6 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

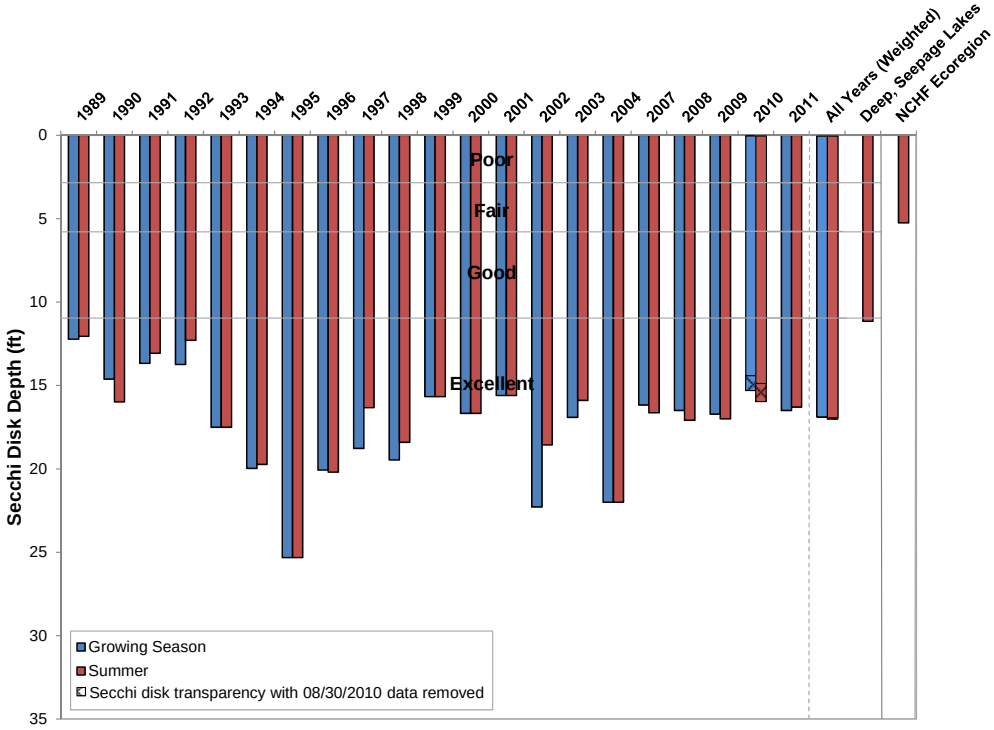


Figure 3.1-5. Marl Lake, state-wide class 6 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

When looking at the annual averages of total phosphorus, chlorophyll-*a*, and Secchi disk transparency values from Marl Lake, aside from the years discussed, the values have remained relatively constant during the time periods for which data are available. However, looking solely at the data that were collected in 2010, a large phosphorus spike was recorded on August 30 as mentioned (Figure 3.1-6). Phosphorus concentrations were recorded to be 121 µg/L on August 30 compared to 18 µg/L just four days before on August 26; representing a nearly seven-fold increase in phosphorus concentration. In addition, chlorophyll-*a* levels increased by over three times and Secchi disk transparency declined by five feet.

Interestingly, water samples collected three feet from the bottom on August 30 did not have elevated phosphorus levels, indicating that the high levels of phosphorus were only present in the epilimnion and not due to internal nutrient loading from bottom sediments. This is also supported by the fact that during the fall turnover event, elevated phosphorus levels were not recorded during the November 3, 2010 visit. After discussions with the WDNR scientists in Madison and at the regional level, it is believed that these elevated phosphorus levels were either created by some type of pollution event (septic system and/or fertilizer discharge) or more likely, a localized rainfall event which may have flushed the wetland on the northwest side of the lake which has been dry for many years since water levels have receded. While we will never know for sure that caused this phosphorus spike, using the approximate volume of the epilimnion on August 30 and assuming the phosphorus was distributed throughout, we calculated that it would have taken an input of approximately 81 lbs of phosphorus to increase the concentration from 18 µg/L to 121 µg/L.

No complaints were received from lake residents regarding increased algae levels or decreased water clarity during this time, and the water quality samples collected in the fall of 2010 indicate that this was a short, temporary event as phosphorus concentrations fell back to normal levels. In addition, Citizen Lake Monitoring Data (CLMN) collected monthly during the growing season of 2011 did not capture any elevated phosphorus concentrations (Figure 3.1-7).

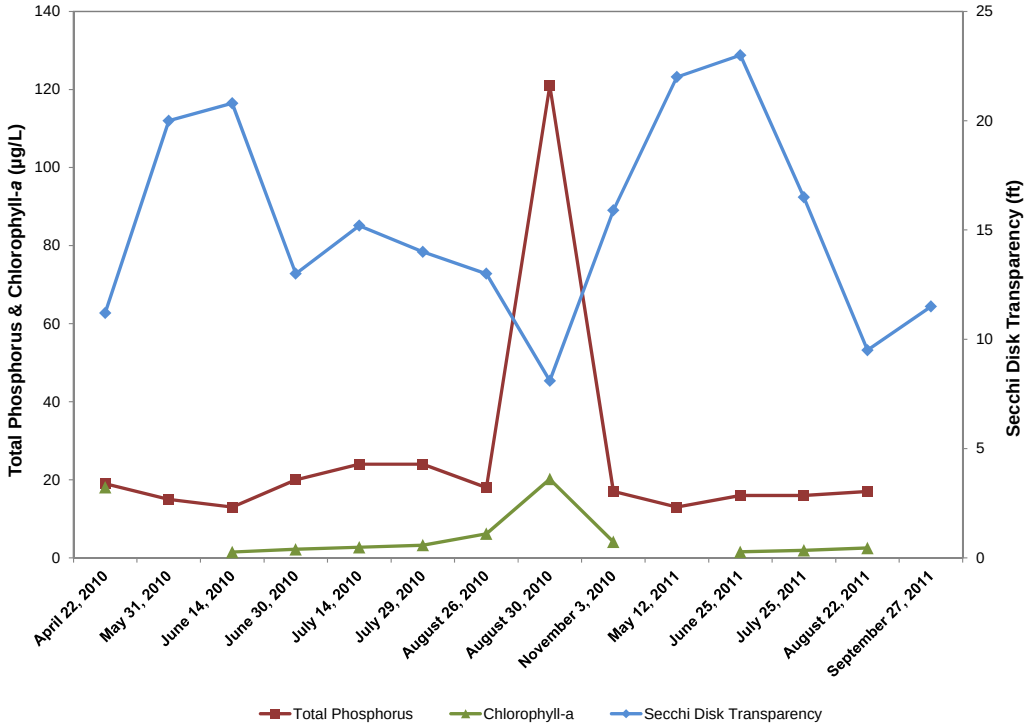


Figure 3.1-6. Marl Lake total phosphorus, chlorophyll-*a*, and Secchi disk transparency data from 2010 and 2011. 2010 data collected by Onterra and Marl Lake CLMN; 2011 data collected by Marl Lake CLMN.

Overall, the water quality on Marl Lake is in great condition, and is of higher quality than many other lakes in the region and the state. While water quality may fluctuate slightly on an annual basis due to climatic factors, the available data do not indicate that any significant long-term trends are occurring on Marl Lake.

Limiting Plant Nutrient of Marl Lake

Using midsummer nitrogen and phosphorus concentrations from Marl Lake, a nitrogen:phosphorus ratio of 24:1 was calculated. This finding indicates that Marl Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Marl Lake Trophic State

Figure 3.1-7 contains the trophic state index (TSI) values for Marl Lake. The TSI uses total phosphorus, chlorophyll-*a*, and Secchi disk transparency values to determine the trophic state (oligotrophic, mesotrophic, eutrophic) of the lake. In general, the biological parameters are the best values to use in judging a lake's trophic state, as water clarity can be affected by factors other than chlorophyll-*a* (e.g. suspended sediments, organic acids). Therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Marl Lake is presently in a mesotrophic state, or is moderately productive.

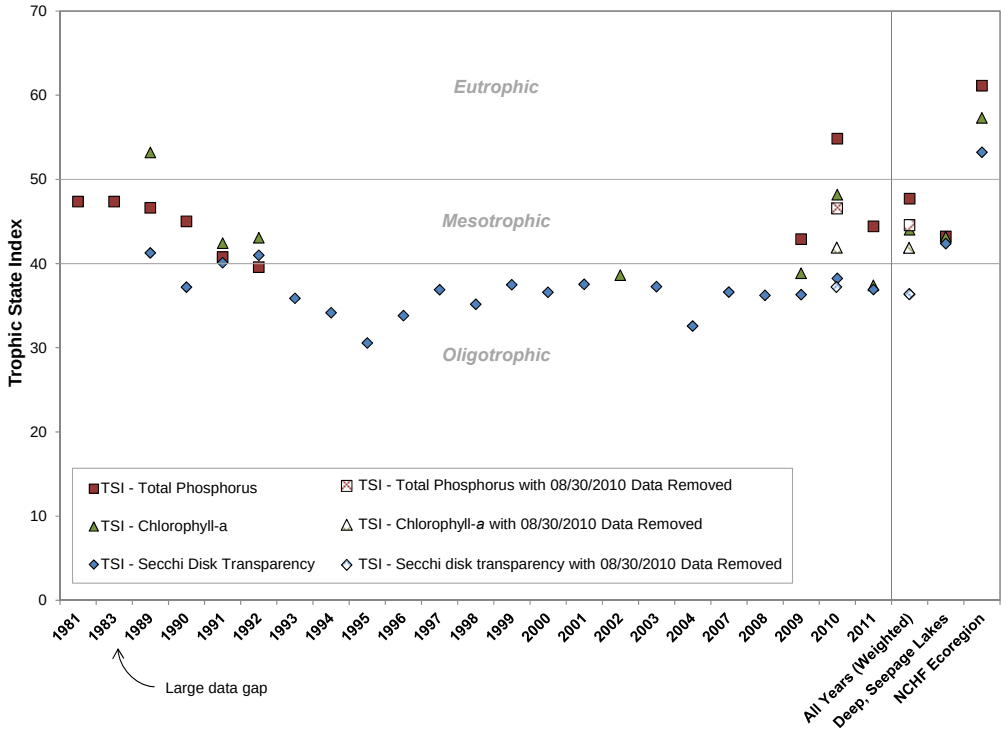


Figure 3.1-7. Marl Lake, state-wide deep seepage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Marl Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Marl Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-8. During the spring and fall, Marl Lake becomes completely mixed and as a result, temperature and oxygen remains the same throughout the water column. During the summer months, the lake became stratified, with a gradient developing for both temperature and dissolved oxygen. This is not uncommon in lakes that are fairly small yet quite deep for their size. Energy from the wind is sufficient to mix only the upper, warm layer of the water column. The lower portion of the lake remained fairly cold throughout the summer months and likely was disturbed little by the upper, warmer water. Without this mixing effect, dissolved oxygen from the surface is unlikely to become mixed within the lower part of the water column. Additionally, the decomposition of organic matter near the bottom of the lake decreases the oxygen concentration further. Dissolved oxygen levels remained high enough (>3.0 mg/L) in the upper 20 feet of the water column during summer months to support aquatic life found in northern Wisconsin lakes.

