Big Twin Lake

Langlade County, Wisconsin

Comprehensive Management Plan

February 2014

Sponsored by:

Big Twin Lake Association, Inc.

WDNR Grant Program

LPL-1447-12

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

Onterra LLC
Lake Management Planning

Big Twin Lake

Langlade County, Wisconsin

Comprehensive Management Plan

February 2014

Created by: Brenton Butterfield, Eddie Heath, Dan Cibulka, and Tim Hoyman
Onterra, LLC
De Pere, WI

Funded by: Big Twin Lake Association, Inc.
Wisconsin Dept. of Natural Resources
(LPL-1447-12)

Acknowledgements

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

Big Twin Lake Planning Committee

Tony Adams	Barb Heimerman	Darlyn Jackson	Russ Schanial
Angie Galante	Dan Heimerman	Dave Jackson	Doug Tomany
Bill Galante	John Incha	Jimy Meyer	June Tomany

Wisconsin Dept. of Natural Resources

Kevin Gauthier

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 22
3.3 Shoreland Condition 25
3.4 Aquatic Plants 35
3.5 Fisheries Data Integration 59
4.0 Summary and Conclusions 64
5.0 Implementation Plan 66
6.0 Methods 75
7.0 Literature Cited 77

FIGURES

2.0-1 Select survey responses from the Big Twin Lake Stakeholder Survey 7
2.0-2 Select survey responses from the Big Twin Lake Stakeholder Survey, continued 8
3.1-1 Wisconsin Lake Classifications 13
3.1-2 Location of Big Twin Lake within the ecoregions of Wisconsin 13
3.1-3 Big Twin Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep, seepage lakes, and Northern Lakes and Forests Ecoregion lakes 15
3.1-4 Big Twin Lake average annual chlorophyll-*a* concentrations and median chlorophyll-*a* concentrations for state-wide deep, seepage lakes, and Northern Lakes and Forests Ecoregion lakes 16
3.1-5 Big Twin Lake average annual Secchi disk transparency and median Secchi disk transparency for state-wide deep, seepage lakes, and Northern Lakes and Forests Ecoregion lakes 17
3.1-6 Big Twin Lake average Trophic State Index values and median Trophic State Index values for deep, seepage lakes in Wisconsin and lakes within the Northern Forests and Lakes Ecoregion... 18
3.1-7 Dissolved oxygen and temperature profiles from Big Twin Lake 19
3.3-1 Shoreline assessment category descriptions 32
3.3-2 Big Twin Lake shoreland categories and lengths 33
3.3-3 Big Twin Lake coarse woody habitat survey results 34
3.4-1 Spread of Eurasian water milfoil within WI counties 48
3.4-2 Big Twin Lake proportion of substrate types 49
3.4-3 Big Twin Lake aquatic plant littoral frequency of occurrence 51
3.4-4 Frequency of occurrence of select aquatic plants from 2006 and 2011 in Big Twin Lake 52
3.4-5 Big Twin Floristic Quality Assessment 53
3.4-6 Big Twin Lake Simpson's Diversity Index 54
3.4-7 2011 relative frequency of occurrence of aquatic plant species in Big Twin Lake 55
3.5-1 Aquatic food chain 60
3.5-2 Location of Big Twin Lake within the Native American Ceded Territory 61

TABLES

3.4-1 Aquatic plant species located in Big Twin Lake during WDNR 2011 and Onterra 2012 surveys 50
3.4-2 Big Twin Lake acres of plant community types 55
3.5-1 Gamefish present in Big Twin Lake with corresponding biological information........ 60
3.5-2 WDNR fishing regulations for Big Twin Lake, 2013-2014 63

PHOTOS

1.0-1 Big Twin Lake, Langlade County........ 3
3.3-1 Example of a biolog restoration site 29

MAPS

1. Project Location and Lake Boundaries........Inserted Before Appendices
2. Watershed and Land Cover Types ....Inserted Before Appendices
3. 2012 Shoreland Condition........Inserted Before Appendices
4. Coarse Woody Habitat ....Inserted Before Appendices
5. 2011 PI Survey: Sediment Types ....Inserted Before Appendices
6. 2011 PI Survey: Aquatic Vegetation Distribution........Inserted Before Appendices
7. Emergent & Floating-leaf Aquatic Plant Communities ....Inserted Before Appendices
8. 2007 Final Treatment Areas ....Inserted Before Appendices
9. 2012 EWM Locations ....Inserted Before Appendices
10. 2013 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

1.0 INTRODUCTION

Big Twin Lake, Langlade County, is an approximate 60-acre seepage lake with a maximum depth of 35 feet and a mean depth of 14 feet (Map 1). This mesotrophic lake has a surficial watershed that encompasses approximately 2,020 acres, yielding a watershed to lake area ratio of 30:1. During the Wisconsin Department of Natural Resources' (WDNR) 2011 and Onterra's 2012 plant surveys, a total of 35 aquatic plant species were located, of which coontail (*Ceratophyllum demersum*) was the most abundant. Two non-native aquatic plants were located, and include Eurasian water milfoil (*Myriophyllum spicatum*) and purple loosestrife (*Lythrum salicaria*).

Field Survey Notes

Water is very clear. Beds of water marigold (Bidens beckii) were observed flowering underwater near the island, which is unusual; they generally flower once emersed out of the water. Eurasian water milfoil was located throughout shallower, near-shore areas around the lake, but was mainly comprised of single plants and clumps of plants.

Photograph 1.0-1 Big Twin Lake, Langlade County

Lake at a Glance - Big Twin Lake

Morphology	
Acreage	60 (WDNR Definition)
Maximum Depth (ft)	35
Mean Depth (ft)	14
Vegetation	
Curly-leaf Survey Date	May 31, 2012
Comprehensive Survey Date	August 15, 2011 & August 29, 2012
Number of Native Species	33
Threatened/Special Concern Species	-
Exotic Plant Species	Eurasian water milfoil; purple loosestrife
Simpson's Diversity	0.87
Average Conservatism	6.5
Water Quality	
Trophic State	Upper Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.8
Sensitivity to Acid Rain	Low
Watershed to Lake Area Ratio	30:1

Big Twin Lake is located Pickerel, Forest County, Wisconsin within the Wolf River Drainage Basin. In 2006, the non-native aquatic plant Eurasian water milfoil was confirmed to be present in Big Twin Lake by WDNR biologists. The following winter (2007), the Big Twin Lake Association, Inc. (BTLA) and the Town of Langlade sought support in the form of a WDNR Aquatic Invasive Species (AIS) Control Grant, and in May of 2007, Onterra ecologists surveyed the lake and recommended a Eurasian water milfoil treatment of approximately 12.7 acres. Following this treatment, no Eurasian water milfoil could be located within the treatment areas or anywhere else within the lake. While no EWM was found, it was believed to still be present within the lake, but at an undetectable level. The post treatment report recommended that the BTLA complete an approved lake management plan if future large-scale herbicide applications were to continue on Big Twin Lake.

Since 2007, the Eurasian water milfoil population within Big Twin Lake has slowly recovered, and in 2011, the BTLA successfully applied for a WDNR Lake Management Planning Grant to aid in funding the creation of a lake management plan for Big Twin Lake. In addition to developing a management strategy for Eurasian water milfoil, the BTLA was also interested in creating a lake management plan in order to ensure the preservation of Big Twin Lake for future generations. Through the development of a lake management plan, they wanted to assure that they are working to preserve the Big Twin Lake ecosystem, not solely a recreational resource. Overall, the BTLA recognized the value of gaining a better understanding of the Big Twin Lake ecosystem and its current condition. In the end, the information obtained from these studies will help guide future SLA plans and programs.

This report discusses the shoreline, watershed, water quality, aquatic plants, and Big Twin Lake stakeholder studies that were conducted on Big Twin Lake in 2011, 2012, and 2013. Also included is the Implementation Plan, which includes goals and actions specific to Big Twin Lake's current and future management that were developed by both members of the Big Twin Lake Planning Committee and Onterra ecologists.

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting

On July 14, 2012 a project kick-off meeting was held at the Big Twin Lake Pavilion to introduce the project to the general public. The meeting was announced through a mailing and personal contact by the Big Twin Lake Association, Inc. (BTLA) board members. The approximately 15 attendees observed a presentation given by Brenton Butterfield, an aquatic ecologist with Onterra. Mr. Butterfield'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 August 12, 2013, Onterra ecologists Brenton Butterfield and Eddie Heath met with members of the Big Twin Lake Planning Committee. In advance of this meeting, a draft copy of the Results and Discussion Sections (Section 3.0) was provided to attendees. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including the aquatic plant inventories, water quality analyses, and watershed modeling were presented and discussed. Information regarding herbicide treatments to control invasive aquatic plants was also presented.

Planning Committee Meeting II

On November 4, 2013, Onterra ecologists Brenton Butterfield met with members of the Big Twin Lake Planning Committee to begin developing management goals and actions for the Big Twin Lake Management Association's Comprehensive Lake Management Plan. One of the major topics of discussion was related to Eurasian water milfoil management and retaining/gaining association members.

Project Wrap-up Meeting

Has not yet occurred.

Management Plan Review and Adoption Process

Has not yet occurred.

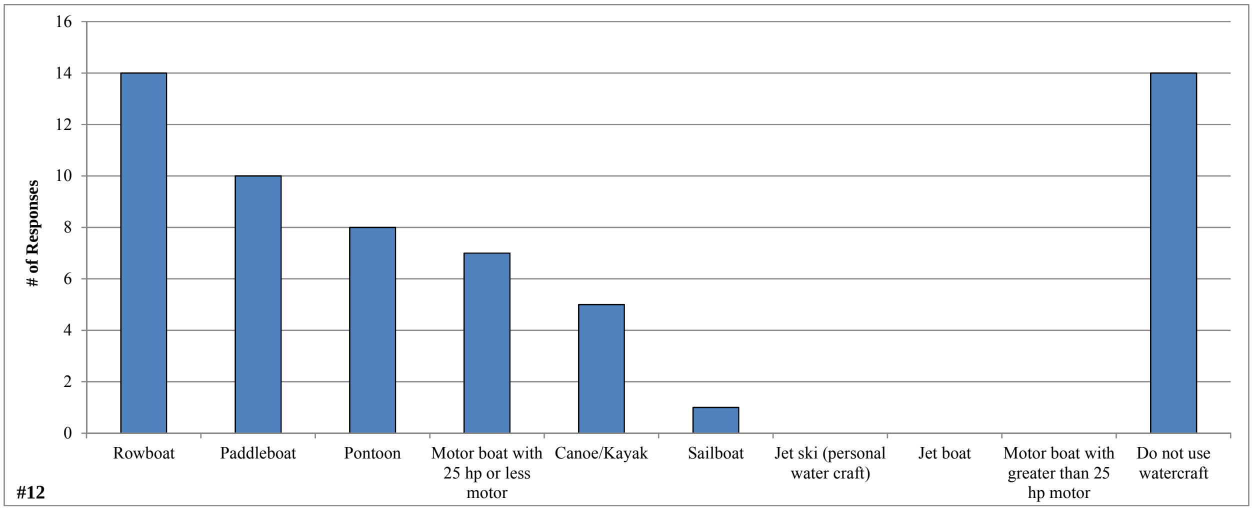
Stakeholder Survey

During October of 2012, a seven-page, 29-question survey was mailed to 77 riparian property owners in the Big Twin Lake watershed. Fifty-five percent of the surveys were returned and those results were entered into a spreadsheet by members of the Big Twin 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 Big Twin Lake. The majority of stakeholders (39%) are year-round residents, while 24% visit on weekends through the year and 7.3% live on the lake during the summer months only. Thirty-nine percent of stakeholders have owned their property for 6-10 years, and 9% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. Greater than half of survey respondents indicate that they use either a rowboat, paddleboat, pontoon, or a combination of these three vessels on Big Twin Lake (Question 12). When asked to rank three activities that are important reasons for owning property on or near Big Twin Lake, the majority of respondents (27%) listed open-water fishing, while 21% listed relaxing/entertaining, and 18% listed nature viewing (Question 13). Survey respondents indicated that they believe aquatic invasive species are have the greatest negative impact on Big Twin Lake, followed by excessive aquatic plant growth, and algae blooms (Question 19). When asked to rank their top three concerns regarding Big Twin Lake, the majority of respondents (23%) indicated that aquatic invasive species where their top concern, while 14% indicated excessive aquatic plant growth was their top concern, and 12% listed water quality degradation (Question 20).

Question 12: What types of watercraft do you currently use on the lake?



Question 13: Please rank up to three activities that are important reasons for owning your property on or near the lake.

