Two Sisters Lake

Oneida County, Wisconsin

Comprehensive Management Plan

July 2013

Sponsored by:

Two Sisters Lake Property Owners Association & the Town of Newbold

WDNR Grant Program

LPL-1432-11, LPL-1433-11, & LPL-1449-12

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Onterra, LLC
Lake Management Planning

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Funded by: Two Sisters Lake Property Owners Association and Town of Newbold.
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Acknowledgements

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

Two Sisters Lake Planning Committee

Bob Nicholson	Paul Kuhn	Kent Bradshaw
Robert Brodhead	John Kraus	Michael Murphy
Dick Holscher	Helen Neumann	Scott Eshelman
Bill Jaeger	Denise Snoeyens	Joeseph Steinhage
Chuck Wood	Kathy Harsh	Ken Steube

Wisconsin Dept. of Natural Resources

Kevin Gauthier, Tim Plude, John Kubisiak

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1.0 INTRODUCTION

Two Sisters Lake, Oneida County, is a 705-acre spring lake with a maximum depth of 64 feet. This oligotrophic lake has a low watershed to lake area ratio and contains 61 native aquatic plant species, of which fern pondweed is the most abundant. No non-native aquatic plant species are known to be present in Two Sisters Lake.

Field Survey Notes

Two Sisters Lake is very clear. Varied substrate encountered during point-intercept survey, as well as many different species. No exotic plants observed during all 2011 summer surveys.

Photograph 1.0-1 Two Sisters Lake, Oneida County

Lake at a Glance - Two Sisters Lake

Morphology	
Acreage	705
Maximum Depth (ft)	64
Mean Depth (ft)	30
Shoreline Complexity	5.7
Vegetation	
Curly-leaf Survey Date	June 23, 2011
Comprehensive Survey Date	July 27, 29, 2011
Number of Native Species	41 (PI Survey) + 20 (Incidental)
Threatened/Special Concern Species	*Potamogeton vaseyi & Utricularia resupinata*
Exotic Plant Species	-
Simpson's Diversity	0.94
Average Conservatism	7.3
Water Quality	
Trophic State	Borderline oligotrophic-mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.6 to 8.7 (alkaline)
Sensitivity to Acid Rain	Low
Watershed to Lake Area Ratio	2:1

Two Sisters Lake is located just north of the city of Rhinelander and is within the Wisconsin River drainage basin. This spring lake has an outlet that is controlled by a small, earthen water level structure that is owned by the Town of Newbold. The structure was built in 1976 for general water retention purposes and has a structural height of four feet. The hydraulic height (two feet) allows the water level structure to hold a max storage of 2,800 acre-feet, though normal containment is 1,400 acre-feet.

The Two Sisters Lake Property Owners Association (TSLPOA) has worked diligently in recent years to protect Two Sisters Lake from AIS infestations. Over the course of that time, the association has partnered with the Town of Newbold to carry out their AIS educational and monitoring initiatives. The TSLPOA has operated a Clean Boats/Clean Waters program at the previously mentioned boat launch since 2006, monitoring about 500 boats per year. In addition to Clean Boats/Clean Waters, the association has an active Adopt-A-Shoreline and Rapid Response Program in operation since 2006. Most years, these efforts were funded by Wisconsin Department of Natural Resources (WDNR) Aquatic Invasive Species (AIS) Control Grants, however in 2007 and 2009 these efforts were funded by the association. In 2010, the TSLPOA completed construction of a boat washing station, which is located at the public launch and includes the capability to wash watercraft with a dilute bleach spray. It is these efforts which have likely kept Two Sisters Lake free of most aquatic plant invasive species. The lake currently has several confirmed invasive species including banded mystery snail (2008), Chinese mystery snail (2008) and rusty crayfish (2010).