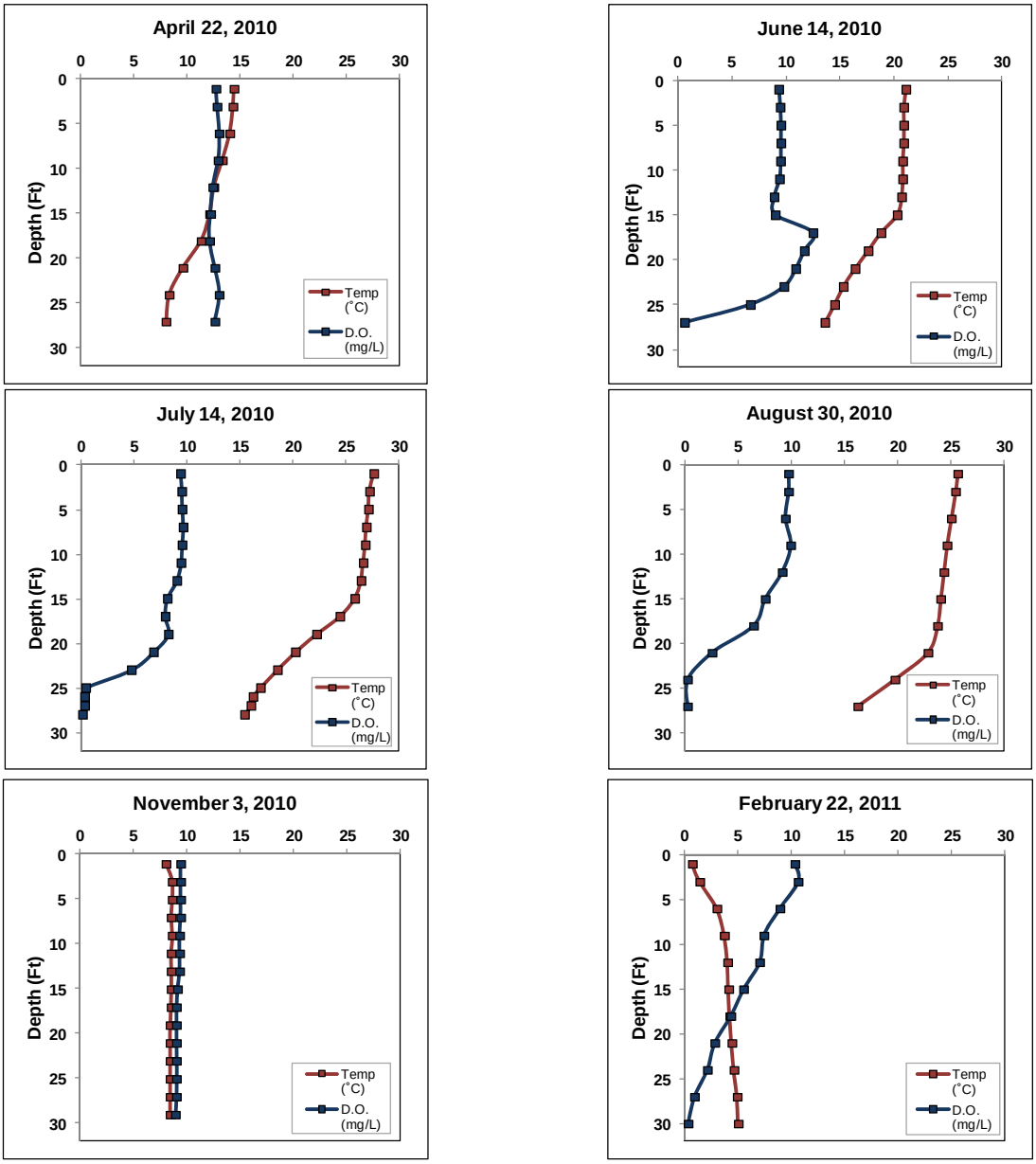


Figure 3.1-8. Marl Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Marl Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Marl Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, calcium, and total suspended solids.

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 (calcium carbonate-rich) lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985).

In 2010, water surface pH values were found to be alkaline, with values ranging from 8.4 to 8.9, which fall slightly above the normal range for Wisconsin lakes. However, these values are natural and are direct cause of Marl Lake's morphology and position within the surrounding landscape, which is largely comprised of clays, sandstone, and dolomite. Being a seepage lake, Marl Lake receives the majority of its water via groundwater inputs, or springs. As water from rainfall or snowmelt passes through the ground, it dissolves the dolomite ($CaMg(CO_3)_2$), which dissociates into calcium (Ca^{++}), magnesium (Mg^{++}), and carbonate ($CO_3^{=}$). When this water eventually enters Marl Lake as groundwater, the carbonate removes excess hydrogen ions and increases the water's pH. Rainwater is naturally acidic, and a lake's ability to remove the excess hydrogen ions from rainwater prevents fluctuations in pH.

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 carbonate and bicarbonate. As discussed, these compounds are present in a lake if the groundwater entering it comes into contact with minerals such as dolomite. Rainwater in Wisconsin is naturally acidic due to dissolved carbon dioxide from the atmosphere and has 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 Marl Lake was measured at 140.0 (mg/L as $CaCO_3$) at the lake's surface, indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. In lakes such as Marl Lake, the dissolved calcium concentrations can reach concentrations to which no additional calcium can be dissolved. When this happens, the calcium recombines with the carbonate forming calcium carbonate, or marl, and it precipitates out of the water and settles to the bottom. These precipitates also absorb phosphorus, removing it from the epilimnion and making it unavailable for free-floating algae. The suspended calcium carbonate within the water is also what gives Marl Lake its turquoise color.

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 Marl Lake's pH values fall 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 Marl Lake was found to be 28.6 mg/L, placing Marl Lake in the *high susceptibility* category for zebra mussel establishment if they are ever introduced. During Onterra's surveys, a number of docks were examined for adult zebra mussels and none were located. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for planktonic larval zebra mussels. Their analysis did not locate any zebra mussels in the 2010 samples. However, Marl Lake contains optimal conditions for supporting zebra mussels, and lake residents should

periodically inspect their docks and bottoms of boats for mussels and report any findings to the WDNR or Onterra. Silver Lake in Wautoma, approximately eight miles from Marl Lake, has a confirmed established population of zebra mussels. Cleaning, removal of water, and inspecting of boats entering and leaving Marl Lake is especially important for this reason.

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 actually occur where lakes with completely forested watersheds have sufficient phosphorus loads to support high rates of plant production. In other systems with high ratios, the conversion of vast areas of row crops to vegetated areas (grasslands, meadows, forests, etc.) may not reduce phosphorus loads sufficiently to see a change in plant production. Both of these situations occur frequently in impoundments.

Regardless of the size of the watershed or the makeup of its land cover, it must be remembered that every lake is different and other factors, such as flushing rate, lake volume, sediment type, and many others, also influence how the lake will react to what is flowing into it. For instance, a

deeper lake with a greater volume can dilute more phosphorus within its waters than a less voluminous lake and as a result, the production of a lake is kept low. However, in that same lake, because of its low flushing rate (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. On the contrary, a lake with a higher flushing rate (low residence time, i.e., days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

A reliable and cost-efficient method of creating a general picture of a watershed's affect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS). Certain morphological attributes of a lake and its watershed 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 surface water drainage basin for Marl Lake covers approximately 396 acres (Map 2), which was modified slightly from what was delineated in the 2003 management plan. The land cover types within the watershed include forests (40%), pasture/grass (17%), row crops (15%), rural residential areas (12%), wetlands (9%), and the surface of Marl Lake (7%) (Figure 3.2-1). The watershed to lake area ratio was found to be 14:1 in 2010, compared to about 9:1 in 2003. While Marl Lake's watershed was delineated to be slightly larger than in 2003, the largest reason for the difference in the watershed to lake area ratio is that water levels have receded nearly five feet, reducing the acreage of the lake. The water levels on Marl Lake will be discussed in the next section.

As discussed earlier, the land cover within the watersheds of lakes with relatively small watershed to lake area ratios has a greater influence on the water quality of the lake. WiLMS was utilized to model the land cover types within the Marl Lake watershed and quantify nutrient runoff into the waterbody. Using the land cover types and acreages in Figure 3.2-1 as well as the average of all available surface phosphorus data from Marl Lake, modeling estimated that approximately 102 pounds of phosphorus are delivered to Marl Lake on an annual basis (Figure 3.2-2). The WiLMS model indicates that while row crop agriculture comprises approximately 15% of Marl Lake's watershed, it is the largest contributor (53%) of phosphorus to the lake, followed by areas of pasture/grass (18%), atmospheric deposition directly into the lake's surface (7%), rural residential areas (5%), wetlands (2%), and septic systems (2%). Septic systems were estimated using residency data gathered from the 2010 stakeholder survey (Figure 3.2-2).

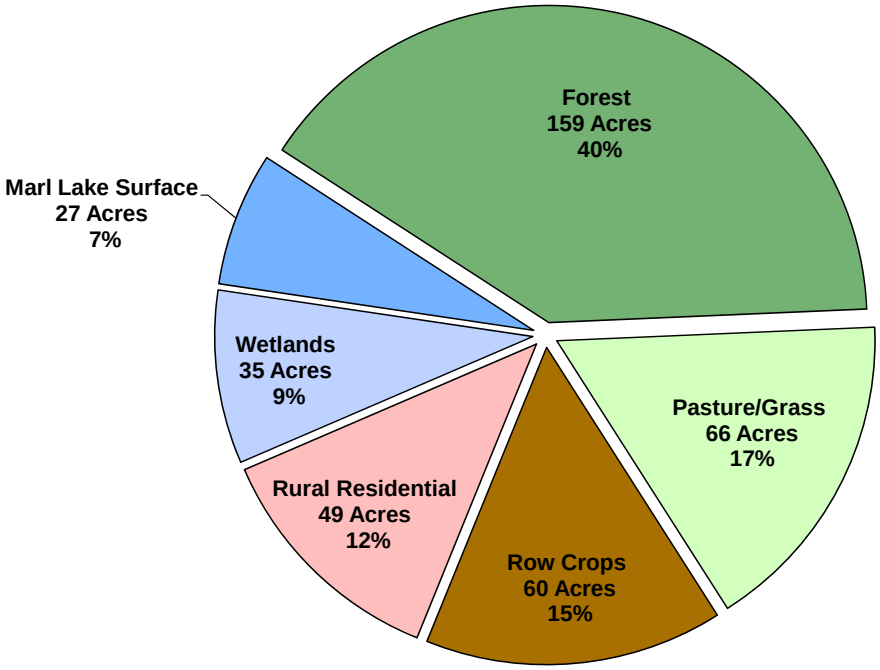


Figure 3.2-1. Marl Lake watershed land cover types in acres. Based upon National Land Cover Database for the Conterminous United States (NLCD) (Fry et. Al 2006).