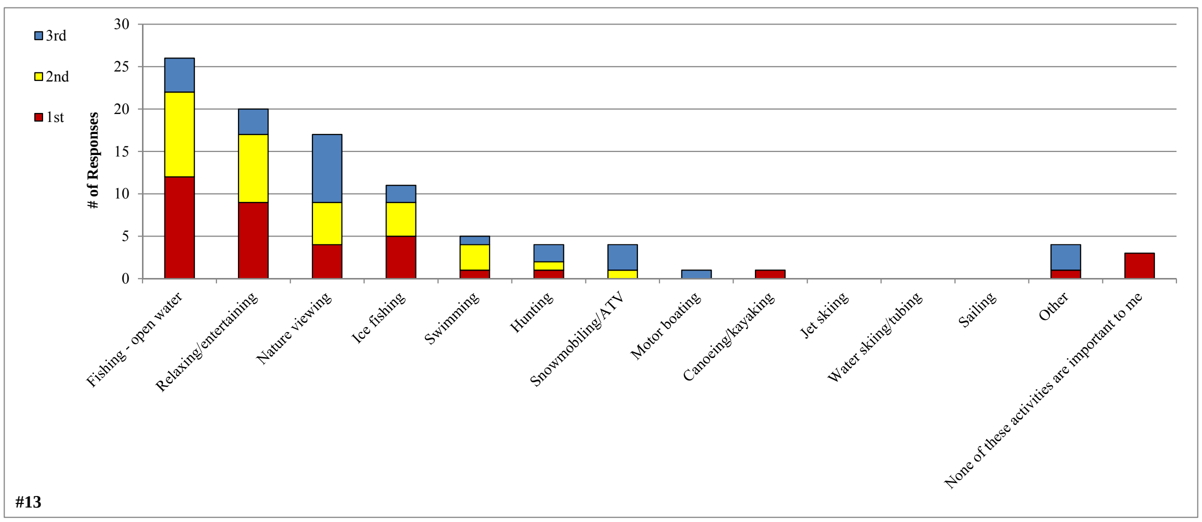
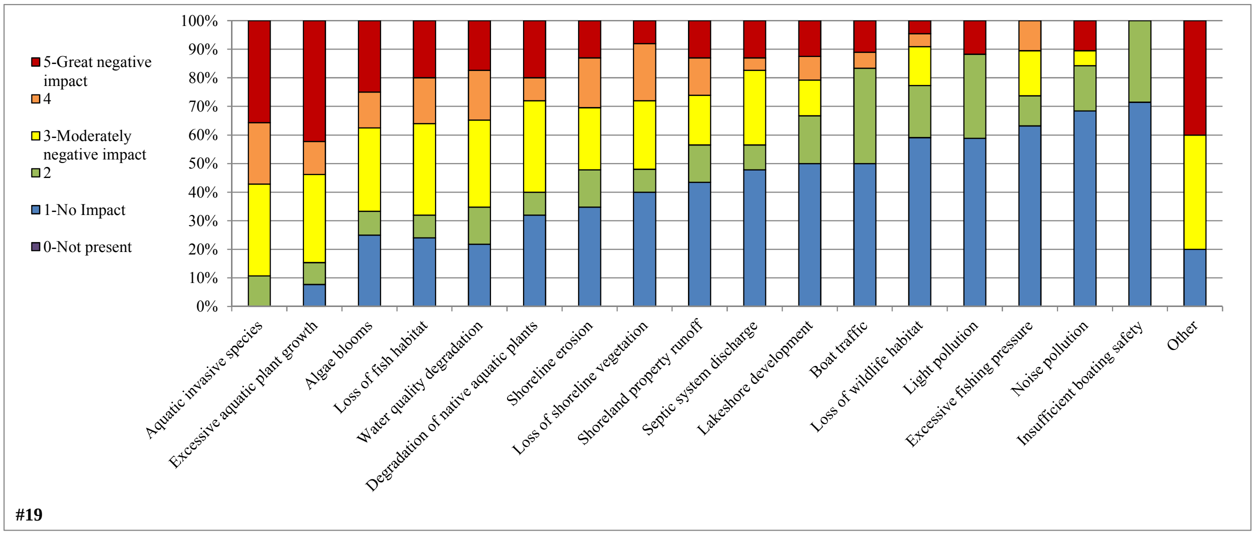


Figure 2.0-1. Select survey responses from the Big Twin Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 19: To what level do you believe these factors may be negatively impacting Big Twin Lake?



Question 20: Please rank your top three concerns regarding Big Twin Lake.

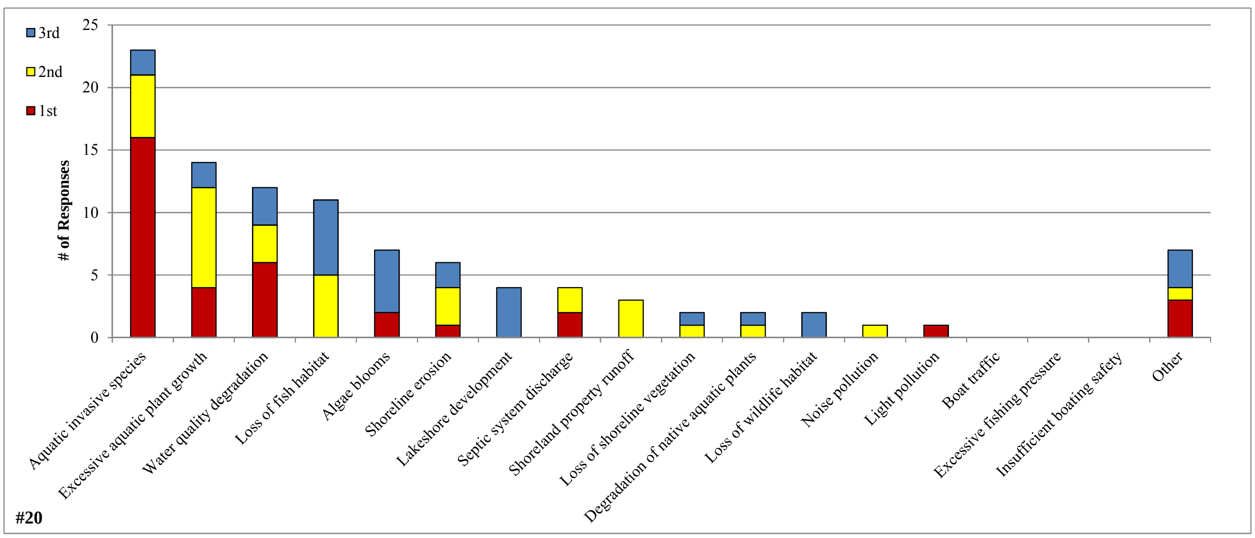


Figure 2.0-2. Select survey responses from the Big Twin Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 Big Twin 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 Big Twin 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.

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

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

Internal Nutrient Loading*

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Big Twin 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)**. These lakes differ in many ways; for example, in their oxygen content and where aquatic plants may be found. 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 all of the 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), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

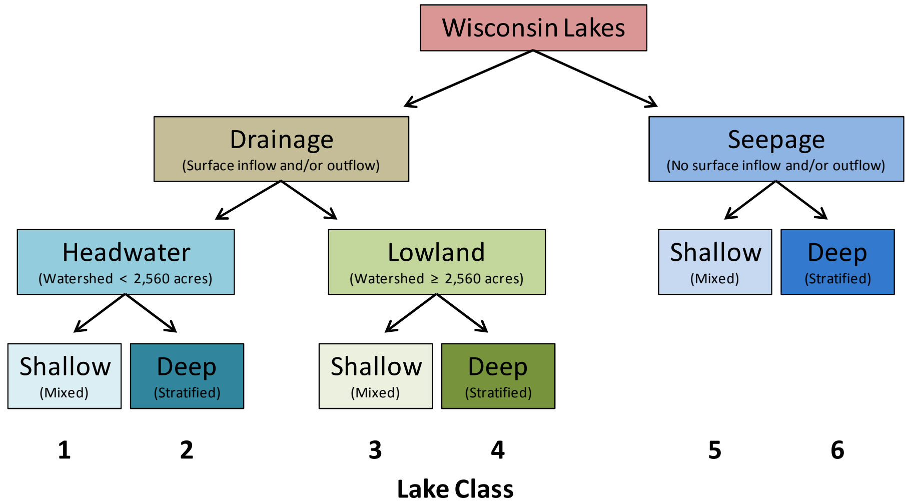


Figure 3.1-1. Wisconsin Lake Classifications. Big Twin Lake is classified as a deep (stratified), seepage lake (Class 6). Adapted from WDNR PUB-SS-1044 2008.

Big Twin Lake is classified as a deep (stratified), seepage lake. The WDNR developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for each of the six lake classifications. Though they did not sample sufficient lakes to create median values for each classification within each of the state's ecoregions, they were able to create median values based on all of the lakes sampled within each ecoregion (Figure 3.1-2). Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Big Twin Lake is within the Northern Lakes and Forests 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.

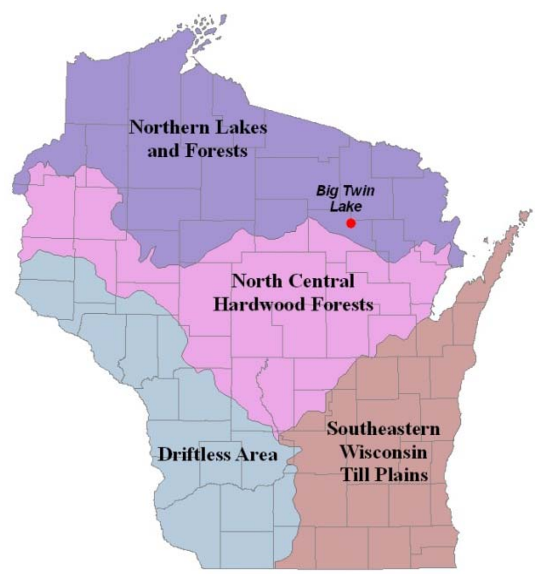


Figure 3.1-2. Location of Big Twin Lake within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Big Twin Lake are displayed in Figures 3.1-3 - 3.1-6. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Big Twin Lake Water Quality Analysis

Big Twin Lake Long-term Trends

As a part of this study, Big Twin Lake stakeholders were asked about their perceptions of the lake's water quality. The majority (62.5%) of respondents rated the water quality of Big Twin Lake as *Good* or *Fair*, 18.8% rated *Excellent*, and 18.8% rated *Poor* or *Very Poor* (Appendix B, Question #14). Approximately 33% of survey respondents indicated that the water quality of Big Twin Lake has *remained the same* since they first visited the lake, while approximately 28% believed the water quality has *somewhat degraded* (Question #15). Algae blooms were among the top three concerns that Big Twin Lake stakeholders believe is have a negative impact on Big Twin Lake (Question #19).

Volunteers have been and continue to be actively collecting data from Big Twin Lake through the Citizens Lake Monitoring Network (CLMN) Program. Through this WDNR-sponsored program, volunteers are trained to collect water quality data on their lake. Samples are analyzed through the State Lab of Hygiene in Madison, WI and data are entered into the Surface Water Integrated Monitoring System (SWIMS), an online database which allows for quick access to all current and historical water quality data. This process allows stakeholders to become directly engaged in protecting their lake, while producing reliable and comparable data that managers may recall through a streamlined website.

As discussed previously, three water quality parameters are of most interest when assessing a lake's water quality: total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Volunteers from Big Twin Lake have been collecting these data on an annual basis since 2008, building a continual dataset that will yield valuable information on Big Twin Lake's water quality through time.

Near-surface total phosphorus data are available from Big Twin Lake from 1985 and annually from 2008-2012. As illustrated in Figure 3.1-3, near-surface total phosphorus values from 1985 and from 2008-2012 have been relatively consistent, falling into the *Good* and *Excellent* categories for deep, seepage lakes. Average near-surface total phosphorus concentrations were slightly higher in 2009 due to sample collected in June of that year which had a value of 40 µg/L. Unfortunately, there are not enough near-surface total phosphorus data to determine if trends (positive or negative) are occurring over time. However, data collected from 2008-2012 indicates that total phosphorus concentrations are relatively consistent and are comparable to those collected in 1985. Overall, the weighted average for both the growing season and summer near-surface total phosphorus concentrations falls within the *Good* category for deep, seepage lakes in Wisconsin, and is slightly lower than the median for lakes in the Northern Lakes and Forests Ecoregion (Figure 3.1-3).

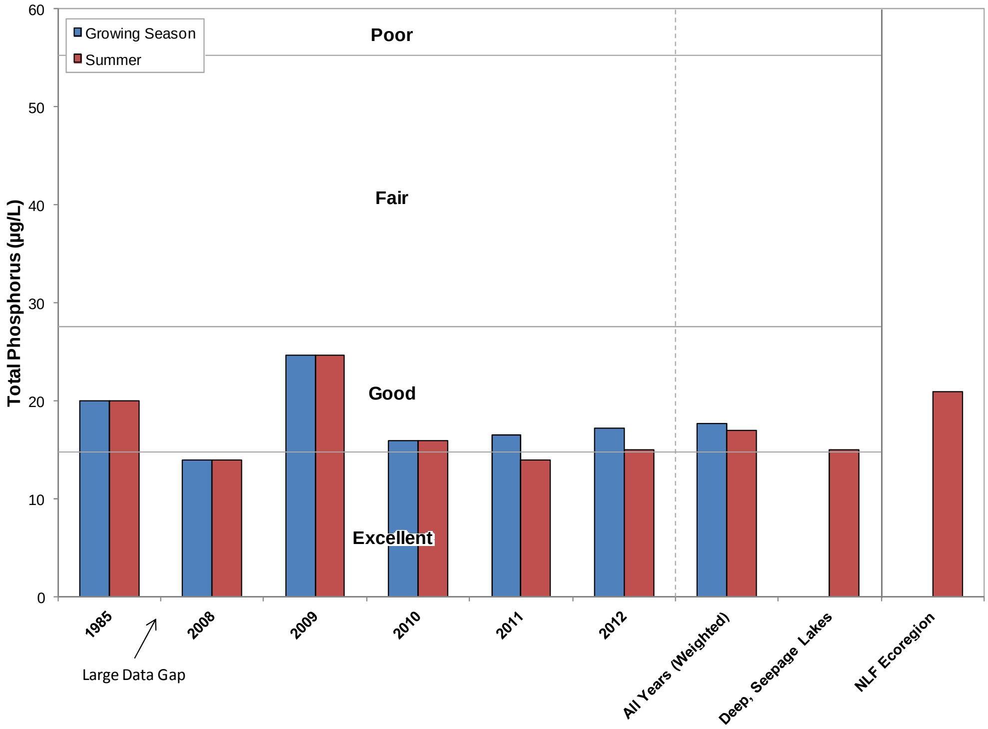


Figure 3.1-3. Big Twin Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep, seepage lakes, and Northern Lakes and Forests Ecoregion lakes. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed earlier, chlorophyll-*a*, or the measure of free-floating algae within the water column, is usually positively correlated with total phosphorus concentrations. While phosphorus limits the amount of algae growth in the majority of Wisconsin's lakes, other factors also affect the amount of algae produced within the lake. Water temperature, sunlight, and the presence of small crustaceans called zooplankton which feed on algae all also influence algal abundance.