Two Sisters Lake is truly a unique resource, with a Class A1, self-sustaining and naturally reproducing muskellunge fishery. Additionally, the lake is classified as an Outstanding Resource Water (ORW) by the WDNR as per NR 102. The TSLPOA, being proactive as they are, pursued grant funds through the WDNR in February of 2011 to complete a comprehensive management plan for protection of Two Sisters Lake. The information learned through the course of this project will not only help the TSLPOA in reacting to future concerns as they arise, but also assist in understanding and preserving this exceptional waterbody.

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting
On July 9, 2011, a project kick-off meeting was held at the McNaughton Pub to introduce the project to the general public. The meeting was announced through a mailing and personal contact by TSLPOA board members. The attendees observed a presentation given by Eddie Heath, an aquatic ecologist with Onterra. Mr. Heath's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting I
The first of two planning committee meetings was held on June 28, 2012. Brenton Butterfield and Tim Hoyman, aquatic ecologists with Onterra, presented the study results to the planning committee in a meeting that lasted a little over 3.5 hours. All project components including water quality analysis, watershed modeling, aquatic plant survey results, and fisheries data summaries were discussed at length.

Planning Committee Meeting II
On July 23, 2012, Tim Hoyman met with the planning committee for a second planning meeting. At this meeting, the group brainstormed challenges that the Association faced regarding their community and the lake environment. From this brainstorm, management goals were developed and drafted into the Implementation Plan, which is found at the end of this report. Some of these goals included matters such as facilitating partnerships with other organizations, developing a succession plan for the association, and matters pertaining to shoreland zoning, the lake's fishery, water quality monitoring and development of a plan to keep Two Sisters Lake free of AIS.

Project Wrap-up Meeting
On August 4, 2012, Tim Hoyman met with the TSLPOA and other members of the public for the project Wrap-up meeting. At this meeting, Mr. Hoyman presented the full study results in addition to the goal components that the Planning Committee had drafted in the previous

planning meetings. The meeting was well attended, and discussions followed the presentation with regards to matters of water quality and AIS.

Management Plan Review and Adoption Process

On November 20, 2012, a draft of the Implementation Plan was provided to the Two Sisters Lake Planning Committee for review. Several comments were received, and these were integrated within the Implementation Plan in December of 2012. A draft management plan was sent to the WDNR for review in that same month. In February of 2013, comments were received from Kevin Gauthier, Tim Plude and John Kubisiak of the WDNR and were addressed by Onterra staff. WDNR staff approved of the plan on July 18, 2013, and the management plan will be accepted by the TSLPOA Board of Directors by a majority vote at their next board meeting.

Stakeholder Survey

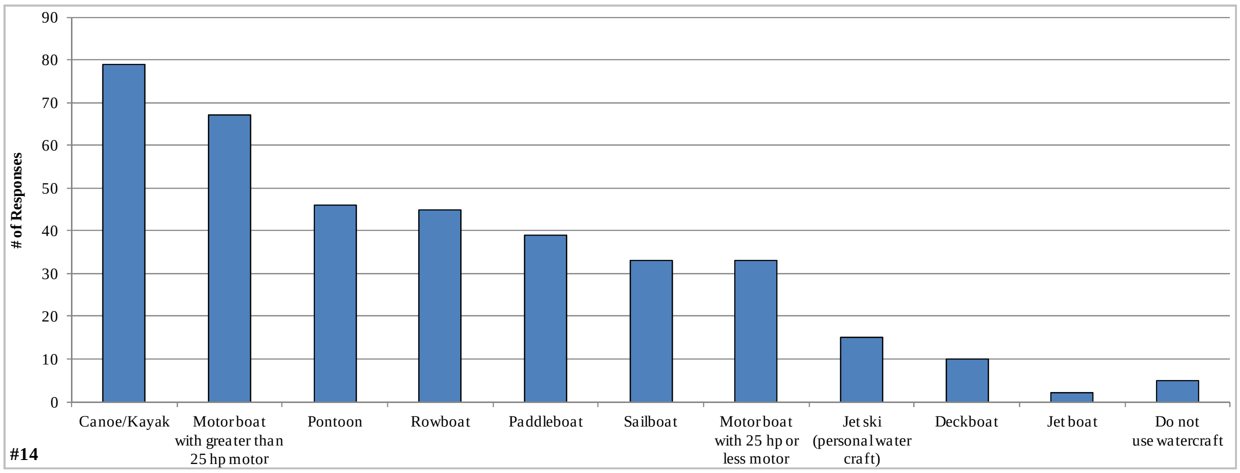
Following WDNR review and approval in October 2011, a nine-page, 41-question survey was mailed to 180 riparian property owners in the Two Sisters Lake watershed. Sixty-nine percent (124) of the surveys were returned and those results were entered into a spreadsheet by members of the Two Sisters Lake Planning Committee. These 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 Two Sisters Lake. The majority of stakeholders (44%) own seasonal (summer residences on the lake), while roughly 21% own year-round residences and 21% own a property that is visited on weekends throughout the year (Appendix B, Question #1). The majority of property owners (53%) have owned their property for more than 25 years (Question #2). Most of the property owners (43%) have decided to either pass their property onto a family member or otherwise continue to own their property (36%) (Question #7).