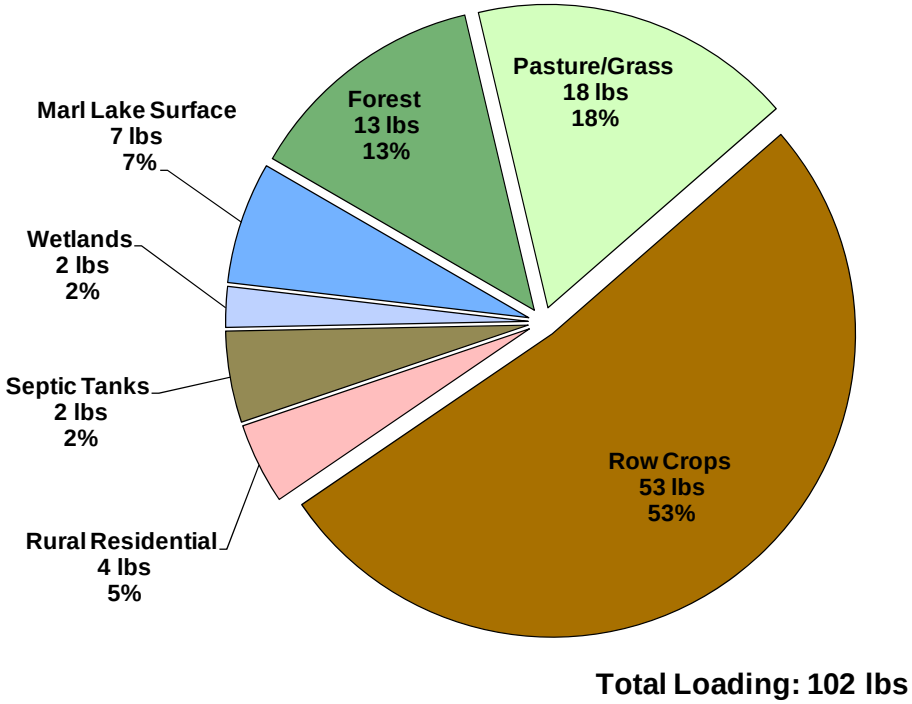


Figure 3.2-2. Marl Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the land cover and phosphorus loading information in Figures 3.3-1 and 3.3-2, WiLMS predicted a growing season, in-lake phosphorus concentration of 48.0 µg/L. However, the available phosphorus data collected from Marl Lake indicates that the actual average growing season phosphorus concentration is much lower at 23.6 µg/L. This discrepancy between predicted and observed growing season phosphorus concentrations in Marl Lake is likely due to the limitations of the WILMS model when it comes to estimating phosphorus loading to seepage lakes. The model is more adapt at predicting phosphorus loading in lakes that receive larger amounts of water from inlets or precipitation runoff. It must be assumed here that the watershed delivers much less than the 100 lbs of phosphorus predicted by WiLMS to annually enter the lake. As discussed previously, phosphorus levels are likely also lower than predicted because of Marl Lake's high calcium carbonate concentrations, which absorb and remove phosphorus from the epilimnion as is precipitates to the bottom sediments. In addition, the Marl Lake District has also taken management actions to minimize potential nutrient-rich runoff from a nearby dairy farm.

3.3 Shoreland Condition Assessment

The Importance of a Lake's Shoreland Zone

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) affects 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. Thus, both the removal of vegetation and the inclusion of development reduces many forms of habitat for wildlife.

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

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

recognized inadequacies within the 1968 ordinance and had actually adopted 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 (Note: counties must adopt these standards by February 2014, counties may not have these standards in place at this time):

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. 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
    - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - 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 may be acceptable mitigation methods, dependent on the county.

- Contact the county's regulations/zoning department for all minimum requirements.

Wisconsin Act 31

While not directly aimed at regulating shoreland practices, the State of Wisconsin passed Wisconsin Act 31 in 2009 in an effort to minimize watercraft impacts upon shorelines. This act

prohibits a person from operating a watercraft (other than personal watercraft) at a speed in excess of slow-no-wake speed within 100 feet of a pier, raft, buoyed area or the shoreline of a lake. Additionally, personal watercraft must abide by slow-no-wake speeds while within 200 feet of these same areas. Act 31 was put into place to reduce wave action upon the sensitive shoreland zone of a lake. The legislation does state that pickup and drop off areas marked with regulatory markers and that are open to personal watercraft operators and motorboats engaged in waterskiing/a similar activity may be exempt from this distance restriction. Additionally, a city, village, town, public inland lake protection and rehabilitation district or town sanitary district may provide an exemption from the 100 foot requirement or may substitute a lesser number of feet.

Shoreland Research

Studies conducted on nutrient runoff from Wisconsin lake shorelands have produced interesting results. For example, a USGS study on several Northwoods Wisconsin lakes was conducted to determine the impact of shoreland development on nutrient (phosphorus and nitrogen) export to these lakes (Graczyk et al. 2003). During the study period, water samples were collected from surface runoff and ground water and analyzed for nutrients. These studies were conducted on several developed (lawn covered) and undeveloped (undisturbed forest) areas on each lake. The study found that nutrient yields were greater from lawns than from forested catchments, but also that runoff water volumes were the most important factor in determining whether lawns or wooded catchments contributed more nutrients to the lake. 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 habitat provides shoreland erosion control, a carbon source for the lake, prevents suspension of sediments and provides a surface for algal growth which important for aquatic macroinvertebrates (Sass 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

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

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

National Lakes Assessment

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

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

The results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect and restore lakes. This will become increasingly important as development pressured on lakes continue to steadily grow.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).



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

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a shoreland buffer zone. The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function.

Enhancement activities also include additions of submergent, emergent, and floating-leaf plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Cost

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

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

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

- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq ft and 2 shrubs/100 sq ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.

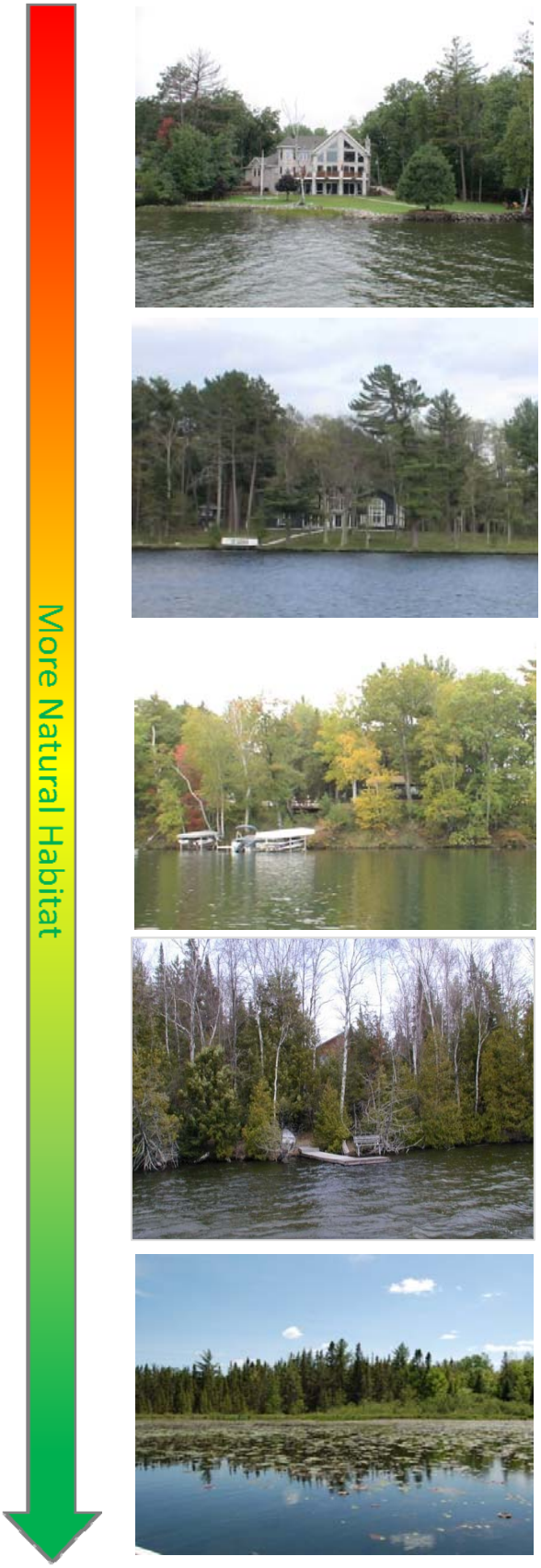
- An aquatic zone with shallow-water 2 - 5' x 35' areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70' of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

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

Marl Lake Shoreland Zone Condition

Shoreland Development

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



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

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

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

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

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

Figure 3.3-1. Shoreline assessment category descriptions.

On Marl Lake, the development stage of the entire shoreline was surveyed during the fall of 2010, using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-1.

Marl Lake has stretches of shoreland that fit four of the five shoreland assessment categories. In all, 0.5 miles (42%) of natural/undeveloped were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.3 miles (23%) of urbanized and developed–unnatural shoreline were observed. If restoration of the Marl Lake shoreline 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 shoreline lengths around the entire lake.

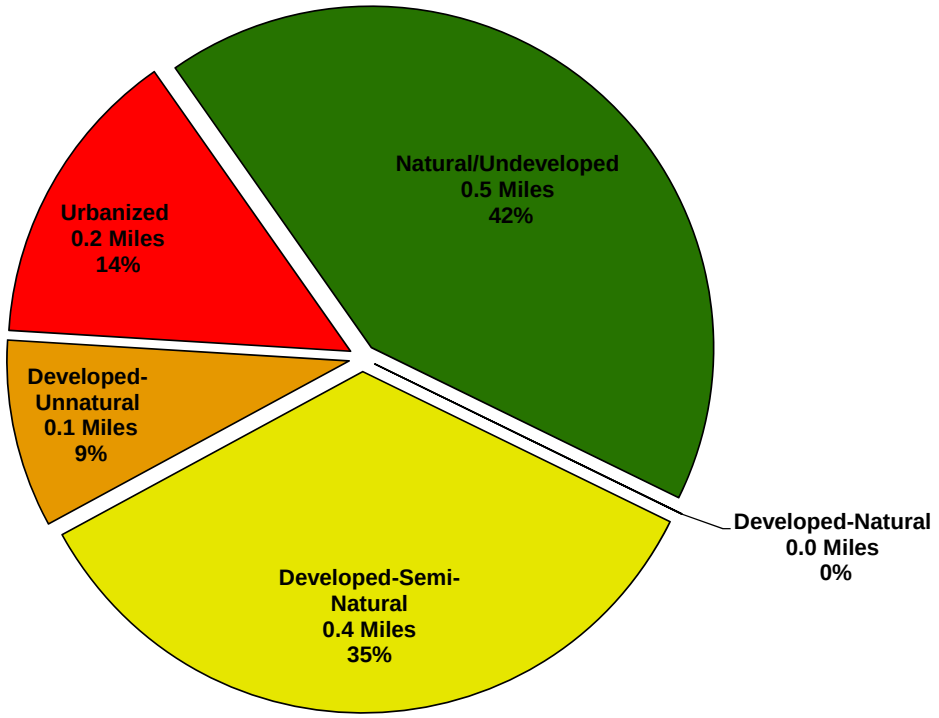


Figure 3.3-2. Marl Lake shoreland categories and total lengths. Based upon a fall 2010 survey. Locations of these categorized shorelands can be found on Map 3.