Chlorophyll-*a* data have been collected annually from Big Twin Lake from 2008-2012 (Figure 3.1-4). Average annual chlorophyll-*a* levels in Big Twin Lake have remained relatively constant over this five-year period, falling into the *Good* and *Excellent* categories for deep, seepage lakes. The weighted average of all chlorophyll-*a* data available from Big Twin Lake straddles the *Good-Excellent* threshold, and is comparable to the median concentration calculated from other deep, seepage lakes in Wisconsin. Big Twin Lake's chlorophyll-*a* concentrations fall below the median for lakes within the Northern Lakes and Forests Ecoregion. Overall, these data indicate that Big Twin Lake has a very low abundance of free-floating algae. As with total phosphorus, there are not enough chlorophyll-*a* data to determine if any trends (positive or negative) are occurring over time.

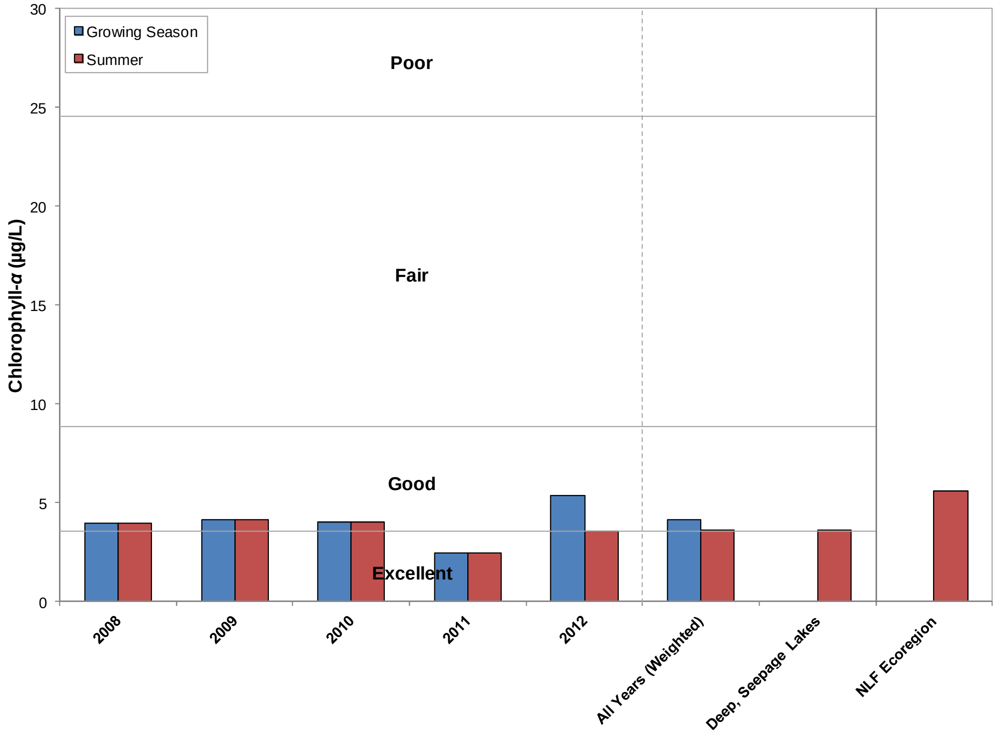


Figure 3.1-4. Big Twin Lake average annual chlorophyll-*α* concentrations and median chlorophyll-*α* concentrations for state-wide deep, seepage lakes, and Northern Lakes and Forests Ecoregion lakes. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disk transparency data have also been collected on Big Twin Lake on an annual basis from 2008-2012 (Figure 3.1-5). Like total phosphorus and chlorophyll-*a*, Secchi disk transparency has been relatively consistent over this five-year period, falling well into the *Excellent* category for Wisconsin's deep, seepage lakes in all five years. The weighted average for all five years is approximately 17 feet, exceeding the median values for both deep, seepage lakes in Wisconsin and lakes within the Northern Lakes and Forests Ecoregion (Figure 3.1-5). The low abundance of free-floating algae within Big Twin Lake allows light to penetrate further into the water column, yielding exceptional water clarity. Like total phosphorus and chlorophyll-*a*, there are insufficient Secchi disk transparency data to determine if any trends (positive or negative) are occurring over time.

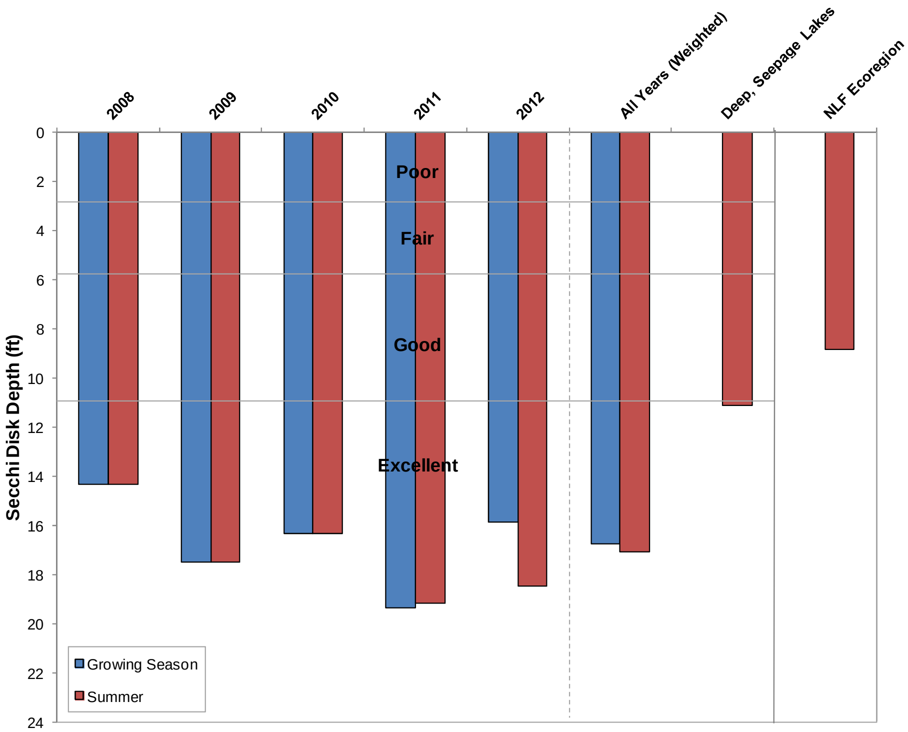


Figure 3.1-5. Big Twin Lake average annual Secchi disk transparency and median Secchi disk transparency for state-wide deep, seepage lakes, and Northern Lakes and Forests Ecoregion lakes. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Big Twin Lake

Using midsummer nitrogen and phosphorus concentrations from Big Twin Lake, a nitrogen:phosphorus ratio of 41:1 was calculated. This finding indicates that Big Twin Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that phosphorus is the nutrient controlling aquatic macrophyte and algae growth within the lake.

Big Twin Lake Trophic State

Figure 3.1-6 contains the Trophic State Index (TSI) values for Big Twin Lake. In general, the best values to use in judging a lake's trophic state are total phosphorus and chlorophyll-*a*, as other factors other than algal abundance can affect a lake's water clarity. The weighted average TSI values for total phosphorus and chlorophyll-*a* indicate that Big Twin Lake is currently in a mesotrophic state. However, much of Big Twin Lake's productivity exists within its aquatic macrophyte community, which is not taken into account in the TSI analysis. Given Big Twin Lake's abundant aquatic macrophyte growth, it's more likely that Big Twin Lake is an upper mesotrophic state. The lake's aquatic plant community is likely maintaining the clearwater state of this lake. Big Twin Lake's total phosphorus and chlorophyll-*a* TSI values are comparable to the median values for other deep, seepage lakes in Wisconsin and are slightly lower than the median value for lakes in the Northern Lakes and Forests Ecoregion (Figure 3.1-6).

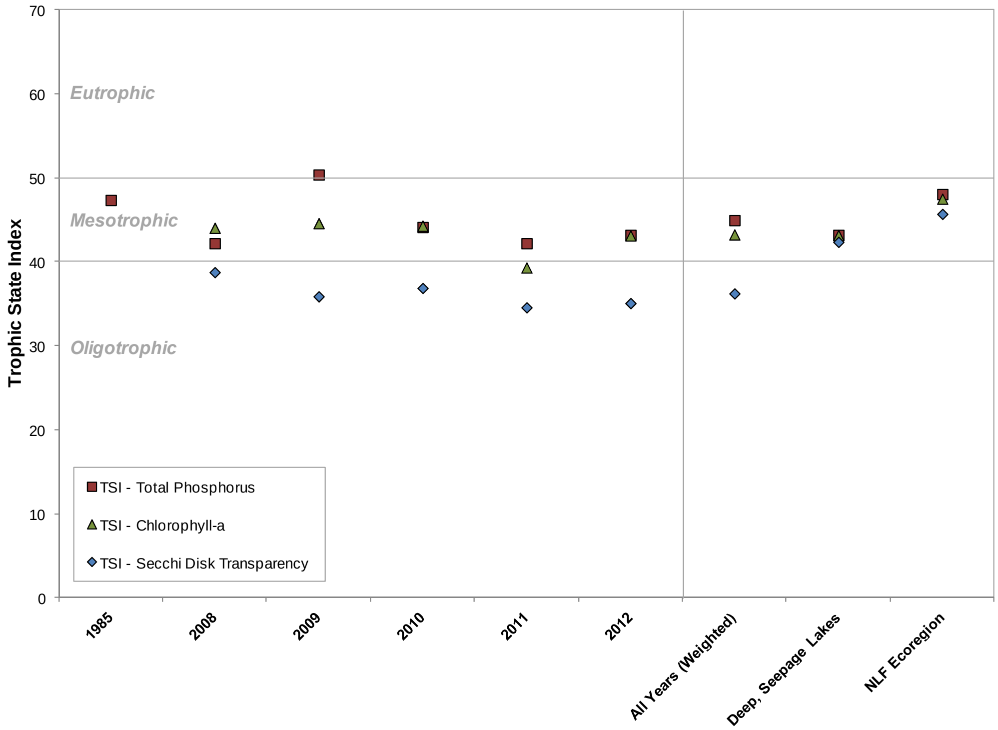


Figure 3.1-6. Big Twin Lake average Trophic State Index values and median Trophic State Index values for deep, seepage lakes in Wisconsin and lakes within the Northern Forests and Lakes Ecoregion.

Dissolved Oxygen and Temperature in Big Twin Lake

Dissolved oxygen and/or temperature were measured during water quality sampling visits to Big Twin Lake by Onterra staff and the CLMN volunteer. Profiles depicting these data are displayed in Figure 3.1-6. These data indicate that Big Twin Lake was already stratified in late March, and remained stratified through the summer months. The lake was not stratified in early November, indicating fall turnover, and was stratified during the winter sampling in February through the ice.