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data as they apply to these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. When asked what type of watercraft they use on Two Sisters Lake, many respondents indicated that they used passive types of watercraft – canoe / kayak, pontoons, rowboats, or paddle boats. However, many respondents indicated they used a large motorboat as well (Question #14). The importance of responsible boating activities is increased on lakes like Two Sisters that have islands, narrow passageways, hazard rock areas and bays. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question #15, several of the top recreational activities on the lake involve boat use. Although boat traffic was not ranked highly as a factor potentially impacting Two Sisters Lake in a negative manner, jet ski traffic ranked first on this question (Question #27). Additionally, this issue was ranked second on a list of stakeholder's top concerns regarding the lake (Question #28). In January of 1999, the Town of Newbold developed a Waterway Ordinance for Two Sisters Lake which defined "control areas" within the lake, enforcement, and also penalties for misconduct in these areas. This ordinance is attached as Appendix C.

Besides concerns regarding jet ski use on Two Sisters Lake, survey respondents indicated AIS, water quality degradation and lakeshore development as issues of concern (Question #28). These items are discussed within the appropriate sections below - AIS are discussed within the Aquatic Plant Section, water quality concerns are discussed within the Water Quality Section, and lake shore development is analyzed within the Watershed Section. Additionally, material may be found pertaining to these issues within the Summary and Conclusions Section and addressed within the Implementation Plan.

Question #14: What types of watercraft do you currently use on the lake?



Question #15: Please rank up to three activities that are important reasons for owning your property on or near the lake.