Marl Lake Water Levels

In a stakeholder survey sent out to Marl Lake riparians, the majority of the comments received included concerns about lake's low water levels. The lakes of central Wisconsin are particularly sensitive to water level fluctuations due to lake morphology, geography, climate, and human use (UW-Extension, 2012). The water levels of natural seepage lakes, like Marl Lake, reflect and are controlled by the elevation of the groundwater table. Lacking supplemental surface inflow from streams or rivers, seepage lakes are prone to dramatic declines in water levels if the groundwater aquifer declines. Precipitation levels vary not only year to year, but over larger periods of time as well, and recent years with lower rainfall and snowfall amounts mean less water to recharge groundwater aquifers. In addition, human use including pumping of groundwater, destruction of

wetlands, and construction of impervious surfaces all reduce groundwater recharge. According to the UW-Extension (2012), central Wisconsin has the highest concentration of high-capacity wells used mainly for irrigational uses. It is likely that a combination of these factors is contributing to lower water levels. The State of Wisconsin is currently conducting a study to determine the significance of high-capacity well pumping on groundwater levels in this region.

While the low water levels on Marl Lake are likely due to a combination of natural and human factors and may have negative recreational and short-term ecological impacts, it is important to remember that lake water level fluctuations are part of a naturally occurring cycle that has happened many times within the lifespan of Marl Lake. While these fluctuations may have their drawbacks, these relatively short-term changes may actually benefit the lake ecosystem in the long-term by increasing emergent and floating-leaf aquatic plant habitat.

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 shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced 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

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

Important Note:
Even though most of these techniques are not applicable to Marl 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 Marl Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that 30 feet. This action can be conducted up to 150 feet from shore. Please note that a permit is needed in all instances if wild rice is to be removed. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR.

Permits are required for chemical and mechanical manipulation of native and non-native plant communities. Large-scale protocols have been established for chemical treatment projects covering >10 acres or areas greater than 10% of the lake littoral zone and more than 150 feet from shore. Different protocols are to be followed for whole-lake scale treatments (≥160 acres or ≥50% of the lake littoral area). Additionally, it is important to note that local permits and U.S. Army Corps of Engineers regulations may also apply. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

Manual Removal



Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

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

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

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

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

Bottom Screens

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

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

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

Water Level Drawdown

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

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

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

Mechanical Harvesting



Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Costs

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may

cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages	***Disadvantages***
• Immediate results. • Plant biomass and associated nutrients are removed from the lake. • Select areas can be treated, leaving sensitive areas intact. • Plants are not completely removed and can still provide some habitat benefits. • Opening of cruise lanes can increase predator pressure and reduce stunted fish populations. • Removal of plant biomass can improve the oxygen balance in the littoral zone. • Harvested plant materials produce excellent compost.	• Initial costs and maintenance are high if the lake organization intends to own and operate the equipment. • Multiple treatments are likely required. • Many small fish, amphibians and invertebrates may be harvested along with plants. • There is little or no reduction in plant density with harvesting. • Invasive and exotic species may spread because of plant fragmentation associated with harvester operation. • Bottom sediments may be re-suspended leading to increased turbidity and water column nutrient levels.

Herbicide Treatment



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

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

Applying herbicides in the aquatic environment requires special considerations compared with terrestrial applications. WDNR administrative code states that a permit is required if "you are standing in socks and they get wet." In these situations, the herbicide application needs to be completed by an applicator licensed with the Wisconsin Department of Agriculture, Trade and Consumer Protection. All herbicide applications conducted under the ordinary high water mark require herbicides specifically labeled by the United States Environmental Protection Agency

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

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

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. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

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 Marl 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 the comprehensive point-intercept surveys conducted in 2011 on Marl Lake, plant samples were collected from plots laid out on a grid that covered the entire system (Map 1). 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, this means that there is a 90% chance that the next species encountered will be different from the previous. 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 Marl 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. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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 shoreline. 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 shoreline may hold. This value is referred to as the shoreline complexity. It specifically analyzes the characteristics of the shoreline 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 shoreline 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 shoreline 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 Marl Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1).

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

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. 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 plant 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.

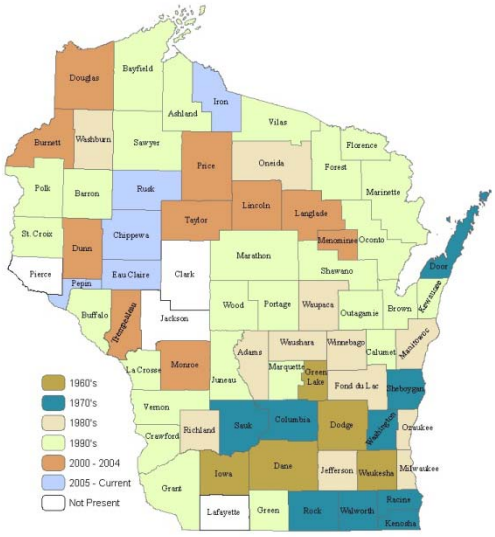


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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 June 9, 2010, a survey was completed on Marl Lake that focused upon locating curly-leaf pondweed. During this meander-based survey of the *littoral zone,* Onterra ecologists could not locate any occurrences of curly-leaf pondweed. However, curly-leaf pondweed was discovered growing in Marl Lake during the comprehensive aquatic plant point-intercept survey conducted in early July 2010. Because of this plants importance, the occurrence of curly-leaf pondweed in Marl Lake and recommended actions to control this invasive plant will be discussed in the Non-native Plants Section.

The comprehensive aquatic plant point-intercept and aquatic plant community mapping surveys were conducted on Marl Lake on July 9, 2010, by Onterra. During these surveys, 22 species of aquatic plants were located in Marl Lake (Table 3.4-1), two of which are considered to be non-native, invasive species: curly-leaf pondweed and reed canary grass. Additionally, the presence of Eurasian water milfoil was also discovered during a curly-leaf pondweed survey in the spring of 2011. DNA analysis confirmed that this milfoil is a hybrid between Eurasian water milfoil (*Myriophyllum spicatum*) and the indigenous species northern water milfoil (*Myriophyllum sibiricum*). These non-native plants will be discussed in detail in the Non-native Plants Section.

Table 3.4-1 compares the aquatic plant species located during this project's aquatic plant surveys to the 2002 NES Ecological Services survey. It should be noted that the survey conducted in 2002 was transect-based, a commonly accepted methodology at that time. Since then, the new point-intercept methodology developed by the WDNR has become the accepted method of assessing a lake's aquatic plant community. The 2002 transect-based survey places more emphasis on the near-shore areas of the lake more so than the point-intercept survey performed in 2010. The point-intercept survey covers more of the lake and has a higher focus on deeper areas. This difference in sampling methodologies is apparent in the species list as more emergent species were located in 2002 than in 2010, while more submergent species were located in 2010 than 2002 (Table 3.4-1). Also, water levels in 2002 where higher than in 2010 allowing access to the species-rich emergent wetland on the western side of the lake.

During the 2010 aquatic plant survey, aquatic plants were found growing throughout most of the lake to a maximum depth of 29 feet, indicating that the majority of the lake is comprised of littoral area. Sediment data gathered during the point-intercept survey indicates that the majority (87%) of Marl Lake's substrate is comprised of fine organic sediment (muck), while a small portion (13%) is comprised of sand (Figure 3.4-2). Map 4 shows that all of the point-intercept locations containing sandy substrates were located in shallow, near-shore areas. No areas of rock-dominated sediment were located during the 2010 survey.

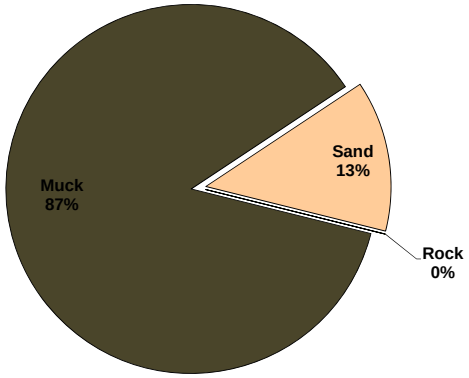


Figure 3.4-2. Marl Lake proportion of substrate types within littoral areas. Created using data from 2010 aquatic plant point-intercept survey.

Table 3.4-1. Aquatic plant species located in Marl Lake during July 2010 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatsim (C)	2002 (NES)	2010 (Onterra)
Emergent	*Eleocharis erythropoda*	Bald spike-rush	3		X
	Eupatorium perfoliatum	Common boneset	6	X	
	Carex comosa	Bristly sedge	5	X	
	Carex vulpinoidea	Brown fox sedge	2	X	
	Juncus effusus	Soft rush	4	X	
	Juncus tenuis	Path rush	1	X	
	Leersia oryzoides	Rice cut grass	3	X	
	Lycopus americanus	American water-horehound	4	X	
	Phalaris arundinacea	Reed canary grass	Exotic	X	I
	Sagittaria latifolia	Common arrowhead	3	X	X
	Salix exigua	Sandbar willow	2	X	
	Schoenoplectus acutus	Hardstem bulrush	5	X	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I
	Typha latifolia	Broad-leaved cattail	1	X	
FF	*Lemna minor*	Lesser duckweed	5	X	
	Wolffia columbiana	Common watermeal	5	X	
FL	*Nuphar variegata*	Spatterdock	6	X	I
	Nymphaea odorata	White water lily	6	X	X
	Polygonum amphibium	Water smartweed	5	X	
Submergent	*Ceratophyllum demersum*	Coontail	3	X	I
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	
	Heteranthera dubia	Water stargrass	6	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	*Myriophyllum sibiricum X M. spicatum**	Northern X Eurasian water milfoil	Exotic		I
	Najas flexilis	Slender naiad	6	X	I
	Potamogeton amplifolius	Large-leaf pondweed	7		X
	Potamogeton crispus	Curly-leaf pondweed	Exotic		X
	Potamogeton friesii	Fries' pondweed	8		X
	Potamogeton gramineus	Variable pondweed	7		X
	Potamogeton illinoensis	Illinois pondweed	6	X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X
	Potamogeton nodosus	Long-leaf pondweed	7	X	
	Potamogeton praelongus X P. richardsonii	White-stem X Clasping-leaf pondweed	N/A		X
	Potamogeton strictifolius	Stiff pondweed	8		X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Stuckenia pectinata	Sago pondweed	3	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	

FF = Free Floating; FL = Floating-leaf; S/E = Submergent and Emergent;
X = Observed during 2002 NES transect survey or located on the rake during the 2011 Onterra point-intercept survey; I = Incidental Species
** Located during 2011 curly-leaf pondweed survey*

Approximately 90% of the point-intercept sampling locations that fell within the littoral zone contained aquatic vegetation. As Map 5 displays, aquatic plants were found growing throughout most of the lake. The combination of high water clarity and nutrient-rich sediments provides excellent conditions for supporting a lush aquatic plant community. Fries' pondweed was the most frequently encountered aquatic plant species during the 2010 point-intercept survey (Figure 3.4-3). A common species in calcareous waters, Fries' pondweed is one of Wisconsin's several narrow-leaved pondweed species and was observed growing across all depths in Marl Lake, and one of only two species observed growing at depths greater than 20 feet. Being the most dominant plant in Marl Lake, Fries' pondweed plays a large role in aquatic ecosystem by providing structural habitat and sources of food to invertebrates, fish, and other wildlife.