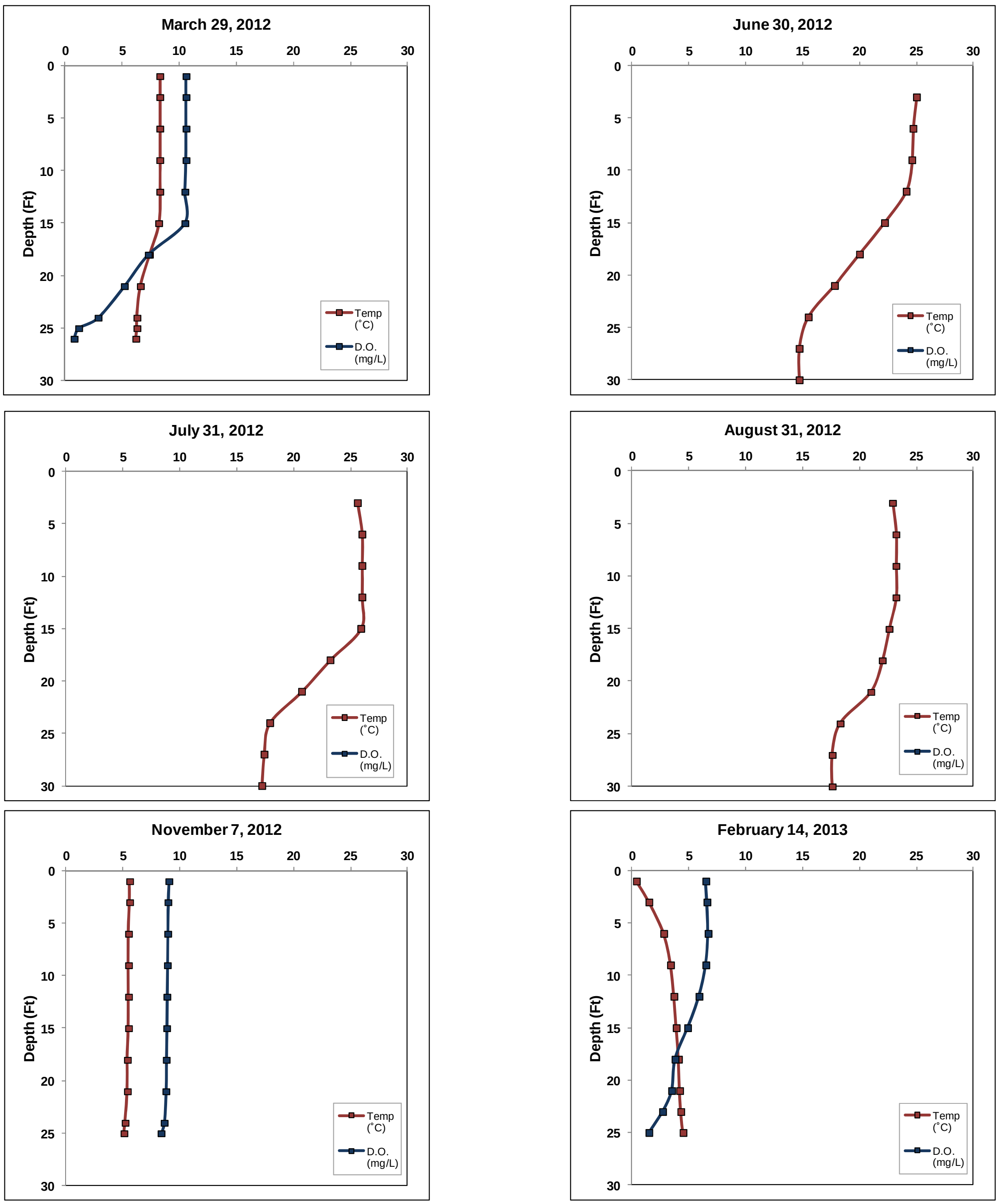


Figure 3.1-7. Dissolved oxygen and temperature profiles from Big Twin Lake.

Additional Water Quality Data Collected at Big Twin 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 Big Twin 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 lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius, 1985). The pH of the water in Big Twin Lake was found to be alkaline with surface values of approximately 7.8.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMg(CO_3)_2$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with little to no alkalinity have lower pH due to their inability to buffer against acid inputs. In 2012, the alkalinity in Big Twin Lake was approximately 70.6 (mg/L as $CaCO_3$) indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Big Twin Lake's pH of 7.8 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Big Twin Lake was found to be 15.5 mg/L in 2012, falling in the *low susceptibility* category for zebra mussel establishment.

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

Based upon this analysis, Big Twin Lake was considered borderline suitable for mussel establishment.

3.2 Watershed Assessment

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

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

In systems with high WS:LA ratios, like those 10-15:1 or higher, the impact of land cover may be tempered by the sheer amount of land draining to the lake. Situations actually occur where lakes with completely forested watersheds have sufficient phosphorus loads to support high rates of plant production. In other systems with high ratios, the conversion of vast areas of row crops to vegetated areas (grasslands, meadows, forests, etc.) may not reduce phosphorus loads sufficiently to see a change in plant production. Both of these situations occur frequently in impoundments.

Regardless of the size of the watershed or the makeup of its land cover, it must be remembered that every lake is different and other factors, such as flushing rate, lake volume, sediment type, and many others, also influence how the lake will react to what is flowing into it. For instance, a deeper lake with a greater volume can dilute more phosphorus within its waters than a less voluminous lake and as a result, the production of a lake is kept low. However, in that same lake, because of its low flushing rate (a residence time of years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time and lead to a problem such as internal nutrient loading. On the contrary, a lake with a higher flushing rate (low residence time, i.e., days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

A reliable and cost-efficient method of creating a general picture of a watershed's affect on a lake can be obtained through modeling. However, as will be discussed further, some lakes, like Big Twin Lake, that do not possess a tributary inlet can be difficult to model. 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.

Big Twin Lake Watershed Assessment

Big Twin Lake's watershed encompasses approximately 2,020 acres (Map 2), of which the majority (51%) is comprised of forests (Figure 3.2-1). Twenty percent (413 acres) is comprised of row crop agriculture, 10% (204 acres) is comprised of wetlands, 7% (134 acres) is comprised of pasture/grass, 6% (114 acres) is comprised of rural residential areas, 3% (66 acres) is comprised of a golf course, and the remaining 3% is comprised of Big Twin Lake's surface itself.

WiLMS was utilized to estimate the annual phosphorus load to Big Twin Lake. As mentioned earlier, WiLMS is designed to model drainage systems that have an inlet and outlet most accurately. Although Big Twin Lake possesses a relatively large watershed when compared to the size of the lake, the lack of tributary inlet to the lack indicates that most of the water that falls within the watershed does not make it to the lake via overland flow. WiLMS assumes that all of the land cover within a lake's watershed contributes nutrients directly to the lake via surface flow, and this is clearly not occurring in Big Twin Lake.

When Big Twin Lake's watershed was modeled in WiLMS, the model predicted that approximately 806 pounds of phosphorus were being delivered to the lake annually. This level of phosphorus entering the lake would equate to an in-lake total phosphorus concentration of approximately 76 µg/L, which is over four times greater than the measured growing season mean total phosphorus concentration of 17.4 µg/L. This discrepancy between the model's prediction and what was actually measured indicate that WiLMS is not suitable for modeling Big Twin Lake's watershed. While the watershed contains a golf course and areas of agriculture which typically impact a lake's water quality, there is no direct flow of water from these areas to Big Twin Lake.

Being a seepage lake, groundwater and the land use around the immediate shoreline areas are going to have the largest influence over the Big Twin Lake's water quality. There are no groundwater models that could be applied to Big Twin Lake, and a groundwater study would have to be conducted to determine the amount of nutrients being delivered to the lake via groundwater. However, because Big Twin Lake has high water quality, nutrient input from groundwater is not a concern at this time.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) 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 the 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 not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

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

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

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

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

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

Big Twin Lake Shoreland Zone Condition

Shoreland Development

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

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

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

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

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

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

Figure 3.3-1. Shoreland assessment category descriptions.

On Big Twin Lake, the development stage of the entire shoreland was surveyed during the fall of 2012, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

Big Twin Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.0 mile of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-2). 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, 0.5 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Big Twin Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

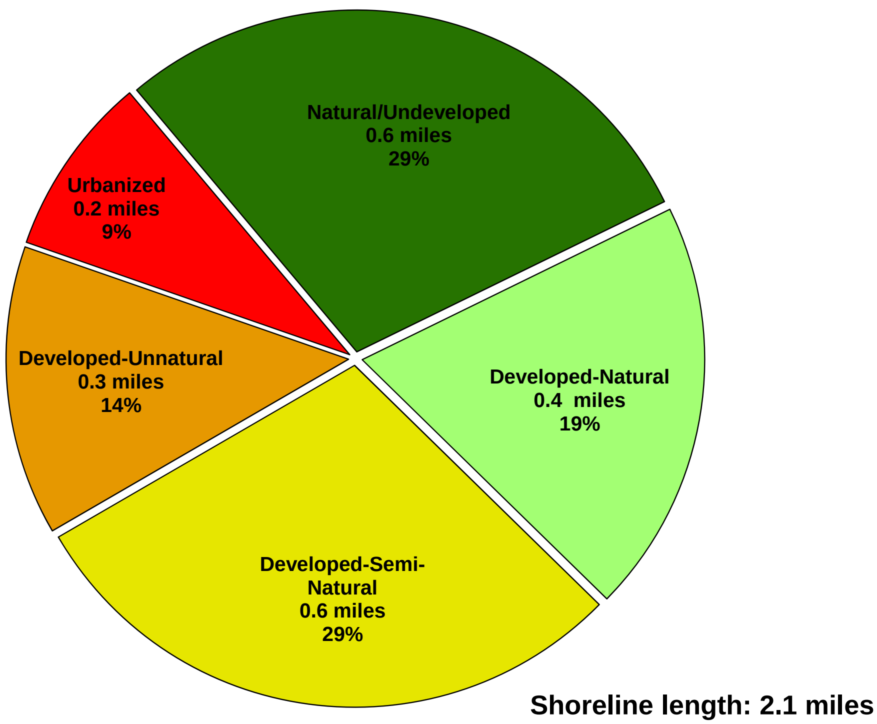


Figure 3.3-2. Big Twin Lake shoreland categories and total lengths. Based upon a fall 2012 survey. Locations of these categorized shorelands can be found on Map 3.

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

Coarse Woody Habitat

Big Twin Lake was surveyed in the fall of 2012 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 25 total pieces of coarse woody habitat were observed along 2.1 miles of shoreline, which gives Big Twin Lake a coarse woody habitat to shoreline mile ratio of 12:1. Locations of coarse woody habitat are displayed on map 4. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

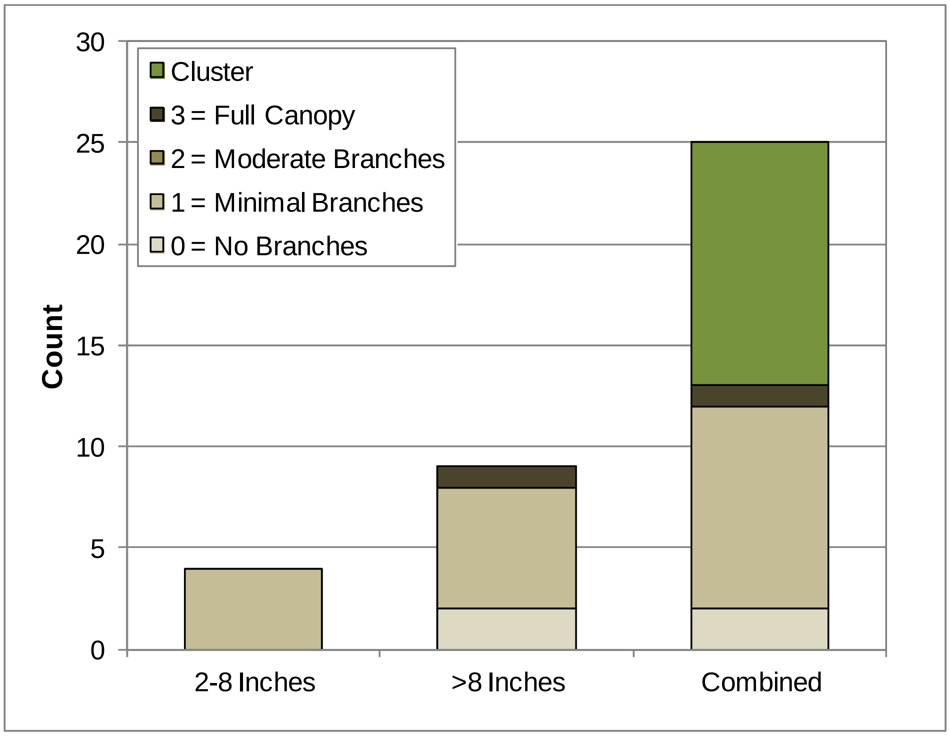


Figure 3.3-3. Big Twin Lake coarse woody habitat survey results. Based upon a fall 2012 survey. Locations of Big Twin Lake coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

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

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

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

Aquatic Plant Management and Protection

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 LakeName, 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 LakeName 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. Please note that depending on the size of the screen a Wisconsin Department of Natural Resources permit may be required.

Cost

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

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

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

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

Cost

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages	*Disadvantages*
• Immediate results. • Plant biomass and associated nutrients are removed from the lake. • Select areas can be treated, leaving sensitive areas intact. • Plants are not completely removed and can still provide some habitat benefits. • Opening of cruise lanes can increase predator pressure and reduce stunted fish populations. • Removal of plant biomass can improve the oxygen balance in the littoral zone. • Harvested plant materials produce excellent compost.	• Initial costs and maintenance are high if the lake organization intends to own and operate the equipment. • Multiple treatments are likely required. • Many small fish, amphibians and invertebrates may be harvested along with plants. • There is little or no reduction in plant density with harvesting. • Invasive and exotic species may spread because of plant fragmentation associated with harvester operation. • 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)
Contact		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; Eurasian water milfoil control when mixed with auxin herbicides
Contact		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance natives species including duckweeds, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
Systemic	Auxin Mimics	Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
Systemic	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
Systemic	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
Systemic	Enzyme Specific (ALS)	Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
Systemic	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
Systemic	Enzyme Specific (foliar use only)	Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to both the applicator and the environment, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to reduce herbicide concentration within aquatic systems. Understanding concentration and exposure times are important considerations for aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Much information has been gathered in recent years, largely as a result of an ongoing cooperative research project between the Wisconsin Department of Natural Resources, US Army Corps of Engineers Research and Development Center, and private consultants (including Onterra). This research couples quantitative aquatic plant monitoring with field-collected herbicide concentration data to evaluate efficacy and selectivity of control strategies implemented on a subset of Wisconsin lakes and flowages. Based on their preliminary findings, lake managers have adopted two main treatment strategies; 1) whole-lake treatments, and 2). spot treatments.