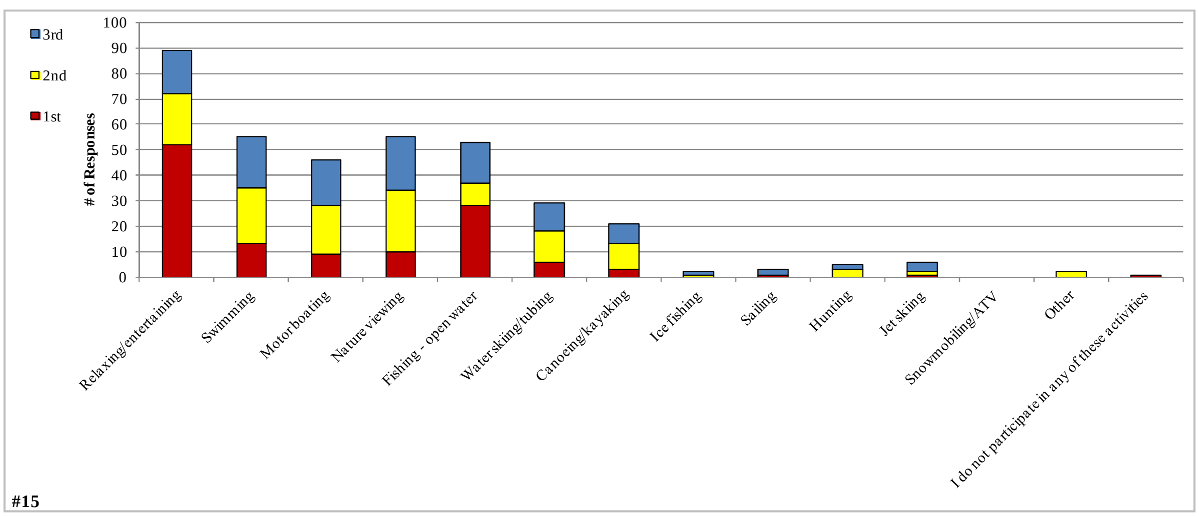
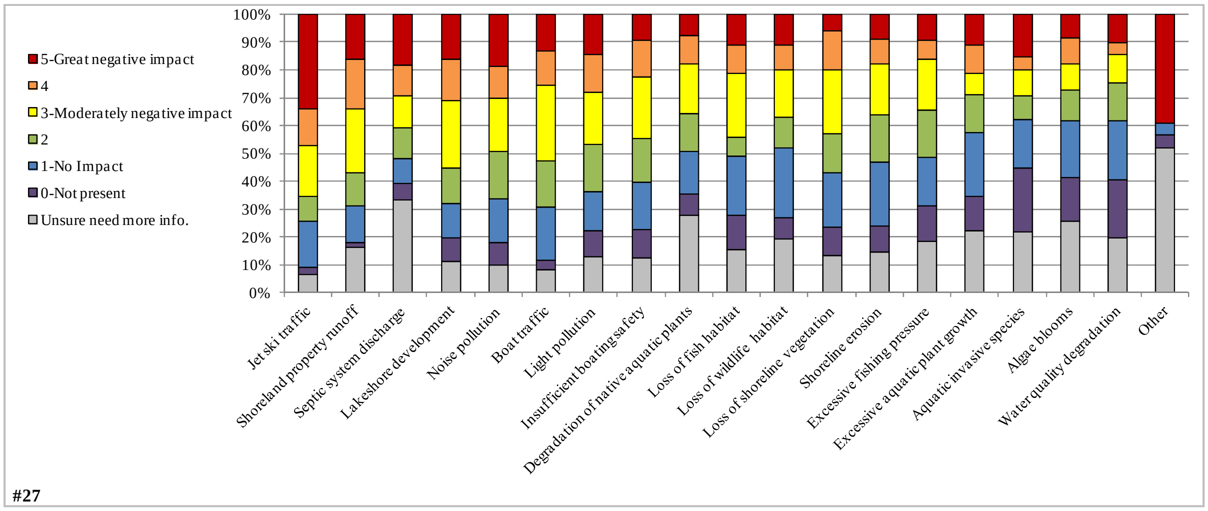


Figure 2.0-1. Select survey responses from the Two Sisters Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question #27: To what level do you believe these factors may be negatively impacting Two Sisters Lake?



Question #28: Please rank your top three concerns regarding Two Sisters Lake.