Growing in deeper water, this species likely supplies oxygen to the deeper, colder layer of water that is sealed off from atmospheric oxygen during the summer.

Interestingly, being the dominant species in 2010, Fries' pondweed was not documented during the 2002 transect surveys on Marl Lake. While this species can be relatively difficult to identify, it is unlikely that it would have been confused for another species. It is believed that this species was likely present in Marl Lake during the 2002 survey but at an undetectable level. While the responses of many aquatic plant species to water level fluctuations are not known, it is believed that the lowering water levels and other associated conditions have favored the increase and eventual current dominance of Fries' pondweed in Marl Lake. In contrast, northern water milfoil was found to be the dominant species in Marl Lake in 2002, while in 2010 it was only encountered at one point-intercept location (Figure 3.4-3). A lake's aquatic plant community in terms of species composition and their abundances can be dynamic over time in response to changing environmental conditions.

Members of the muskgrasses were the second-most frequently encountered group of aquatic plants in Marl Lake in 2010 (Figure 3.4-3). Though these plants appear similar to other submersed aquatic plants, they are actually a group of macroalgae. Several species of muskgrasses occur in Wisconsin, though this study did not identify this group to the species level. As their name suggests, muskgrasses exude a strong, skunk-like odor when brought out of the water. Often, large mats of these plants will break free from the bottom, float to the surface and wash ashore. They are common in calcareous waters like Marl Lake and usually form large beds along the bottom where their fine branches provide excellent habitat for aquatic organisms. Muskgrasses were also very common in the 2002 survey, and their populations appear to have remained relatively unchanged over this eight-year period.

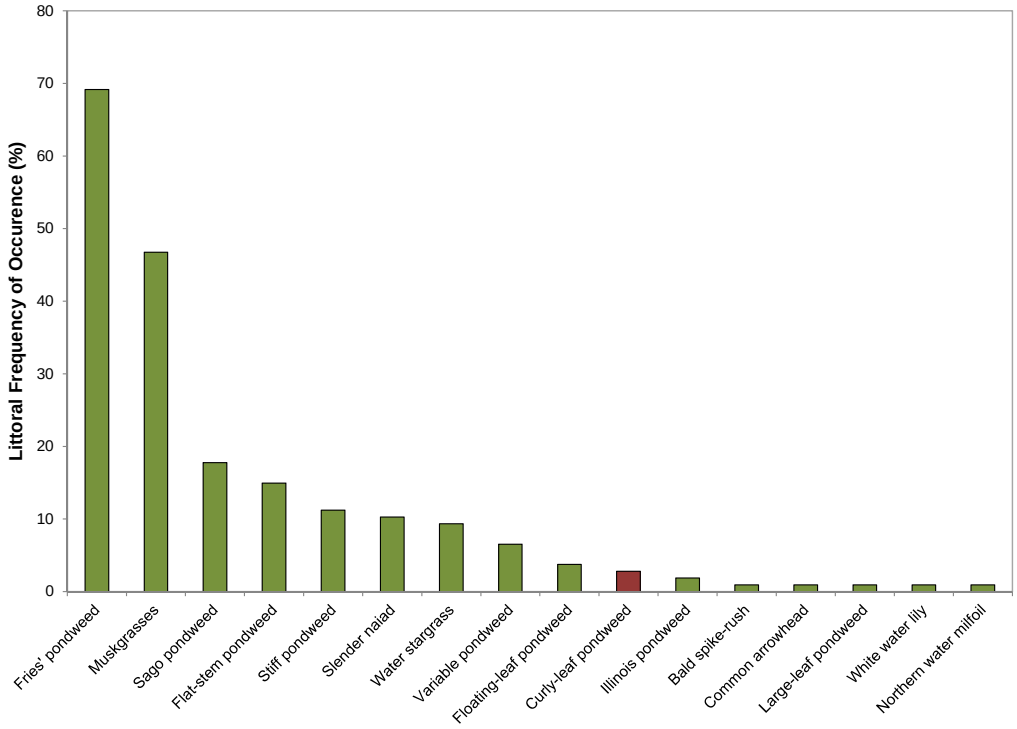


Figure 3.4-3. Marl Lake aquatic plant littoral occurrence analysis. Created using data from July 2010 aquatic plant point-intercept survey. Exotic species indicated with red.

As discussed previously, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while 20 native aquatic plant species were located in Marl Lake during the 2010 surveys, only 15 were encountered on the rake during the point-intercept survey. These 15 native species and their conservatism values were used to calculate the FQI of Marl Lake's aquatic plant community in 2010 (equation shown below). The FQI was also calculated based on the species located during the 2002 survey. It must be noted that some of the conservatism values of certain species have been changed since the 2002 study, and the FQI has been recalculated using this updated values.

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

Figure 3.4-4 compares the FQI values of Marl Lake's aquatic plant community from the 2002 and 2010 surveys. Again, it should be remembered that the 2002 survey was transect-based, which targeted near-shore areas of the lake more so than the point-intercept survey performed in 2011. As Figure 3.4-4 illustrates, species richness was much higher in 2002 than in 2010. However, due to the 2002 survey methodology, this includes many emergent wetland species that normally would not be encountered in a point-intercept survey. The native species richness in 2010 (15) is higher than the *median* values for lakes in both the North Central Hardwood Forests Ecoregion as well as the entire state (Figure 3.4-4).

Median Value This is the value that roughly half of the data are smaller and half the data are larger. A median is used when a few data are so large or so small that they skew the average value to the point that it would not represent the population as a whole.

The average conservatism in 2010 (5.9) is considerably higher than in 2002 (4.5), and is due to the high number of emergent species included in 2002 which have relatively low conservatism values, as well as the addition of a couple species in 2010 with higher conservatism values. Despite the differences in species richness and average conservatism values between 2002 and 2010, the floristic quality values for both years were fairly similar. The 2010 floristic quality value is higher than the ecoregion median and similar to state median, indicating that the plant community of Marl Lake is of higher quality than most lakes in the region and of comparable quality to most lakes in the state (Figure 3.4-4).

Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. 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 Marl Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. As discussed earlier, species diversity is also influenced by how evenly the plant species are distributed within the community. Using the data collected from the 2010 point-intercept survey, Marl Lake's plant community was shown to have relatively low diversity with a Simpson's diversity value of 0.80 (Figure 3.4-5).

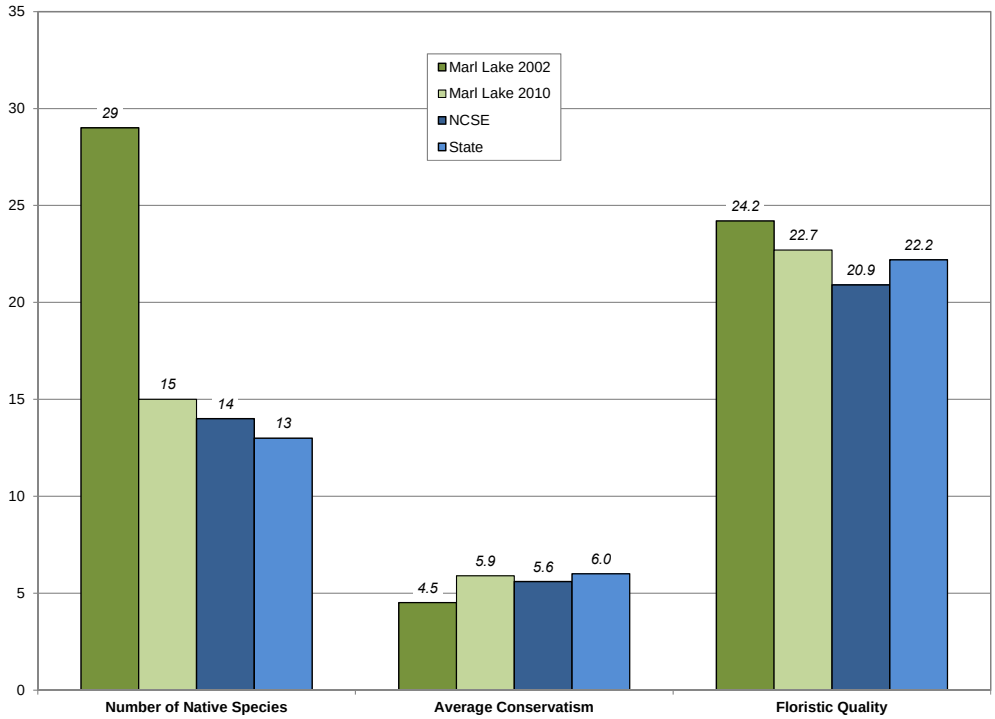


Figure 3.4-4. Marl Lake Floristic Quality Assessment. Created using data from 2002 NES Ecological Services transect survey and 2010 Onterra aquatic plant point-intercept survey.

Smaller lakes tend to have fewer aquatic plant species because not only is there less area, but there are generally fewer habitat types that support different species. While a method of characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Marl Lake's diversity values rank. Using data obtained from WDNR Science Services, quartiles were calculated for 71 lakes within the North Central Hardwood Forests Ecoregion (Figure 3.4-5). Marl Lake's diversity value falls within the lower quartile for both the ecoregion and the state, indicating that the diversity of its plant community falls within the bottom 25% of lakes sampled. This low diversity comes from the dominance of one or few species in the plant community.

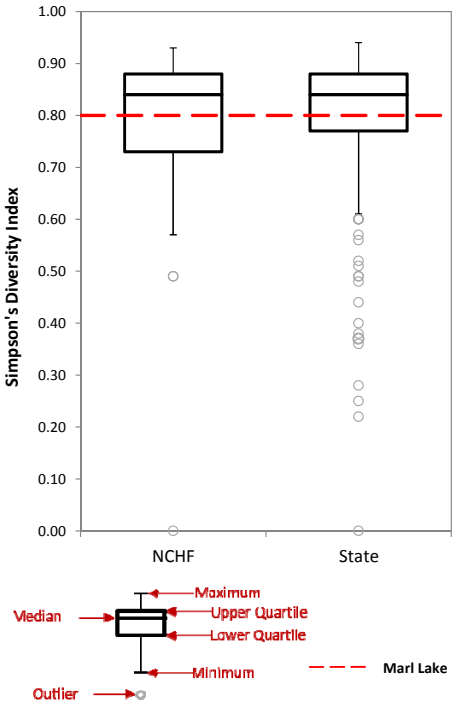


Figure 3.4-5. Marl Lake species diversity index. Created using data from 2010 point-intercept surveys.