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively.

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

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

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

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

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

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

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

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, such as variable water levels or negative, such as increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways. For example, there may be a loss of one or more species. Certain life forms, such as emergents or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Big Twin 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 Big Twin Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency of occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

Species Diversity and Richness

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Big Twin 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 shoreland. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreland may hold. This value is referred to as the shoreland complexity. It specifically analyzes the characteristics of the shoreland and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreland complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreland complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Big Twin Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.1-2).

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

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

Community Mapping

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

Exotic Plants

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

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

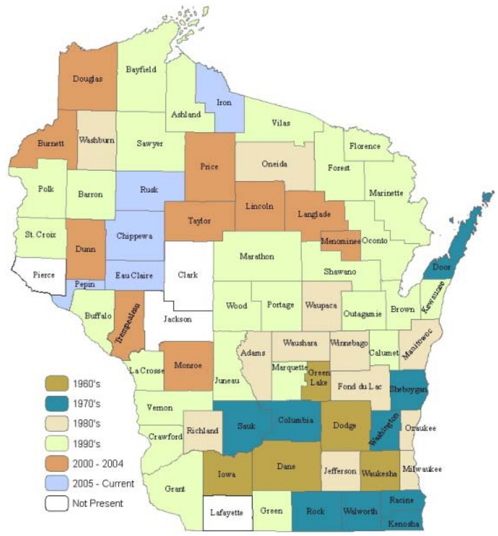


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

Aquatic Plant Survey Results

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

As mentioned earlier, numerous aquatic plant surveys were completed as a part of this project. On May 31, 2012, an early-season aquatic invasive species (AIS) survey was completed on Big Twin Lake. While the intent of this survey is to locate any potential non-native species within the lake, it's primarily focused on locating any occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the *littoral zone*, Onterra ecologists did not locate any occurrences of curly-leaf pondweed, and it is believed that this invasive plant does not exist in Big Twin Lake at the present time or exists at an undetectable level. Eurasian water milfoil was observed during this survey, and notes regarding its locations were made to aid in the Eurasian water milfoil peak-biomass survey conducted in the late summer of 2012.

The whole-lake aquatic plant point-intercept survey was conducted by the WDNR in 2011, and the aquatic plant community mapping survey was conducted by Onterra on August 29, 2012. During these surveys, 35 species of aquatic plants were located in Big Twin Lake, two of which are considered to be non-native, invasive species: Eurasian water milfoil and purple loosestrife (Table 3.4-1). Because of their significance, both Eurasian water milfoil and purple loosestrife will be discussed in the Non-native Aquatic Plants Section.

During the WDNR's point-intercept survey, sediment data were collected at each sampling location. The data gathered shows that the majority of these areas (94%) are comprised of soft sediments, 5% contained sand, and 1% contained rock (Figure 3.4-2). Map 5 illustrates that most of the point-intercept sampling locations containing sand or rock were located in shallow, near-shore areas of the lake. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

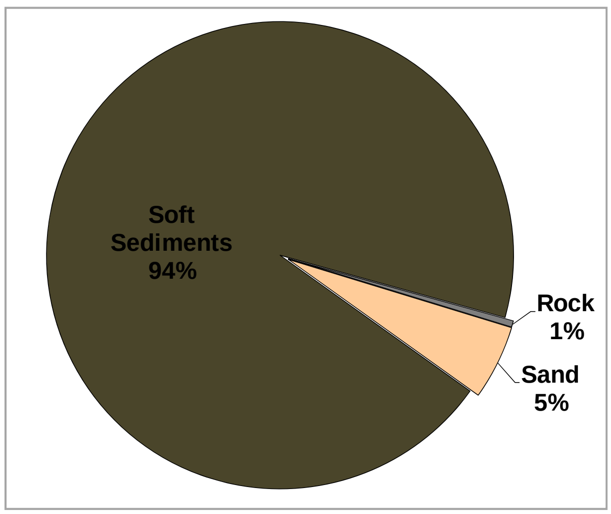


Figure 3.4-2. Big Twin Lake proportion of substrate types. Created using data from WDNR 2011 point-intercept survey.

During the 2011 point-intercept survey, aquatic plants were found growing to a maximum depth of 25 feet. As was discussed within the Water Quality Section, Big Twin Lake has excellent water clarity which allows sunlight to penetrate deeper into the water column and support aquatic plant growth at deeper depths. Of the 228 point-intercept sampling locations that fell at or below the maximum depth of plant growth, 83% contained aquatic vegetation, indicating Big Twin Lake is highly vegetated. Map 6 illustrates that the majority of Big Twin Lake contains and is able to support aquatic plant growth.

Table 3.4-1. Aquatic plant species located in Big Twin Lake during WDNR 2011 and Onterra 2012 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	WDNR (2011) & Onterra (2012)
Emergent	*Carex comosa*	Bristly sedge	5	I
	Carex sp. (sterile)	Sedge sp. (sterile)	N/A	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Juncus effusus	Soft rush	4	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Sagittaria latifolia	Common arrowhead	3	I
	Sagittaria rigida	Stiff arrowhead	8	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Scirpus cyperinus	Wool grass	4	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
	Polygonum amphibium	Water smartweed	5	I
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	I
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Bidens beckii	Water marigold	8	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Utricularia geminiscapa	Twin-stemmed bladderwort	9	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Juncus pelocarpus	Brown-fruited rush	8	X
	Sagittaria cuneata	Arum-leaved arrowhead	7	I

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent
X = Located on rake during WDNR point-intercept survey; I = Incidental species located during Onterra 2012 community mapping survey

While a total of 35 aquatic plant species were located during the 2011 and 2012 surveys on Big Twin Lake, 23 were physically recorded on the rake during the WDNR's point-intercept survey while the remaining 13 were incidentally located during the point-intercept survey or were recorded as a part of the community mapping survey. Of the 23 aquatic plant species located on the rake, coontail, fern pondweed, common waterweed, and small pondweed were the four-most frequently encountered (Figure 3.4-3). Coontail, the most abundant aquatic plant species in 2011 with a littoral occurrence of 55%, is a common native aquatic plant that can be found throughout North America and around the world. It produces long stems that contain whorls of stiff leaves, and as its name suggests, resemble the tail of a raccoon. The dense leaves and stems produced by coontail offer excellent structural habitat for a number of aquatic organisms. However, under certain conditions, it can often grow to nuisance levels where it can inhibit recreation. Coontail lacks true roots, and derives all of its nutrients directly from the water. Because of this, large mats of coontail are often observed floating and growing at or near the water's surface.

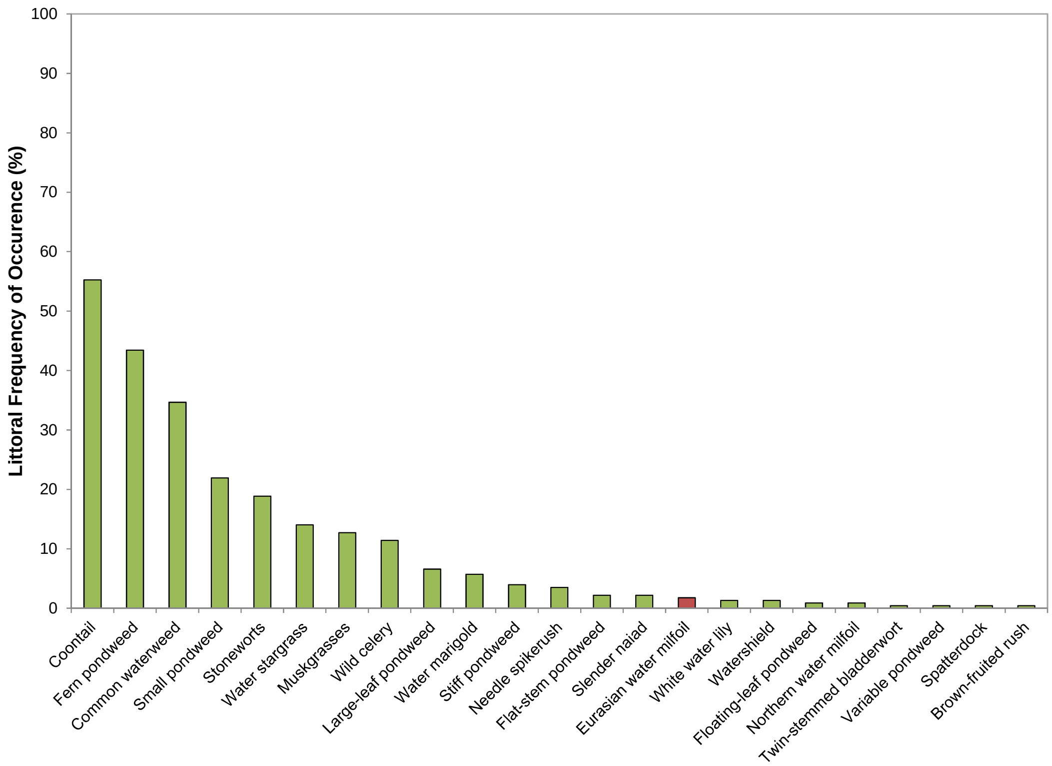


Figure 3.4-3. Big Twin Lake aquatic plant littoral frequency of occurrence. Created using data from WDNR 2011 point-intercept survey. Non-native species indicated with red.

Fern pondweed was the second-most abundant plant in Big Twin Lake in 2011 and had a littoral occurrence of approximately 43%. As its name suggests, has the appearance of a fern's leaf and is a common pondweed found in lakes in northern Wisconsin. This plant generally grows in dense beds which creep along the bottom of the lake, where they provide excellent structural habitat for aquatic invertebrates and fish.

Common waterweed, the third most abundant plant in Big Twin Lake in 2011 with a littoral occurrence of 35%, can be found in lakes throughout Wisconsin and North America. It is usually found growing in soft substrates, and possesses long stems with whorls of three, slender leaves. Like coontail, common waterweed can tolerate and thrive in lakes with lower water clarity, and can often grow to nuisance levels forming large mats on the water's surface. However, when not growing to nuisance levels, common waterweed provides excellent structural habitat for aquatic organisms and is an important food source for animals such as muskrats.

Small pondweed was the fourth-most abundant aquatic plant encountered in Big Twin Lake in 2011 with a littoral occurrence of approximately 22% (Figure 4.6-2). Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin, and one of two narrow-leaved pondweeds located in Big Twin Lake in 2011. Its long, narrow submersed leaves provide excellent structural habitat for aquatic organisms.

Because whole-lake point-intercept surveys were conducted on Big Twin Lake in 2006 and 2011, a statistical comparison of aquatic plant species' littoral occurrences can be made. A Chi-square distribution analysis ($\alpha = 0.05$) was used to determine of any statistically valid changes in aquatic plant species' littoral frequency of occurrences have occurred from 2006-2011. Figure 3.4-4 displays the littoral frequency of occurrences of Eurasian water milfoil and native aquatic plants from 2006 and 2011 that had an occurrence of at least 5% in one of the two surveys. As illustrated, Eurasian water milfoil and three native aquatic plant species exhibited statistically valid changes in their littoral frequency of occurrence from 2006 to 2011. Like Eurasian water milfoil, northern water milfoil and watershield are dicots and particularly susceptible to the herbicide 2,4-D, which was utilized in 2007 on Big Twin Lake to control Eurasian water milfoil. Unlike Eurasian water milfoil, small pondweed is a monocot and was not historically believed to be susceptible to dicot-selective herbicides like 2,4-D. However, emerging research is indicating that small pondweed and certain other monocot species may be prone to decline following 2,4-D treatments like the one conducted on Big Twin Lake in 2007.

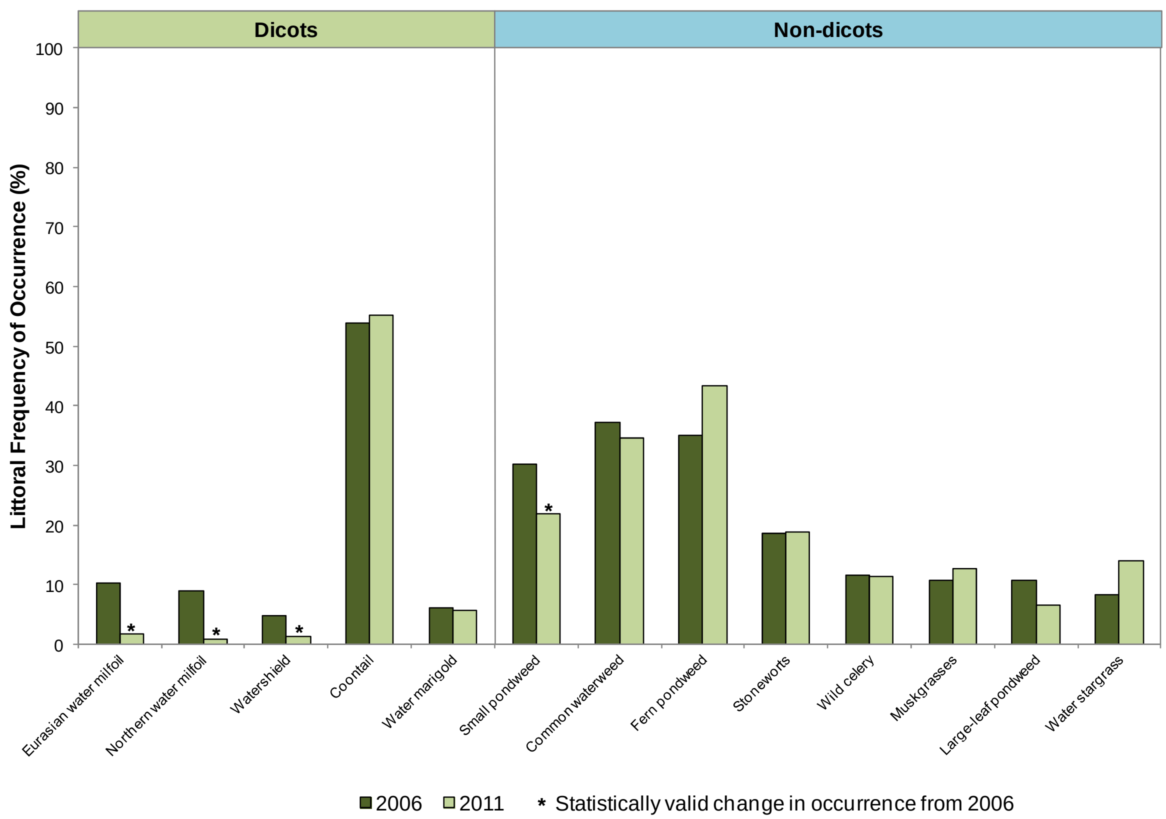


Figure 3.4-4. Frequency of occurrence of select aquatic plants from 2006 and 2011 in Big Twin Lake. Please note that only those aquatic plant species with a littoral occurrence of at least 5% in either survey are displayed. Created using data from WDNR 2006 and 2011 point-intercept surveys.