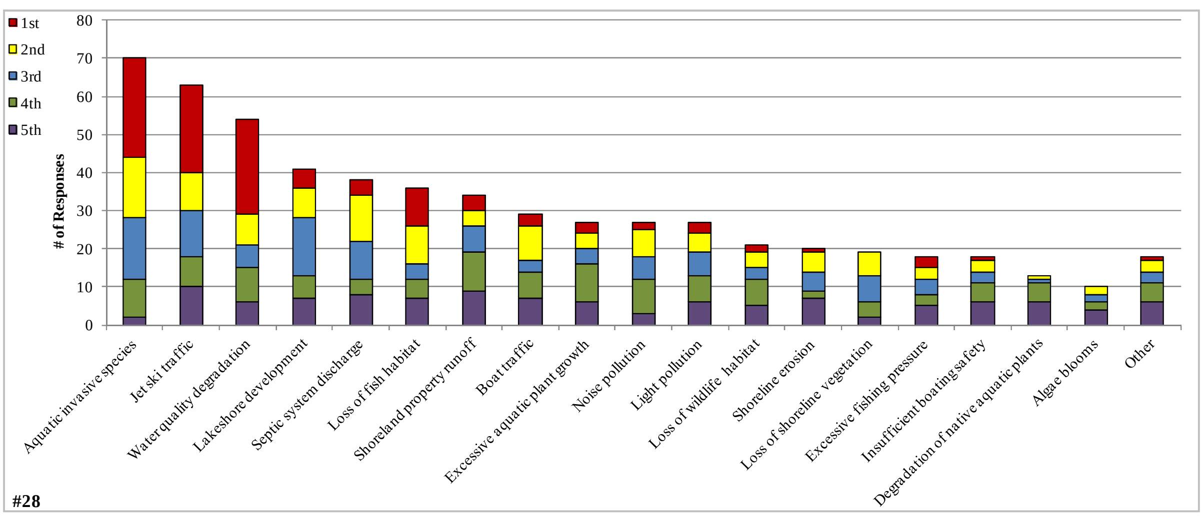


Figure 2.0-2. Select survey responses from the Two Sisters Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 Two Sisters Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix D). 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 Two Sisters Lake's water quality analysis:

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

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

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

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

Trophic State

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

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

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

Limiting Nutrient

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

In most Wisconsin lakes, phosphorus is the limiting nutrient controlling the production of plant biomass. As a result, phosphorus is often the target for management actions aimed at controlling plants, especially algae. The limiting nutrient is determined by calculating the nitrogen to phosphorus ratio within the lake. Normally, total nitrogen and total phosphorus values from the surface samples taken during the summer months are used to determine the ratio. Results of this ratio indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 15:1, the lake is considered phosphorus limited; if it is less than 10:1, it is considered nitrogen limited. Values between these ratios indicate a transitional limitation between nitrogen and phosphorus.

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Two Sisters Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

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

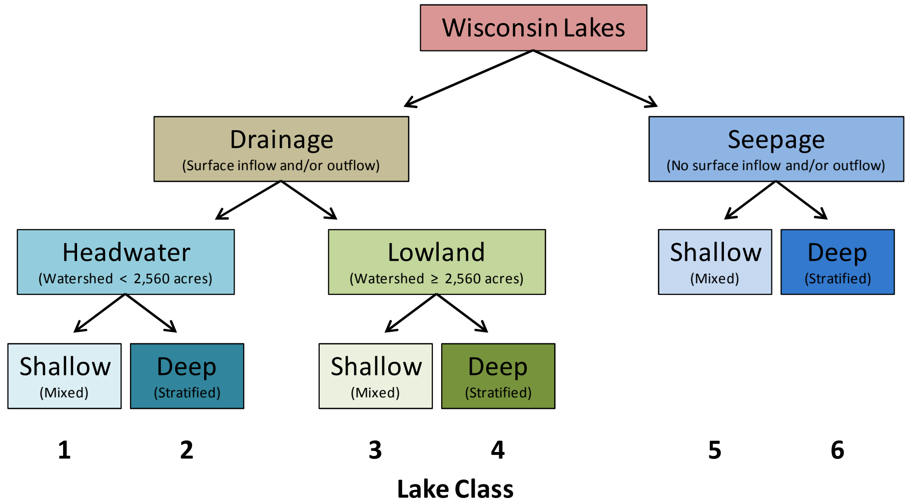


Figure 3.1-1. Wisconsin Lake Classifications. Two Sisters Lake is classified as a deep (stratified), headwater drainage lake (Class 2). Adapted from WDNR PUB-SS-1044 2008.