As explained previously in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plant species is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found

(composition of population). For instance, while Fries' pondweed was found at almost 70% of the sampling locations in Marl Lake in 2010, its relative frequency of occurrence is 35%. Explained another way, if 100 plants were randomly sampled from Marl Lake, 35 of them would be Fries' pondweed. Figure 3.4-6 displays the relative frequency of occurrence of aquatic plant species from the 2010 point-intercept survey and illustrates the uneven distribution of species, or low species diversity, with Fries' pondweed and muskgrasses together accounting for 58% of the lake's plant community.

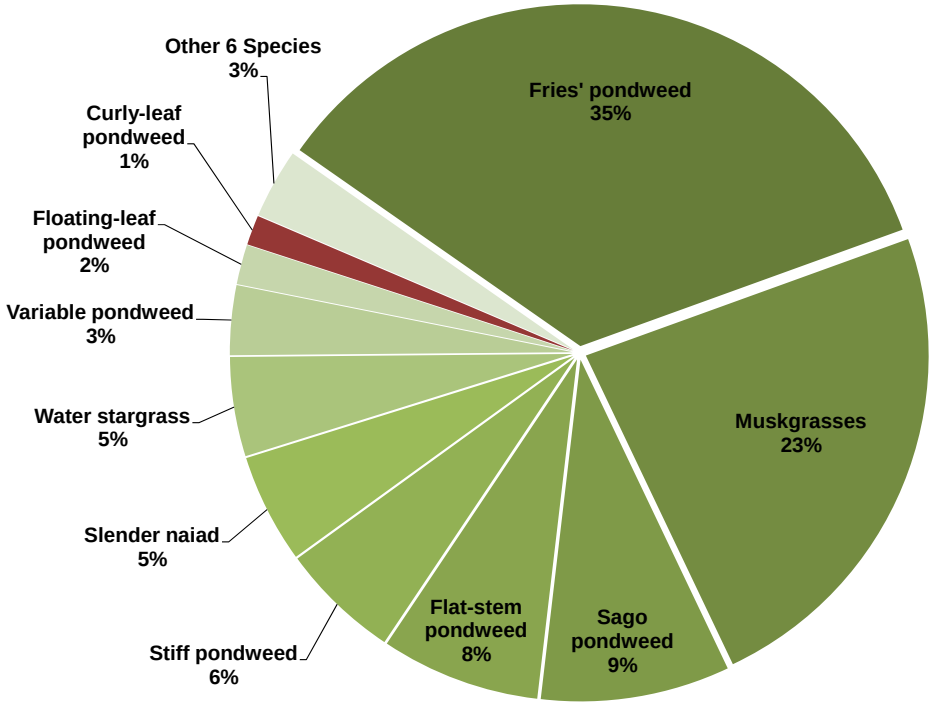


Figure 3.4-6. Marl Lake aquatic plant relative occurrence analysis. Created using data from July 2010 aquatic plant point-intercept survey. Exotic species indicated with red.

The 2010 community mapping survey conducted on Marl Lake was the second survey of this type to be conducted, the first being conducted by NES Ecological Services in 2002. The quality of Marl Lake's aquatic plant community is also indicated by the number of floating-leaf and emergent species (7) that were located in near-shore areas around the lake. The 2010 community map indicates that approximately 1.1 acres (4%) of the 27-acre lake contain these types of plant communities (Map 6). These communities were comprised of both floating-leaf and emergent aquatic plant species, all of which provide valuable habitat to wildlife and stabilize substrate and shoreline areas be dampening wave action.

Map 6 illustrates how these communities have responded and shifted their locations in response to the lowering water levels since 2002. With the lowering water levels, the floating-leaf and emergent plant communities on Marl Lake have declined by approximately 3.8 acres since 2002 (Table 3.4-2), most prominently along the western shoreline which is now dry. Because these communities have reduced in size on Marl Lake, their conservation for wildlife habitat, particularly as fish nurseries, becomes even more important. In addition, any fallen trees or other

forms of coarse woody debris now lie above the waterline and can no longer function as structural habitat for aquatic organisms.

Table 3.4-2. Marl Lake acres of emergent and floating-leaf plant communities from the 2002 NES Ecological Services and 2010 Onterra community mapping surveys.

	Acres	
Plant Community	**2002**	**2010**
Floating-leaf	0.6	0.0
Emergent	0.3	0.2
Floating-leaf/Emergent	4.0	0.9
Total	**4.9**	**1.1**

Continuing the analogy that the community map may represent a 'snapshot' of the important emergent and floating-leaf plant communities, this survey provided a valuable understanding of the dynamics of these communities within Marl Lake, and replications in the future will further this understanding. 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 Marl Lake

Curly-leaf pondweed

As mentioned in the previous section, the invasive aquatic plant curly-leaf pondweed (*Potamogeton crispus*) was discovered during the July 2010 comprehensive point-intercept survey on Marl Lake. Since some of the curly-leaf pondweed located was in deeper water (17-20 feet), Onterra ecologists Tim Hoyman and Eddie Heath visited Marl Lake on July 16, 2010 to map the curly-leaf pondweed colonies utilizing SCUBA. After deploying buoys from underwater at the edges of the plant colonies, they were able to map them using sub-meter Global Positioning System (GPS) technology. Map 7 displays the locations of curly-leaf pondweed colonies along with a few clumps/single plants at this time. During the winter of 2010/2011, the MLD received WDNR AIS Early Detection and Response Grant funds to conduct a multi-year CLP control and monitoring project for Marl Lake. Specifically, the goal of this project is to monitor and assess herbicide treatments for CLP from 2011-2013.

Curly-leaf pondweed primarily reproduces annually via structures called turions (asexual reproductive shoots). The majority of the turions are produced along the stem in the leaf axils and fall to the bottom of the lake in late summer when the plants die back. Some turions are produced lower on the plant and along the underground rhizome. The turions lie dormant until autumn when they germinate to produce small winter foliage. While not really growing, the fact that these plants exist under the ice gives this plant a head start on outcompeting many of our native species in the spring. The intent of any CLP treatment is to kill (or remove) the plants before they can produce and release their turions. A single year of treatment effectively controls

a single year of CLP without allowing it to produce subsequent generations. Treatment areas will need to be focused on for 3-5 years until the turion base within that area is exhausted.

Onterra ecologists first visited Marl Lake on May 5, 2011 to conduct a pretreatment survey but were not able to locate CLP in known areas with a submersible video camera. Numerous rake tows completed over these known locations yielded only a single, small CLP plant. A crew surveyed the lake again on May 18, 2011 and again had difficulty locating CLP and was not confident that the growth stage of the plant was sufficient for refinement of treatment areas. A crew visited the lake for the third time on May 31, 2011 and found plants to be about one-foot tall. Based on these surveys and the uncharacteristic growth stage of the CLP, the proposed strategy shifted towards hand-harvesting in the deep areas were the lake had begun to stratify and herbicide treatments in the shallow areas where plants were too numerous to harvest.

On June 8, 2011 four crew members from Onterra conducted the hand-harvesting and associated mapping activities. Three scuba divers were deployed most of the day harvesting from two deep areas that were originally located in 2011. These locations are displayed on Map 8. As shown on Photo 3.4-1 (middle), a good amount of biomass (and litter) was removed from the sites. One of the divers located a highly dominant CLP colony to the north of one of the areas which were being focused upon for hand-removal (Map 8, Photo 3.4-1). The plants were located in about 19-feet of water and were very dense and growing high (8-10 feet) in the water column. It was determined that there was far too much biomass at the site for hand removal.



Photograph 3.4-1. Marl Lake CLP Hand-harvesting. Left: Onterra ecologists preparing for hand-harvesting. Middle: Hand-harvested CLP. Right: Tall, dense colony of CLP discovered during hand-harvesting that was not able to be removed.

An alternate strategy was developed to target this area for herbicide application. Endothall, an aquatic contact herbicide, is normally applied at water temperatures between 50 and 60°F when targeting CLP. During this early-June survey, the water temperatures exceeded 60°F and the lake was thermally stratified. The reaction of CLP to endothall in higher water temps is not fully understood and concerns arose about whether the treatments would effectively kill the CLP or simply cause injury. Research by the US Army Corps of Engineers (USACE) indicates that injured CLP plants are still able to produce turions, and these stressed plants may produce even more turions in this condition (John Skogerboe, personal comm.). After careful discussion between Onterra, the USACE, and the WDNR, it was determined to advise the MLD not to conduct a treatment in 2011.

Onterra ecologists once again visited the lake in June 2012 to assess curly-leaf pondweed. Donning SCUBA gear, four staff members visited known locations, as well as conducting an underwater-based meander survey to locate missed occurrences of the plant in previous surveys. The results of this survey indicate that curly-leaf pondweed has spread throughout the entire lake, occupying areas in small clumps, small colonies, or larger colonies (Map 9). [Management of curly-leaf pondweed is discussed further in the Summary & Conclusions Section as well as within the Implementation Plan.]

Eurasian water milfoil

During the 2011 spring curly-leaf pondweed pretreatment survey, Onterra ecologists encountered some suspicious looking milfoil plants that were not observed during the numerous surveys conducted in 2010. Live specimens were sent to the Annis Water Resources Institute at Grand Valley State University in Michigan to undergo genetic testing, which revealed that this milfoil in Marl Lake is a hybrid between the non-native Eurasian water milfoil (*Myriophyllum spicatum*) and the native northern water milfoil (*Myriophyllum sibiricum*). The majority of the plants were found growing in shallow water in the northwestern area of the lake, but a few single plants were located along the southwestern and northeastern shores (Map 10).

In August of 2012, Onterra ecologists surveyed Marl Lake again for Eurasian water milfoil. The results of this survey (Map 11) were much different than what was seen in 2011 (Map 10), as the invasive plant was able to take hold of much of the shoreline, particularly on the western and north/north-eastern sides of the lake. 2012 was referred to by most AIS managers as a "good year for Eurasian water milfoil"; the early ice-out in most Wisconsin lakes followed by a summer that included very warm temperatures and a lot of sunlight provided ideal environmental conditions for the plant to flourish. Management of Eurasian water milfoil is discussed further in the Summary & Conclusions Section as well as within the Implementation Plan.

Reed Canary Grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines.

Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic.

At this time, populations on the shorelines of Marl Lake are not excessive, though it is recommended that continued monitoring of reed canary grass takes place. During the community mapping survey of Marl Lake in 2010, Onterra ecologists mapped an occurrence of reed canary grass along the northwest shoreline of the lake with sub-meter GPS technology (Map 6). As water levels recede, reed canary grass is often one of the first species to colonize these newly exposed sites.