As discussed in the primer section, 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 a total of 33 native aquatic plant species were located in Big Twin Lake during the 2011 and 2012 surveys, 22 were encountered on the rake during the WDNR's 2011 point-intercept survey. These 22 native species and their conservatism values were used to calculate the FQI of Big Twin Lake's aquatic plant community in 2011 (equation shown below). The data collected during the WDNR's 2006 point-intercept survey were also used to calculate the FQI for 2006.

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

Figure 3.4-5 compares the FQI components of Big Twin Lake from the 2006 and 2011 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. As illustrated, Big Twin Lake's native aquatic plant species richness in both 2006 and 2011 exceeds the upper quartile for both lakes in the NLFL Ecoregion and the State of Wisconsin. Big Twin Lake's average conservatism values are comparable to the median value for lakes in the NLFL Ecoregion and higher than the median value for lakes in Wisconsin. This indicates that the quality of the aquatic plant species present in Big Twin Lake is comparable to other lakes in the region, but is of higher quality when compared to lakes throughout Wisconsin. Combining Big Twin Lake's native species richness and average conservatism values to calculate the FQI creates a high values of 32.9 and 30.3 for 2006 and 2011, respectively; which is comparable to the upper quartile of lakes in the NLFL Ecoregion and well above the upper quartile value for lakes in Wisconsin. Overall, this analysis indicates that Big Twin Lake's native aquatic plant community is of high quality and is of better quality than the majority of lakes in Wisconsin, and that the quality of Big Twin Lake's aquatic plant community had not changed significantly from 2006 to 2011.

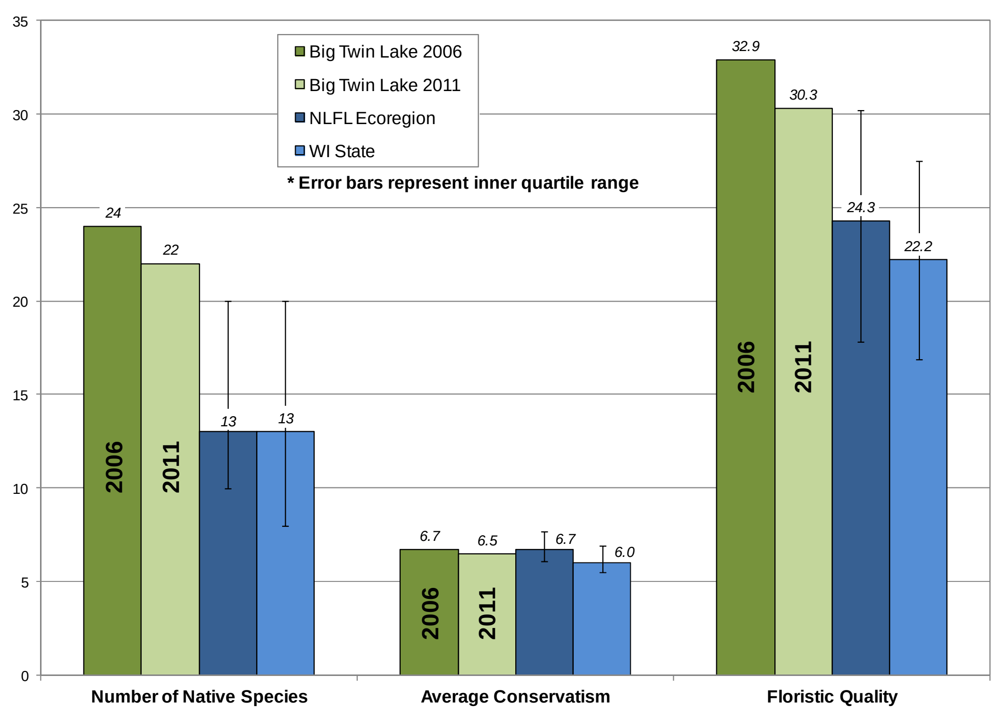


Figure 3.4-5. Big Twin Floristic Quality Assessment. Created using data from WDNR 2006 and 2011 point-intercept surveys. Analysis following Nichols (1999).

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Big Twin Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 3.4-6). Using the data collected from the WDNR's 2006 and 2011 point-intercept survey, Big Twin Lake was found to have high species diversity with a Simpson's Diversity Index value of 0.89 and 0.87, respectively, which exceeds the median for both lakes in the Northern Lakes and Forests Ecoregion and lakes throughout Wisconsin (Figure 3.4-6).

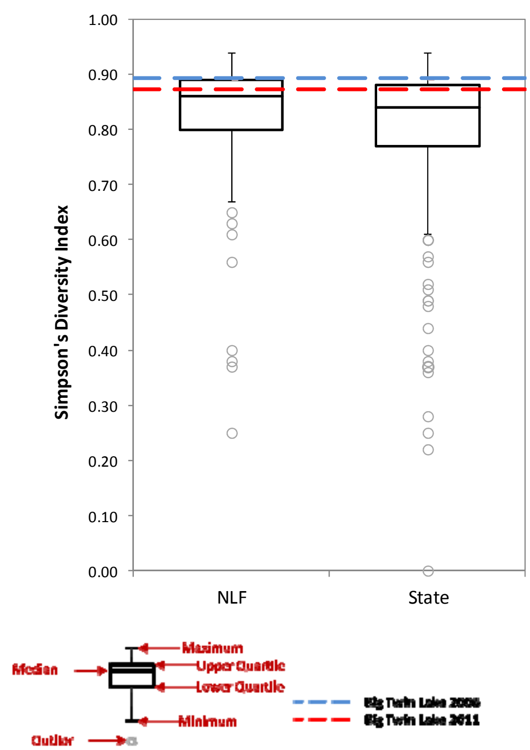


Figure 3.4-6. Big Twin Lake Simpson's Diversity Index. Created using data from WDNR 2011 point-intercept survey. Ecoregion data provided by WDNR Science Services.

Figure 3.4-7 displays the relative frequency of occurrence of aquatic plant species in Big Twin Lake from the 2011 point-intercept survey and illustrates relative abundance of species within the community to one another. For example, coontail has a relative occurrence of approximately 23%. This means that if 100 aquatic plants were randomly sampled from Big Twin Lake, it would be expected that 23 of them would be coontail. As illustrated, the aquatic plant community is not overly dominated by a single or few species, yielding high diversity.

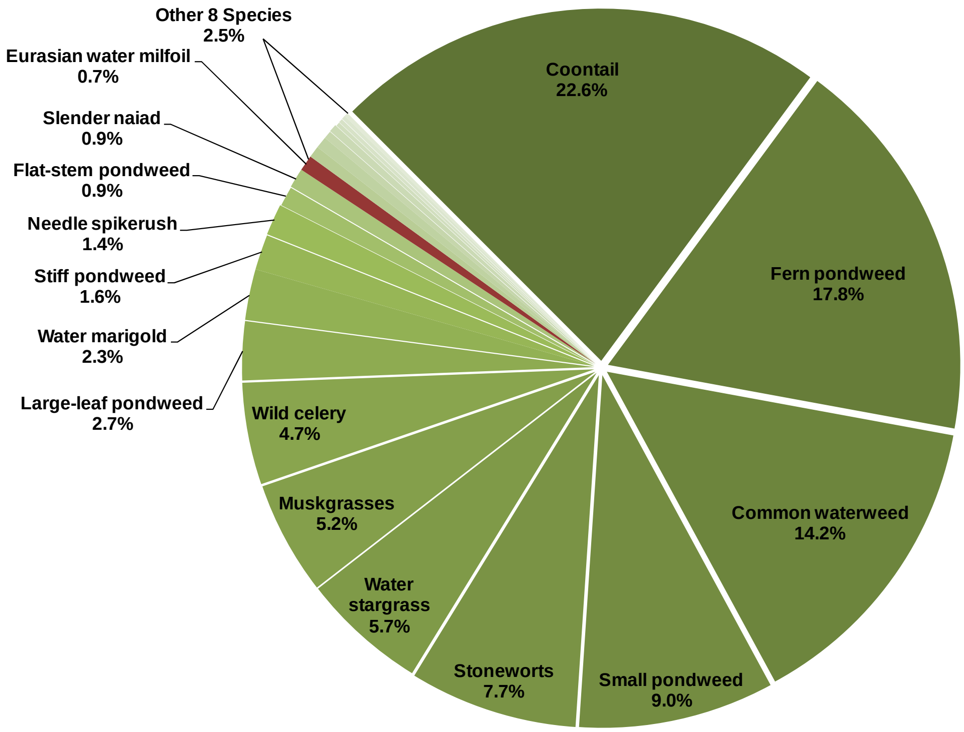


Figure 3.4-7. 2011 relative frequency of occurrence of aquatic plant species in Big Twin Lake. Created using data from WDNR 2011 point-intercept survey. Non-native species indicated with red.

The 2012 aquatic plant community mapping survey revealed that approximately 20 acres (33%) of Big Twin Lake's approximately 60 acres contains emergent and/or floating-leaf aquatic plant communities (Table 3.4-2, Map 7). Fourteen native emergent and floating-leaf aquatic plant species were recorded in Big Twin Lake during the 2011 and 2012 surveys (Table 3.4-1). These communities provide valuable structural habitat for invertebrates, fish, and other wildlife, and also stabilize bottom sediments and shoreline areas by dampening wave action from wind and watercraft. These communities become even more important during periods of low water levels, as course woody habitat is left above the receding water line.

Table 3.4-2. Big Twin Lake acres of plant community types. Created from Onterra 2012 community mapping survey.

Aquatic Plant Community	Acres
Emergent	10.6
Floating-leaf	4.1
Mixed Emergent & Floating-leaf	4.9
Total	**19.6**

Because the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Big Twin Lake. This is important because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes.

Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

Non-native Aquatic Plants Big Twin Lake

Eurasian water milfoil

Eurasian water milfoil (*Myriophyllum spicatum*) was first discovered in Big Twin Lake in the fall of 2005. In 2006, the WDNR conducted a whole-lake point-intercept survey which revealed that Eurasian water milfoil was spread throughout much of the lake with a littoral frequency of approximately 10% (Map 8). In 2007, the BTLA funded a Eurasian water milfoil herbicide treatment and associated monitoring. The herbicide application areas were determined using the data collected by the 2006 WDNR point-intercept survey (Map 8). Approximately 12.7 acres of Eurasian water milfoil were applied with granular 2,4-D Navigate ® at 100 lbs/acre in the spring of 2007.

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 dilute herbicide concentration within aquatic systems. Understanding concentration-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 a joint research project between the WDNR and US Army Corps of Engineers (USACE). 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 effects 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.

Whole-lake or whole-basin treatments are those where the herbicide is applied to specific sites, but when the herbicide reaches equilibrium within the entire volume of water (of the 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 whole-lake treatments is dictated by the volume of water in which the herbicide will reach equilibrium with. Because exposure time is so much greater, target herbicide levels for whole-lake treatments are significantly less than for spot treatments.

At the time of the herbicide treatment in 2007 treatment on Big Twin Lake, the concept of whole-lake treatments had not been realized. The intent of the 2007 treatment on Big Twin Lake was to target specific areas of Eurasian water milfoil (spot treatments). However, with the recent studies being conducted on herbicide treatments in Wisconsin's lakes and that herbicide quickly dissipates from areas where it is applied, it is believed that the 2007 treatment on Big Twin Lake did have lake-wide effects; the herbicide likely dissipated throughout the entire lake or upper layer of water (epilimnion). Using the volume of Big Twin Lake's epilimnion (to 12 feet) and the amount of herbicide applied in 2007, it was estimated that the epilimnion-wide herbicide concentration was approximately 0.150 ppm acid equivalent (ae).