Two Sisters Lake which is drained by Two Sisters Creek, has a watershed of less than four square miles, and stratifies during the summer months, designating Two Sisters Lake as deep, headwater drainage lake (Figure 3.1-1). Technically, the lake is classified as a spring lake, but headwater drainage lakes encompass this lake type. 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. Two Sisters 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 a process by which the general condition of Wisconsin surface waters are assessed to determine if they meet federal requirements in terms of water quality under the Clean Water Act (WDNR 2009). It is another useful tool in helping lake stakeholders understand the health of their lake compared to others within the state. This method incorporates both biological and physical-chemical indicators to assess a given waterbody's condition. In the report, they divided the phosphorus, chlorophyll-*a*, and Secchi disk transparency data of each lake class into ranked categories and assigned each a "quality" label from "Excellent" to "Poor".

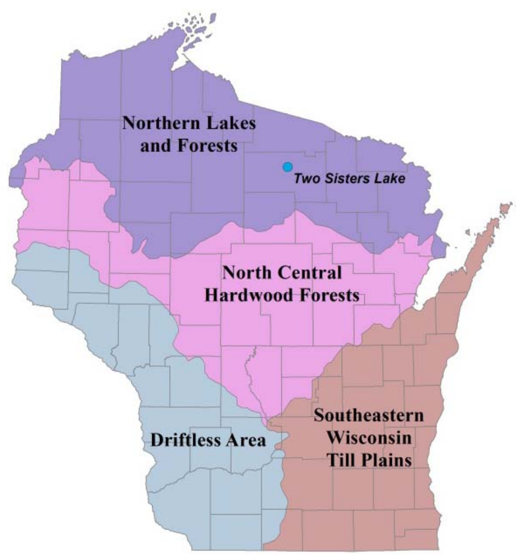


Figure 3.1-2. Location of Two Sisters Lake within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake medians, historic, current, and average data from Two Sisters Lake are displayed in Figures 3.1-3 – 3.1-8. Please note that the data in these graphs represent concentrations taken only taken during the growing season (April-October) from both basins in Two Sisters Lake. Since state and regional medians were calculated using summer (June, July, August) data, summer data for Two Sisters Lake have also been displayed. Furthermore, the total 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.

Two Sisters Lake Water Quality Analysis

Two Sisters Lake Long-term Trends

As part of the stakeholder survey associated with this project, lake residents were asked questions regarding their perspectives on the water quality of Two Sisters Lake. The majority of respondents hold the water quality of Two Sisters Lake in high regards with approximately 98% of respondents describing the current water quality as good or excellent (Appendix B, Question #16). Approximately 73% of the same individuals believe that the water quality in Two Sisters Lake has remained unchanged over the time period for which they first visited the lake (Appendix B, Question #17). Although these statements by Two Sisters Lake stakeholders regarding the lake's water quality are subjective due to the variation in perception of water quality among individuals, data collected over the past four decades provides quantitative substance to these observations made by respondents.

Total phosphorus data collected by the Two Sisters Lake Citizens Lake Monitoring Network (CLMN) are available from both the east and west basins of Two Sisters Lake, extending back to 1990. While additional total phosphorus data had been collected by the TSLPOA prior to 1990 to present, the lab processing the samples did not utilize analysis methodology that was sensitive enough to accurately measure the relatively low amounts of phosphorus present in Two Sisters Lake; therefore, these data are not included in this report. Figure 3.1-3 displays total phosphorus data collected during the summer months (June, July, August) within both the east and west basins. All of the total phosphorus data collected during the summer fall within the *Excellent* category for deep, headwater drainage lakes. The weighted summer mean for which all data are available falls into the *Excellent* category, and is below the median values for both state-wide deep, headwater drainage lakes and all lake types within the Northern Lakes and Forests Ecoregion (Figure 3.1-3).