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. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR (WDNR 2010).

Marl Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was 4th highest ranked important or enjoyable activity on Marl Lake (Question #11). About 59% of survey respondents have fished the lake for over 10 years (Question #6). Approximately 47% of these same respondents believed that the quality of fishing on the lake was either very poor or poor, while 24% believe the fishing is currently good (Question #8). The majority (82%) believe that the quality of fishing has gotten worse since they have obtained their property (Question #9). Loss of fish habitat (likely due to low water levels on the lake) and excessive fishing pressure ranked highly as factors that were of top concern and are potentially negatively impacting Marl Lake (Questions 17 and 18, and stakeholder survey comments).

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 Marl 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 piscovores, and are the larger gamefish that are sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscovores 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.

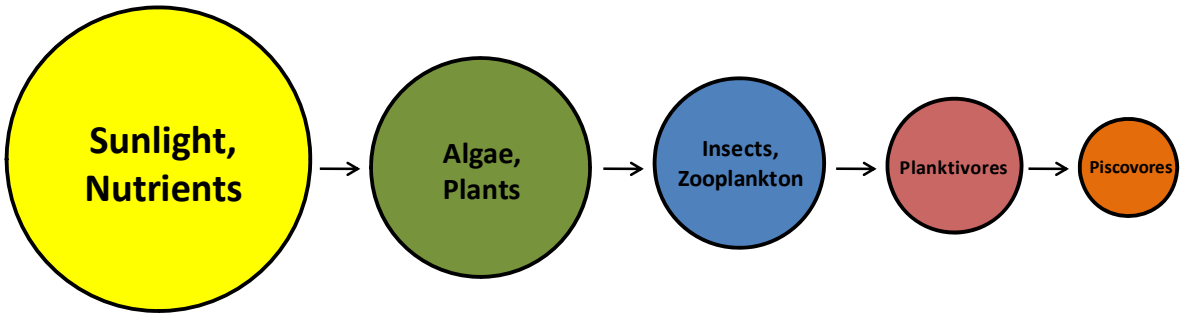


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Marl Lake is oligotrophic, meaning it has high water clarity, but a low amount of nutrients and thus low primary productivity. Simply put, this means it is difficult for the lake to support a large population of predatory fish (piscovores) because the supporting food chain is relatively small.

Table 3.5-1 shows the popular game fish that are present in the system. Management actions that have taken place and will likely continue on Marl Lake according to this plan include herbicide applications to control Eurasian water milfoil and curly-leaf pondweed. In the future, these applications will occur in May when the water temperatures are below 60 - 65°F. It is important to understand the effect the chemical has on the spawning environment which would be to remove the submergent plants that are actively growing at these low water temperatures. Yellow perch is a species that could potentially be affected by early season herbicide applications, as the treatments could eliminate nursery areas for the emerged fry of these species.

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

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
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)
Yellow Bullhead	*Ameiurus natalis*	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Currently, there are no special fishing regulations on Marl Lake besides those declared at the state level. Marl Lake is in the southern region of the northern pike management zone, meaning that during the northern pike fishing season, 2 pike may be harvested daily with a minimum length of 26 inches. Largemouth bass may be harvested at a rate of 5 fish per day and a minimum length limit of 14 inches has been set on this gamefish.

Marl Lake Fisheries Management

In 2006, WDNR biologists conducted sampling studies on Marl Lake to assess the fish community and provide direction for management. This report is attached as Appendix F. Largemouth bass and northern pike were the two gamefish species sampled in Marl Lake. Bluegill were the most common panfish species found during these surveys.

According the 2006 WDNR survey report, in 1960 Marl Lake was stocked with trout and managed as a trout/largemouth bass fishery for several years. Trout fishing was very good for several years, however, in 1965 this fishery declined at the same time as bluegill and yellow perch populations began to rise. The impact of panfish on the trout fishery was detrimental to the trout management program, and in 1968 it was decided that Marl Lake would no longer be managed as a trout waterbody. In the 1970's and 1980's, panfish were removed from the lake with seine nets and used to supplement other area lakes.

Following the 2006 surveys, WDNR biologists noticed that the predator/prey relationship had changed from what was observed in previous surveys. Marl Lake typically had overabundant panfish, but in 2006, largemouth bass abundance was high while panfish abundance was low. This may be due to fluctuating water levels. At the time of the survey, water levels were down considerably. This reduces the near shore habitat for smaller species of fish, and exposes them to predation by larger gamefish.

Marl Lake Substrate Type

According to the point-intercept survey conducted by Onterra, 87% of the substrate sampled in the littoral zone on Marl Lake was muck, with the remaining 13% being classified as sand (Map 4). 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. Some fish prefer to spawn over mucky areas. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result (Becker 1983). 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.

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 Marl Lake ecosystem and compare it with data collected in 2002 to determine if changes have occurred over time.
2) Collect detailed information regarding invasive plant species within the lake, if any were found.
3) Collect sociological information from Marl Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

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

Overall, the studies completed on Marl Lake in 2010 indicate that the lake is healthy in terms of its water quality and watershed. While the native aquatic plant community is of comparable quality to other lakes in Wisconsin, the recent introductions of the non-native species curly-leaf pondweed and hybrid Eurasian water milfoil currently threaten its integrity.

Analysis of the water quality data collected as part of this project in 2010 and available historical data indicate that Marl Lake's water quality falls within the *Good* and *Excellent* categories for deep seepage lakes in Wisconsin and is significantly better than other lakes within the North Central Hardwood Forests Ecoregion. The water quality data collected in 2010 was very similar to the data gathered as part of the 2002 management plan. Analysis of available data also shows that no apparent trends (positive or negative) are occurring over time. Total phosphorus concentrations in Marl Lake are relatively low, and thus free-floating algae levels are low and water clarity is high. However, as data collected on August 30, 2010 show, increasing the levels of phosphorus, the lake's limiting plant nutrient, will increase the amount of algae and decrease water clarity. While the source of phosphorus measured during this event may never be known, it was shown to be only a temporary event.

The water quality of Marl Lake is influenced by and is a reflection of the landscape in which the lake sits. The majority of Marl Lake's drainage basin, or surface watershed, is comprised of intact forests. While a small portion is comprised of row crop agriculture (15%), modeling indicated that the majority of Marl Lake's phosphorus budget (53%) came from this land cover type. However, there was a great discrepancy between the model's predicted growing season average phosphorus and the actual growing season average phosphorus measured in Marl Lake; the model's predicted value was significantly higher than what was actually measured. This discrepancy is believed to be due to the fact that Marl Lake is a seepage lake and most of the precipitation that falls within its watershed does not enter the lake via overland flow, but percolates into the ground due to the highly porous soils in this region. In addition, being a seepage lake, Marl Lake receives a large portion of its water from groundwater, which in central Wisconsin is rich in dissolved minerals. These minerals also aid in removing phosphorus from the water column and making them unavailable to algae and plants. It is these factors that drive the excellent water quality in Marl Lake.

The 2010 shoreline assessment survey revealed that the majority (42%) of Marl Lake's shoreline is currently in a completely natural or undeveloped state. These areas are important for maintaining the integrity of Marl Lake's environment as they buffer runoff from the immediate watershed and provide essential habitat for aquatic and terrestrial wildlife. In 2010, two sandhill cranes were observed nesting in these areas. While it may be of interest for Marl Lake stakeholders to restore some of the more developed shorelines around the lake, it may be even more important to preserve the shoreline areas that are currently undeveloped.

Since the 2002 studies, water levels in Marl Lake have declined by approximately five feet and are a major concern to Marl Lake stakeholders. While likely a result of both climatic and anthropogenic factors, it is important to understand that the water levels in Marl Lake are a reflection of the ground water table. This means that one large rain event will not be enough to raise the water levels in Marl Lake, but it will take a number of years with higher precipitation at the regional level to increase the ground water table and thus Marl Lake's water levels. The State of Wisconsin is currently conducting a study in the central sands region to determine the significance of high-capacity wells on ground water levels.

The 2010 aquatic plant studies revealed that Marl Lake contains a high number of native aquatic plant species, and the quality of the aquatic plant community is comparable to other lakes within Wisconsin. When compared to the aquatic plant surveys completed in 2002, some species, most notably Fries' pondweed and northern water milfoil, demonstrated drastic changes in abundance, while most saw little or no change. The changes in occurrences observed in some species are likely due to fluctuating water levels and associated factors. The high water clarity of Marl Lake allows aquatic plants to inhabit most of the lake, to a depth of 29 feet. Overall, the native aquatic plant community of Marl Lake is very healthy and indicative of a high quality environment when compared to other lakes in this ecoregion. However, over the course of this project, the non-native plants curly-leaf pondweed and hybrid Eurasian water milfoil were discovered, and since 2010, these species have continued to spread and threaten the native aquatic plant community in Marl Lake.

Following a meeting with the Marl Lake District (MLD) Planning Committee and Ted Johnson with the Wisconsin Department of Natural Resources (WDNR) in early October 2012, the MLD decided to move forward with an integrated control strategy utilizing both herbicides and hand-removal efforts. Because curly-leaf pondweed is more abundant than hybrid Eurasian water milfoil at this time, this strategy will primarily target curly-leaf pondweed with a low-dose, whole-lake liquid endothall treatment in the spring of 2013 followed by aggressive hand-removal of remaining areas. Liquid endothall applications have also been shown to decrease the occurrence of Eurasian water milfoil, so a side-benefit of the 2013 curly-leaf pondweed treatment will be an impact to the hybrid Eurasian water milfoil population. The control of curly-leaf pondweed and Eurasian water milfoil are discussed in greater detail in the Implementation Plan Section.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Marl Lake District Planning Committee and ecologist/planners from Onterra. It represents the path the Marl Lake District 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 Marl 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 Current Water Quality Conditions

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

Timeframe: Continuation of current effort.

Facilitator: Board of Directors

Description: Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Data collected by a Marl Lake District volunteer through this program allowed for a more detailed analysis and deeper understanding of changes in Marl Lake's water quality over time. Early discovery of negative trends may lead to the reason as of why the trend is developing. Volunteers from the Marl Lake District have collected Secchi disk clarities and water chemistry samples during this project and in the past through the WDNR Citizen Lake Monitoring Program. Stability will be added to the program by selecting an individual from the Marl Lake District to coordinate the lake's volunteer efforts and to recruit additional volunteers to keep the program fresh.

Action Steps:

1. Board of Directors recruits volunteer coordinator from association.
2. Coordinator directs water quality monitoring program efforts and volunteers.
3. Volunteers collect data and coordinator/volunteers report results to WDNR and to association members during annual meeting.

Management Action: Reduce phosphorus and sediment loads from immediate shoreline areas to Marl Lake.