However, current research indicates that the estimated concentration of 0.150 ppm ae would have resulted in little Eurasian water milfoil control (Nault et al 2012). In addition, research suggests that this lake-wide concentration calculated for the 2007 treatment was likely overestimated due to factors such as herbicide degradation and the availability of 2,4-D granules that sunk into the sediment. Typically whole-lake 2,4-D treatments are effective on Eurasian water milfoil when the target whole-lake herbicide concentration is between 0.250 ppm ae and 0.350 ppm ae and is maintained for approximately 7-14 days.

The reduction in Eurasian water milfoil observed following the 2007 treatment was better than expected given the lake-wide concentration. The control strategy was likely effective because the Eurasian water milfoil treatment areas experienced 2-4 hours of high 2,4-D concentration, coupled with 7-14 days of a very low 2,4-D concentration. Based on the calculated whole-lake concentrations, the native plant community impacts were likely confined to the areas where the herbicide was directly applied.

Since the 2007 treatment, the Eurasian water milfoil population has not rebounded to the levels observed in 2006. A Eurasian water milfoil peak-biomass survey was completed by Onterra on August 9, 2012, and the results of this survey can be found on Map 9. While Eurasian water milfoil was found throughout shallower areas around the lake, the majority was comprised of single plants or clumps of plants. A few larger, colonized areas of Eurasian water milfoil were located along the northern shoreline of the lake. After discussing the results of this survey with the BTLA, it was decided that there was not a sufficient amount of Eurasian water milfoil to warrant a treatment in the spring of 2013, and that another survey would be conducted in the summer of 2013 to reassess the Eurasian water milfoil population.

Onterra volunteered their services to conduct an additional Eurasian water milfoil peak-biomass survey on August 1, 2013, the results of which can be found on Map 10. Like in 2012, most of the Eurasian water milfoil around the lake was comprised of single plants and clumps of plants, though the number of single plants observed increased from 2012 to 2013. In addition, the density of one of the colonized areas denoted as *scattered* in 2012 increased slightly to *highly dominant* in some areas. As indicated by the WDNR's 2011 point-intercept survey, though widespread, Eurasian water milfoil is still present at a low frequency in Big Twin Lake.

Purple loosestrife

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

Purple loosestrife populations were located primarily along the northern shore of Big Twin Lake (Map 7) in 2012. The abundance of this plant is of concern, and it may spread further throughout the system if management of its population is not conducted. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal.

3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing Big Twin Lake. The goal of this section is to provide an overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the BTLA stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2013 & GLIFWC 2013A and 2013B).

Big Twin Lake Fishery

Big Twin Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the highest ranked important or enjoyable activity on Big Twin Lake (Question #13). Approximately 96% of these respondents have fished the lake within the past three years (Question #8) and while the vast majority believe the quality of fishing is Fair (Question #10), 48% believe the quality has gotten much or somewhat worse since they began fishing the lake while 32% believe the quality has remained the same (Question #11). Survey respondents indicated that bluegill/sunfish, crappie and largemouth bass are their favorite species to catch (Question #9).

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

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.5-1.

Table 3.5-1. Gamefish present in the Big Twin 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 pikes, crayfish, small mammals, water fowl, frogs
Walleye	*Sander vitreus*	18	Mid April - Early May	Rocky, wave-washed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

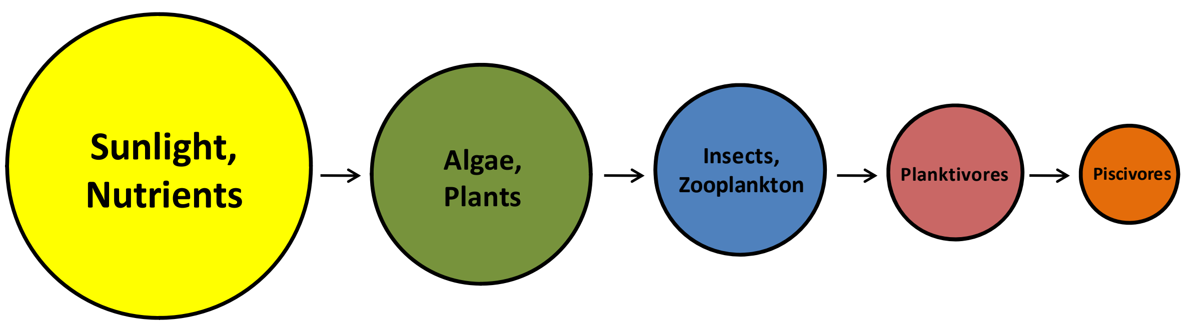


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

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

Big Twin Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.5-1). Big Twin Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake's known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the "safe harvest level". Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

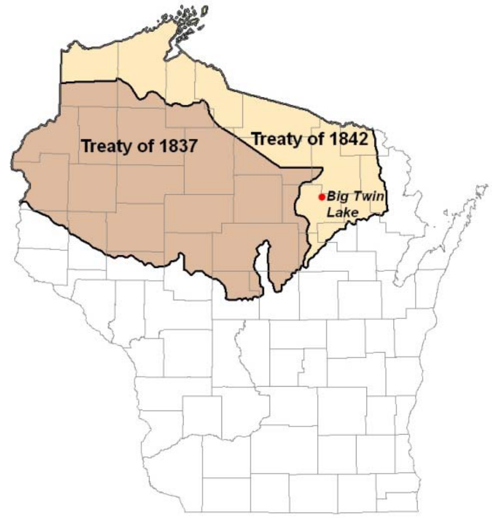


Figure 3.5-2. Location of Big Twin Lake within the Native American Ceded Territory (GLIFWC 2013A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2010B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Although Big Twin Lake has been declared as a spear harvest lake, it has not historically seen a harvest. It is possible that spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for both walleye and muskellunge.

Big Twin Lake Substrate and Near Shore Habitat

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

According to the point-intercept survey conducted by Onterra, 94% of the substrate sampled in the littoral zone on Big Twin Lake was muck, with 5% being classified as sand and the remaining 1% being classified as rock (Map 5). Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone.

Big Twin Lake Regulations and Management

Because Big Twin Lake is located within the northern region of Wisconsin, special regulations may occur that differ from those in other areas of the state. For example, the lake is within ceded territory so walleye bag limits may be adjusted annually. Because Big Twin Lake does not typically see a spear harvest, these limits have not been adjusted in years past.

Big Twin Lake is in the northern large and smallmouth bass management zone. Table 3.5-2 displays the 2013-2014 regulations for species that may be found in Big Twin Lake. Please note that this table is intended to be for reference purposes only, and that anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Table 3.5-2. WDNR fishing regulations for Big Twin Lake, 2013-2014.

Species	Season	Regulation
Panfish	Open All Year	No minimum length limit and the daily bag limit is 25.
Largemouth and smallmouth bass	May 4, 2013 to June 14, 2013	Fish may not be harvested (catch and release only)
Largemouth and smallmouth bass	June 15, 2013 to March 4, 2014	The minimum length limit is 14" and the daily bag limit is 5.
Muskellunge and hybrids	May 25, 2013 to November 30, 2013	The minimum length limit is 40" and the daily bag limit is 1.
Northern pike	May 4, 2013 to March 2, 2014	No minimum length limit and the daily bag limit is 5.
Walleye, sauger, and hybrids	May 4, 2013 to March 2, 2014	The minimum length limit is 15" and the daily bag limit is 5.
Rock, yellow, and white bass	Open All Year	No minimum length limit and the daily bag limit is unlimited.

Dave Seibel is the WDNR fisheries biologist who oversees Big Twin Lake. WDNR biologists have had difficulty surveying Big Twin Lake in years past due to low water conditions at the public access. To date, there is no known comprehensive survey of the Big Twin Lake fishery. Mr. Seibel would like to conduct a survey on the fish community at some point, potentially when normal water conditions return.

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 Big Twin Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian water milfoil.
3) Collect sociological information from Big Twin 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 Big Twin Lake ecosystem, the people who care about the lake, and what needs to be completed to protect and enhance it.

Through the studies conducted on Big Twin Lake, it is clear that the ecosystem is in a very healthy condition. As discussed within the Water Quality Section, Big Twin Lake's water quality parameters range from *Good* to *Excellent*. The lake holds low levels of nutrients which limits algal production and creates the high clarity conditions that are present. The Secchi disk transparency data collected by BTLA CLMN volunteers indicates that Secchi disk transparency averages approximately 17 feet annually. Some variations exist in the dataset, however these are most likely attributable to fluctuations in annual environmental conditions. Understanding these fluctuations and any potential trends in the water quality of Big Twin Lake can only be achieved through continued monitoring of the lake's water. Thus, the Implementation Plan that follows outlines a strategy to continue water quality monitoring in Big Twin Lake.

A lake's water quality is largely a reflection of its drainage basin, or watershed. Big Twin Lake's surficial watershed encompasses approximately 2,020 acres and results in a watershed to lake area ratio of 30:1. However, as discussed within the Watershed Section, the modeling greatly overestimated the amount of phosphorus delivered to the lake on an annual basis, and most of the precipitation that falls within Big Twin Lake's watershed likely infiltrates into the ground and does not reach the lake via overland flow. And while Big Twin Lake's watershed contains developed areas such as agricultural fields and a nearby golf course, the modeling did not indicate that these areas were having a detectable impact on the lake's water quality. A large portion of Big Twin Lake's immediate shoreland zone is in a minimally developed state. In regards to protecting Big Twin Lake, conserving the existing natural shoreline and restoring areas of disturbed shoreline may be one of the best options at this time.

The aquatic plant community within the lake and along the shorelines of Big Twin Lake was found to be of high quality. The overall plant community contains a high number of native aquatic plant species, many of which are indicative of a high-quality, undisturbed system. The benefits of Big Twin Lake stakeholders may see from protecting this plant community include the presence of diverse fish habitat, maintaining the lake's excellent water quality, and providing competition against non-native, invasive plants like Eurasian water milfoil.

The robust native aquatic plant community in Big Twin Lake is likely aiding in reducing the rate of spread and colonization of Eurasian water milfoil within the lake. The 2011-2013 surveys indicated that Eurasian water milfoil is still in low abundance in Big Twin Lake, mainly comprised of single plants and clumps of plants. Eradication of Eurasian water milfoil is certainly a difficult, if not impossible task with what is currently known about aquatic invasive species management. The Implementation Plan that follows discusses the strategy for managing the Eurasian water milfoil in Big Twin Lake.

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

5.0 IMPLEMENTATION PLAN

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

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

Timeframe: Continuation of current effort.

Facilitator: Planning Committee

Description: Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring.

The Citizen Lake Monitoring Network (CLMN) is a WDNR/UW-Extension program in which volunteers are trained to collect data on Wisconsin's lakes and rivers. One aspect of the CLMN is the collection of water quality data. Water quality data has been actively collected on Big Twin Lake by volunteers enrolled within the CLMN's advanced program since 2008. This program involves volunteers taking Secchi disk readings and water chemistry samples three times during the summer and once during the spring at the lake's deep hole.

It is the responsibility of the current CLMN volunteer in conjunction with the Big Twin Lake Planning Committee to coordinate new volunteers as needed. According to the stakeholder survey, 26% of respondents indicated they would be willing to participate in water quality monitoring (Appendix B, Question #28). When a change in the collection volunteer occurs, Sandy Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff should be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting.
2. CLMN volunteer and/or Big Twin Lake Planning Committee would facilitate new volunteer(s) as needed.
3. Coordinator contacts Sandy Wickman (715.365.8951) to acquire necessary materials and training for new volunteer(s).

Management Action: Investigate restoring highly developed shoreland areas around Big Twin Lake.

Timeframe: Initiate 2014.

Facilitator: Planning Committee

Description: As discussed in the Shoreland Condition Section, the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. In 2012, the shoreland assessment survey indicated that 0.5 miles, or 23% of Big Twin Lake's 2.1-mile shoreline, consists of Urbanized or Developed-Unnatural areas.

Fortunately, restoration of the shoreland zone can be less expensive, less time-consuming and much easier to accomplish than restoration efforts in other parts of the watershed. Cost-sharing grants and Langlade County staff devoted to these types of projects give private property owners the funds and informational resources to restore quality shoreland habitat to their lakeside residence.

Map 3 indicates the locations of Urbanized and Developed-Unnatural shorelands on Big Twin Lake. These shorelands should be prioritized for restoration. A Big Twin Lake Planning Committee appointee will inquire information from and work with appropriate entities such as Molly McKay (715.627.6206) from the Langlade County Land Conservation Department to research grant programs, shoreland restoration techniques and other pertinent information that will help the BTLA if they decide to move forward with shoreland restoration projects. Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, properties with restoration on their shorelands could serve as demonstration sites. Other lakeside property owners could have the opportunity to view a shoreland that has been restored to a more natural state, and learn about the maintenance, labor, and cost-sharing opportunities associated with these projects.

Action Steps:

1. Recruit facilitator from Planning Committee

2. Facilitator contacts Molly McKay (715.627.6206) from the Langlade County Land Conservation department to gather information on initiating and conducting shoreland restoration projects. If she is able, Molly will come and speak to BTLA members about shoreland restoration at their annual meeting.

Management Action: Protect natural shoreland zones around Big Twin Lake.

Timeframe: Initiate 2014.

Facilitator: Planning Committee

Description: Approximately 1 mile (48%) of Big Twin Lake's shoreline was found to be in either a natural or developed-natural state. It is therefore very important that owners of these properties become educated on the benefits their shoreland is providing to Big Twin Lake, and that these shorelands remain in a natural state.

Map 3 indicates the locations of Natural and Developed-Natural shorelands on Big Twin Lake. These shorelands should be prioritized for education initiatives and physical preservation. A Planning Committee appointed person will work with appropriate entities to research grant programs and other pertinent information that will aid the BTLA in preserving the Big Twin Lake shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of.

Valuable resources for this type of conservation work include the WDNR, UW-Extension and Oneida County Land & Water Conservation Department. Several websites of interest include:

- Wisconsin Lakes website: www.wisconsinlakes.org/shorelands)
- Conservation easements or land trusts: (www.northwoodslandtrust.org)
- UW-Extension Shoreland Restoration: http://www.uwex.edu/ces/shoreland/Why1/whyres.htm)
- WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)

Action Steps:

1. Recruit facilitator (potentially same facilitator as previous management action).
2. Facilitator gathers appropriate information from sources described above.

Management Goal 2: Solidify and Strengthen the Big Twin Lake Association's Functionality.

<u>Management Action:</u> Increase membership and participation.

Timeframe: Initiate in 2014.

Facilitator: Planning Committee

Description: The effectiveness of a lake association is often a reflection of the time and talents of the individuals the association draws from. While it is true that several dedicated people can conduct a vast amount of association-related work, it is helpful to have a large pool of volunteers and talent to draw upon for various lake association and lake management related tasks.

The BTLA is a fairly new organization, but has grown strong in its initial years, undertaking many large projects and drawing a good foundation of support from riparian property owners. The board of directors has discussed improving membership still, and also improving participation within the group. At the second planning meeting, these topics were discussed at length.

To increase membership within the BTLA, volunteers from the association will meet with their neighbors face-to-face for friendly conversations about the benefits of membership, what a BTLA membership entails, etc. This type of membership drive is not only more effective than a limited form of contact, but helps to build a sense of community and friendship amongst neighbors. These face-to-face drives may be utilized to ask for assistance in volunteer-heavy tasks, such as the CLMN water quality monitoring program.

Also discussed at the second meeting was having a periodic BTLA-sponsored auction and raffle to raise funds for the association. The BTLA held an auction and raffle in 2007and it was met with success. Holding this auction and raffle will not only aid in raising moneys for the association, but will allow association members to reach out and acquire new members.

Members of the BTLA will also create an informational brochure containing information about the BTLA, benefits of being a member, and a summary of the projects the BTLA has undertaken to improve the quality of Big Twin Lake. This brochure would be sent to households around the lake.

Action Steps:

1. See above description.

Management Action: The BTLA will create and support an education committee to promote water quality, safe boating, and other educational topics to maintain and improve the quality of life on Big Twin Lake.

Timeframe: Initiate in 2014.

Facilitator: Planning Committee

Description: Education is an effective tool to address issues that impact water quality such as lake shore development, lawn fertilization, and other issues such as air quality, noise pollution, and boating safety. Within the 2012 Big Twin Lake stakeholder survey, 80% of respondents indicated that they were members of the BTLA. To facilitate better communication between members, an Education Committee will be created to promote lake protection through a variety of educational efforts.

The most important aspect of educating those involved in an organization is successful communication. Communication among lake stakeholders is important because it builds a sense of community around a lake while encouraging the spread of information regarding association news, educational topics or social events. Communication also ensures that volunteer or other efforts are not duplicated and that resources are spent efficiently.

Communication within a lake group can be a cumbersome task, as lake residents can range from full-time, seasonal or weekend-only residents. The preferred communication medium of lake residents seems to range often as well; some may be familiar with using email and social media sources while others are not and thus prefer physical mailings or phone calls.

Communication between the BTLA and others is not ineffective at this point, as shown through results of a stakeholder survey (Appendix B, Question #27). Nevertheless, the BTLA is committed to maintaining and even improving education and open communication amongst stakeholders. Currently, the BTLA communicates with stakeholders via an annual meeting. Members of the Planning Committee indicated that they would be interested in creating an association newsletter to be sent out on a periodic basis (e.g. biannually). Newsletters are an effective form of direct communication with association members.

Currently, the BTLA does not have the necessary funds to create and distribute an association newsletter, and they will investigate if a WDNR Small-Scale Lake Planning or AIS Education, Planning and Prevention Grants would be appropriate to cover initial setup costs. Within the newsletter, the BTLA would include educational topics that may include:

- Aquatic invasive species monitoring
- Boating safety and ordinances (slow-no-wake zones and hours) as well as courtesy codes
- Catch and release fishing
- Shoreland restoration and protection
- Septic system maintenance
- Fishing regulations
- Lake property values

Action Steps:

1. Recruit volunteers to form Education Committee.
2. Investigate if WDNR small-scale Lake Planning or AIS Education, Planning, and Prevention Grants would be appropriate to cover initial setup costs.
3. The BTLA Board will identify a base level of annual financial support for educational activities to be undertaken by the Education Committee.

Management Goal 3: Control existing Eurasian water milfoil population in Big Twin Lake and Prevent Further AIS Introductions To and From Other Lakes

Management Action: Continue volunteer-based monitoring of Eurasian water milfoil and other aquatic invasive species.

Timeframe: Continuation of current effort.

Facilitator: Planning Committee

Description: While the Eurasian water milfoil population in Big Twin Lake was greatly reduced following the herbicide treatment in 2007, surveys in 2012 and 2013 show that it is beginning to increase in occurrence around the lake. While Eurasian water milfoil is spread around near-shore areas of Big Twin Lake, it was believed that the level of Eurasian water milfoil in 2013 was not sufficient to warrant a treatment.

Monitoring of the Eurasian water milfoil population on an annual basis and reporting the findings to resource managers will yield an understanding of its dynamics and when the threshold for initiation a particular control strategy has been reached. In addition, volunteers also survey the lake for other potential invasive species including curly-leaf pondweed, which occurs in nearby Rolling Stone Lake. Early detection and response to curly-leaf pondweed infestations commonly leads to successful control.

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

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

BTLA volunteers will conduct AIS surveillance monitoring on Big Twin Lake with coordination from the Northern Region CLMN Coordinator (Sandy Wickman – 715.35.8951) and following CLMN protocols, which are outlined within the AIS Monitoring Handbook and can be found at the CLMN website:

www4.uwsp.edu/cnr/uwexlakes/clmn

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

Action Steps:

1. Volunteers from BTLA are trained on CLMN Aquatic Invasive Species Monitoring protocols (Sandy Wickman – 715.35.8951).
2. Volunteer monitors report findings to BTLA, WDNR, and consultant (as necessary).

Management Action: Enact Eurasian water milfoil monitoring and control strategy.

Timeframe: Begin 2014.

Facilitator: Planning Committee

Description: As described in the Aquatic Plant Section, the most pressing threat to the health of Big Twin Lake is Eurasian water milfoil. First discovered in the lake in 2005, surveys in 2006 revealed that it was widespread around the littoral areas of the lake. Granular 2,4-D was applied to nearly 13 acres of Eurasian water milfoil in 2007 and was met with very good results. As previously discussed, because of Big Twin Lake's smaller size, the 2007 spot treatment, while intended to target EWM within the application areas, likely had lake-wide effects as the herbicide dissipated throughout the entire lake. However, calculations indicate that this concentration was likely around 0.150 ppm ae within the lake's epilimnion (warmer, upper layer of water). Current research is indicating that a lake-wide concentration of 0.150

ppm ae is too low to have a significant impact on EWM. In addition, research suggests that this lake-wide concentration calculated for the 2007 treatment was likely overestimated due to factors such as herbicide degradation and the availability of 2,4-D granules that sunk into the sediment. The success of the 2007 treatment was likely a combination of the direct application of granular 2,4-D onto areas of EWM which created a higher herbicide concentration directly in these areas initially, followed by a longer, low-concentration exposure of herbicide throughout the lake once it dissipated from the application areas.

With Big Twin Lake's smaller size, any spot treatments targeting specific areas of EWM will likely have lake-wide effects due to dissipation of the herbicide throughout the lake. Low-concentration, whole-lake treatments are proving to be an effective strategy at controlling EWM on a lake-wide level. Because of this and the fact that EWM is widespread throughout the lake, it is believed that a whole-lake treatment strategy would be the most appropriate and effective method to control EWM in Big Twin Lake in the future.

<u>Volunteer-based monitoring</u>

The Eurasian water milfoil management strategy discussed by Onterra and BTLA Planning Committee members involves both volunteer and professional monitoring. In 2014, BTLA volunteers will conduct monitoring of the Eurasian water milfoil around Big Twin Lake, as discussed in the previous management action. The information gathered by the volunteers will be transferred to professional consultants. Professional monitoring will occur in these areas under one of two scenarios: 1) the BTLA believed that the amount of Eurasian water milfoil found warrants control action during the following spring (e.g. large, colonized areas of *dominant* or greater Eurasian water milfoil), or 2) a period of five years has passed from the previous professional survey (2013).

At this time, management of Eurasian water milfoil populations is not done to eradicate Eurasian water milfoil from Big Twin Lake, as that would be impossible. The objective is to reduce Eurasian water milfoil to more manageable levels that minimally affect the aquatic ecosystem of these areas. Because the primary goal is to better the lake's ecological state, control actions must implemented to maximize impact on the target species while minimizing impacts on non-target, native species. To accomplish this, both target and non-target species must be monitored closely and treatment strategies need to be tuned to minimize the amount of herbicides being used.

<u>Professional surveying strategy</u>

As discussed previously, if BTLA volunteers locate numerous large, *dominant* or greater colonies of Eurasian water milfoil and feel that control actions need to be taken, this will trigger a whole-lake survey by professionals to map Eurasian water milfoil. The impacts to native aquatic plants are believed to occur when the non-native species reaches an aerial coverage of approximately 50%. Therefore, action should be taken to minimize these dense colonies. While 21% of stakeholders are not supportive of herbicide control on Big Twin Lake, 32% area supportive of this management technique, 21% are neutral, and 26% are unsure about the matter (Appendix B, Question #23).

If ecologists conducting the professional Eurasian water milfoil survey feel that the Eurasian water milfoil population has reached levels where it is beginning to impact the lake's native aquatic plant community and interfere with recreational activities on the lake, this would trigger a professional whole-lake aquatic plant point-intercept survey. This point-intercept survey would be used to determine the littoral frequency of occurrence of Eurasian water milfoil. If the littoral frequency of Eurasian water milfoil is 10% or greater, this would trigger the process of implementing a whole-lake herbicide treatment strategy to take place the following spring. In the event that a whole-lake treatment takes place, the data collected from the point-intercept survey would be used as a pre-treatment survey. Another whole-lake point-intercept survey (post-treatment survey) would be conducted the summer immediately following the treatment.

Action Steps:

1. If a number of larger, colonized areas of Eurasian water milfoil are discovered by volunteers, then a professional survey of Eurasian water milfoil within Big Twin Lake would be initiated.
2. If the professional survey reveals Eurasian water milfoil is approaching levels at which are detrimental to the lake's ecology and recreation, a whole-lake point-intercept survey would be conducted to determine the littoral frequency of occurrence of Eurasian water milfoil
3. If Eurasian water milfoil frequency of occurrence is 10% or greater, the process to conduct a low-dose, whole-lake herbicide treatment would be initiated.
4. BTLA receives proper permit to conduct a whole-lake herbicide treatment.
5. Post-treatment evaluations of the whole-lake treatment would occur the summer immediately following the treatment.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Big Twin Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred once in spring and three times during the summer. In addition to the samples collected by BTLA members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, winter, and fall. Although BTLA members collected a spring total phosphorus sample, professionals also collected a near bottom sample to coincide with the bottom total phosphorus sample. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle. Secchi disk transparency was also included during each visit.

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

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

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Big Twin Lake during a May 31, 2012 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Big Twin Lake by the DNR in 2011 to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study. A point spacing of 30 meters was used resulting in approximately 287 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Big Twin 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 BTLA.

7.0 LITERATURE CITED

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

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

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

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

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

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

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

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

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

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

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

Great Lakes Indian Fish and Wildlife Service. 2010A. Interactive Mapping Website. Available at http://www.glifwc-maps.org. Last accessed March 2012.

Great Lakes Indian Fish and Wildlife Service. 2010B. GLIFWC website, Wisconsin 1837 & 1842 Ceded Territories Regulation Summaries – Open-water Spearing. Available at http://www.glifwc.org/Enforcement/regulations.html. Last accessed March 2012.

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

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

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

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

Nault, M. A. Mikulyuk, J. Hauxwell, J. Skogerboe, T. Asplund, M. Barton, K. Wagner, T. Hoyman, E. Heath. 2012. Herbicide Treatments in Wisconsin Lakes. Lakeline. Spring 2012: 21-26.

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

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

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

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

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

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

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

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

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

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

Spangler, G.R. 2009. "Closing the Circle: Restoring the Seasonal Round to the Ceded Territories". Great Lakes Indian Fish & Wildlife Commission. Available at: *www.glifwc.org/Accordian_Stories/GeorgeSpangler.pdf*

United States Department of the Interior – Bureau of Indian Affairs. 2007. Fishery Status Update in the Wisconsin Treaty Ceded Waters. Fourth Edition.

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

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

Wisconsin Department of Natural Resources. 2002. 2002-2003 Ceded Territory Fishery Assessment Report. Administrative Report #59.

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

Wisconsin Department of Natural Resources – Water Division. 2009. Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM). PUB WT-913.

Wisconsin Department of Natural Resources – Bureau of Fisheries Management. 2011. Fish data summarized by the Bureau of Fisheries Management. Available at: http://infotrek.er.usgs.gov/wdnr_public. Last accessed March 2013.

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