Timeframe: 2013

Facilitator: Marl Lake Planning Committee

Description: As the Watershed Section discusses, the Marl Lake watershed and majority of immediate shoreline areas are in good condition. However, Marl Lake's small size means that any development within these nearshore areas has a greater impact on the lake. These sources include faulty septic systems, shoreland areas that are maintained in an unnatural manner, and impervious surfaces. To reduce these impacts, the MLD will initiate an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include newsletter articles and guest speakers at district meetings.

Topics of educational items may include benefits of good septic system maintenance, methods and benefits of shoreland restoration, including reduction in impervious surfaces, and the options available regarding conservation easements and land trusts. This effort, if it results in shoreland restorations, would not only reduce phosphorus inputs into Marl Lake, but would also increase the amount of quality habitat around the lake.

Action Steps:

1. Recruit facilitator.
2. Facilitator gathers appropriate information from the WDNR, UW-Extension, Waushara County, and other sources.
3. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for district meetings.

Management Goal 2: Control Existing and Prevent Further Aquatic Invasive Species Infestations within Marl Lake

Management Action: Initiate large-scale herbicide application and hand-removal strategy to reduce the occurrence of curly-leaf pondweed in Marl Lake.

Timeframe: Initiate 2013

Facilitator: Marl Lake Planning Committee with professional help as needed

Applicable Grant Funding: WDNR Aquatic Invasive Species Early Detection and Response Grant

Description: As was discussed in the Aquatic Plant Section, Onterra ecologists located occurrences of the non-native, invasive plant curly-leaf pondweed in Marl Lake during 2010 studies. Following this discovery, Onterra assisted the Marl Lake District (MLD) in successfully applying for a WDNR Aquatic Invasive Species (AIS) Early Detection and Response Grant to conduct a multi-year curly-leaf pondweed control

and monitoring project on Marl Lake.

During hand-removal efforts of curly-leaf pondweed by Onterra SCUBA divers in 2011, additional areas of curly-leaf pondweed were located that were too large and dense for hand-removal. Over the following winter, discussions between Onterra, the US Army Corps of Engineers (USACE), the WDNR, and the MLD led to a strategy that would target the curly-leaf pondweed locations with an early-spring herbicide application in 2012. However, due to the unusually warm weather, water temperatures in Marl Lake rose very rapidly. It was advised that the treatment should not occur for concerns regarding the impacts to native plants and emerging research from the USACE that the mortality rate of curly-leaf pondweed exposed to herbicides at water temperatures greater than 60°F is reduced.

Onterra ecologists visited Marl Lake again in June 2012 to assess the curly-leaf pondweed. The results indicated that curly-leaf pondweed had spread throughout much of the lake, inhabiting shallow, near-shore areas as well as deeper areas up to 20 feet (Map 9). These results were presented to and discussed with the MLD Planning Committee at a meeting in early October 2012. Based upon those discussions, the MLD has chosen to utilize the remaining WDNR AIS grant funds and move forward with a 2013 integrated control strategy utilizing both herbicides and hand-removal efforts. Treatments in subsequent years will likely be funded with a second AIS Early Detection and Response grant. The eradication of curly-leaf pondweed from Marl Lake is not realistic; therefore, the goal of this program is to control the exotic and minimize its impact on the ecology of Marl Lake. At present, there is too much curly-leaf pondweed in the lake to stage a successful hand-removal effort. Because of this, the integrated strategy devised involves a low-dose, whole-lake herbicide application in the spring of 2013 followed by aggressive hand-removal of applicable areas by both professionals and volunteers.

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. Spot treatments that target a specific colony of that target plant have extremely short exposure times (hours) due to dilution of the herbicide within the lake. In spot treatments, a high herbicide dose is required to offset the short exposure time. But when the target plant is distributed widely throughout an entire lake, a whole-lake treatment strategy can be taken. In a whole-lake treatment, the herbicide may be applied to specific sites but the amount of herbicide applied is dictated by what the lake-wide concentration will be once the herbicide reaches equilibrium. Contrary to spot treatments, whole-lake treatments have a long exposure time (weeks), and therefore a low dose can be used to achieve control. Whole-lake treatments rely on concentrations 10 times less than spot treatments to be effective.

2013 Curly-leaf pondweed Pre-treatment Survey

In May 2013, prior to the application of the herbicide, Onterra ecologists would survey the areas of curly-leaf pondweed with SCUBA to assure that the plants are actively growing.

Herbicide Concentration Monitoring

Following the application of the herbicide, trained MLD volunteers will collect water samples from both near the surface and near the bottom at set intervals to understand the herbicide concentration and its longevity. These samples will be collected following a study design that will be determined by the USACE. Members of the MLD would collect samples within the lake at different locations and time-periods following the treatment. Properly preserved samples will then be sent to the USACE laboratory for analysis.

2013 Curly-leaf pondweed Post-treatment Survey

In June 2013, when curly-leaf pondweed is at or near its peak growth, Onterra ecologists would again survey known areas of curly-leaf pondweed to qualitatively assess the effectiveness of the treatment. Because of curly-leaf pondweed's unique lifecycle, quantitative assessments following the treatment would not be able to differentiate mortality caused by the herbicide and the natural senescence of the plant at that time of year. During this time, remaining curly-leaf pondweed will be targeted for hand removal.

2013 Native Aquatic Plant Community Monitoring

While it is never the intent of these treatments to impact native aquatic plant species, endothall is a contact herbicide, meaning it is not selective in the types of plants it can impact. While actions such as treating early in the spring are taken to minimize impacts to these native plants, it is likely that some species may see a decline following the treatment. To assess the impact of this whole-lake treatment on Marl Lake's aquatic plant community, a whole-lake point-intercept survey will be conducted in late summer. This post-treatment data will be compared with the point-intercept data collected in 2010 as part of the lake management planning project to determine if there were any adverse impacts to native species.

In June of 2014, Onterra ecologists would reassess the areas of curly-leaf pondweed. If the 2013 treatment is successful, no turions should have been produced and curly-leaf pondweed should not have spread. The curly-leaf pondweed remaining in 2014 will be from turions that were deposited in 2012 or earlier. It is the goal of curly-leaf pondweed control to prevent the formation of new turions and deplete the turion base within the sediment over time with repeated treatments.

Action Steps:

1. Retain consultant to map curly-leaf pondweed and oversee 2013 curly-leaf pondweed treatment and monitoring.
2. The MLD, with assistance from an herbicide applicator if applicable, obtains the proper permits to implement management action.
    a. WDNR Plant Management and Protection Program: www.dnr.state.wi.us/lakes/plants
    b. The UW-Extension Lake List is a great resource for locating an herbicide applicator: www.uwsp.edu/cnr/uwexlakes/lakelist/businessSearch.asp
3. Monitoring plan is executed as described above.

Management Action: Reduce the occurrence of hybrid Eurasian water milfoil in Marl Lake.

Timeframe: Initiate 2013

Facilitator: Marl Lake Planning Committee with professional help as needed

Description: As described in the aquatic plant section, during surveys for curly-leaf pondweed in 2011, Onterra ecologists discovered occurrences of the non-native Eurasian water milfoil. Later, DNA analysis indicated that this milfoil was actually a hybrid between Eurasian water milfoil and the indigenous northern water milfoil. While it has spread to many areas around the lake, its occurrence is still relatively low. It is not being targeted for control at this time, but monitoring of this population will continue. However, low-dose Endothall treatments have led to decreases in Eurasian water milfoil in other lakes, and it is the hope that the 2013 curly-leaf pondweed treatment will have a side-benefit of also controlling the hybrid milfoil. In the summer of 2013, the locations of hybrid milfoil will be assessed and plants encountered during the June 2013 curly-leaf pondweed assessment will be targeted for hand removal.

Action Steps:

1. See description above.

Management Action: Investigate feasibility of Clean Boats Clean Waters program on Marl Lake.

Timeframe: Initiate 2013

Facilitator: Marl Lake Planning Committee

Description: The Clean Boats/Clean Waters program of Wisconsin has proven to be an effective tool at not only reducing the spread of AIS to and from waterbodies in the state, but also in educating lake users on the threat AIS poses, how AIS is spread, etc. Marl Lake stakeholders, concerned about the current AIS present in their lake, expressed interest in participating in the Clean Boats/Clean Waters program during this management planning project. While the program has been successful and worthwhile on many larger lakes throughout the state, there are concerns about its impact on Marl Lake. The reason for this is that

Marl Lake is relatively small, and because of this receives very low watercraft use stemming from the public access location. Additionally, there are few residences on the lake compared to larger lakes, meaning that the number of volunteers may be limited. Because of these factors, there is concern that the efforts of Clean Boats/Clean Waters volunteers may not be as effective as hoped.

Nevertheless, Marl Lake stakeholders are anxious to do their best to protect the lake from further AIS, as well as reduce the chance of AIS transport from Marl Lake elsewhere. A Marl Lake Planning Committee member will contact Clean Boats/Clean Waters personnel (contact information below) in winter/spring of 2013 to learn more about this initiative, what it entails, and how Marl Lake may benefit from implementation of the program. This planning committee member will relay obtained information to Marl Lake stakeholders, and a consensus will be reached on whether or not this is an initiative the MLD will pursue. The MLD may wish to adopt a modified approach to the program, where volunteers oversee watercraft inspections only during holiday or other busy weekends.

Action Steps:

1. Marl Lake Planning Committee member will contact Erin McFarlane, AIS Outreach Specialist and Clean Boats/Clean Waters Educator with the UW-Extension Lakes (715.346.4978).

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Marl 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.

All samples that required laboratory analysis were processed through the Wisconsin State Laboratory of Hygiene (SLOH). The parameters measured, sample collection timing, and designated collector are contained in the table below.

Table 6.0-1. Water Quality Sample Parameters and Timing (● = Collected as a part of standard sampling procedures. ♦ = Collected to provide data for Waushara County Planning Project.)

Parameter	Spring		June		July		August		Fall		Winter	
	S	B	S	B	S	B	S	B	S	B	S	B
Dissolved Phosphorus	●	●			●	●			●		●	●
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Total Kjeldahl Nitrogen	●	●			●	●			●		●	●
Nitrate-Nitrite Nitrogen	●	●			●	●			●		●	●
Ammonia Nitrogen	●	●			●	●			●		●	●
Laboratory Conductivity	●	●			●	●			●			
Laboratory pH	●	●			●	●			●			
Total Alkalinity	●	●			●	●			●			
Chloride	♦								♦		♦	
Chlorophyll-*a*	●		●		●		●		●			
True Color	♦								♦			
Sulfate	♦								♦			
Total Suspended Solids	●	●	●	●	●	●	●	●	●	●	●	●
Turbidity	♦								♦			
Calcium	●								♦			
Magnesium	♦								♦			
Potassium	♦								♦			
Sodium	♦								♦			
Atrazine (DATC)					♦							

Watershed Analysis

The watershed analysis began with an accurate delineation of Marl Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003).

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Marl Lake during a June 2010 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 Marl Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in "Appendix D" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin, (April, 2007) was used to complete this study on July 9, 2010. A point spacing of 32 meters was used resulting in 109 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Marl 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 Marl Lake District.

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