All of the available total phosphorus data collected during the growing season (April-October) within both basins on Two Sisters Lake also falls within the *Excellent* category for deep, headwater drainage lakes (Figure 3.1-4). Looking at the summer and growing season figures for total phosphorus, one can see that the average concentrations recorded from 1990-1996 are slightly lower than what has been recorded from 2002-2011. The mean growing season total phosphorus concentration from 1990-1996 with the eastern basin was 7.4 µg/L compared to 12.7 from 2002-2011. However, statistical analyses indicate that the variance, or a measure of how far apart the data are spread out, is statistically different between the 1990-1996 and 2002-2011 datasets. The variance was shown to be significantly higher for the data collected from 2002-2011, meaning that a wider range of total phosphorus concentrations were recorded over this period. It is not believed that total phosphorus values were more variable in the most recent decade, but that total phosphorus concentrations were measured more frequently. Figures 3.1-3 and 3.1-4 also display the number of samples (N) collected that comprised the annual averages; as illustrated, the number of samples collected was higher in the most recent decade. The increased number of samples collected form 2002-2011 spread through time during the growing season provides a better representation of average total phosphorus values within the lake than just one or two samples.

Statistical analyses (two-sample t-test assuming equal variance, α = 0.05) of growing season total phosphorus data were used to determine if there is a statistical difference between values within the east and west basins. These analyses indicate that there is no statistically valid difference between the east and west basins in terms of total phosphorus concentrations (α = 0.79).

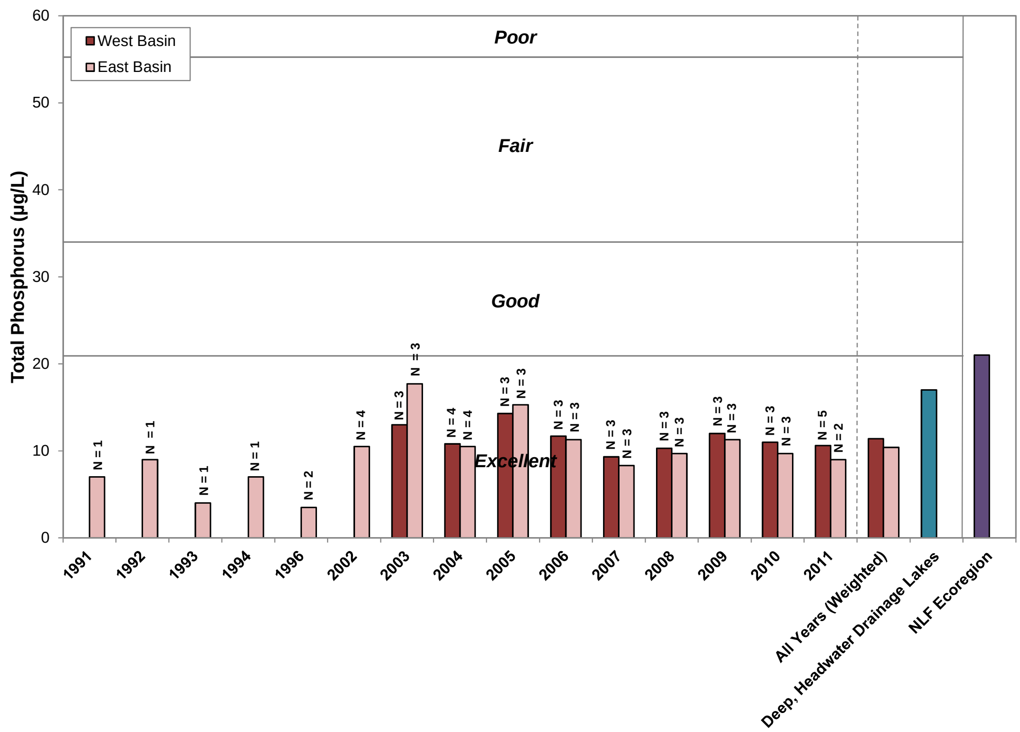


Figure 3.1-3. Two Sisters Lake average summer, state-wide class two lakes and regional median total phosphorus concentrations. Values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

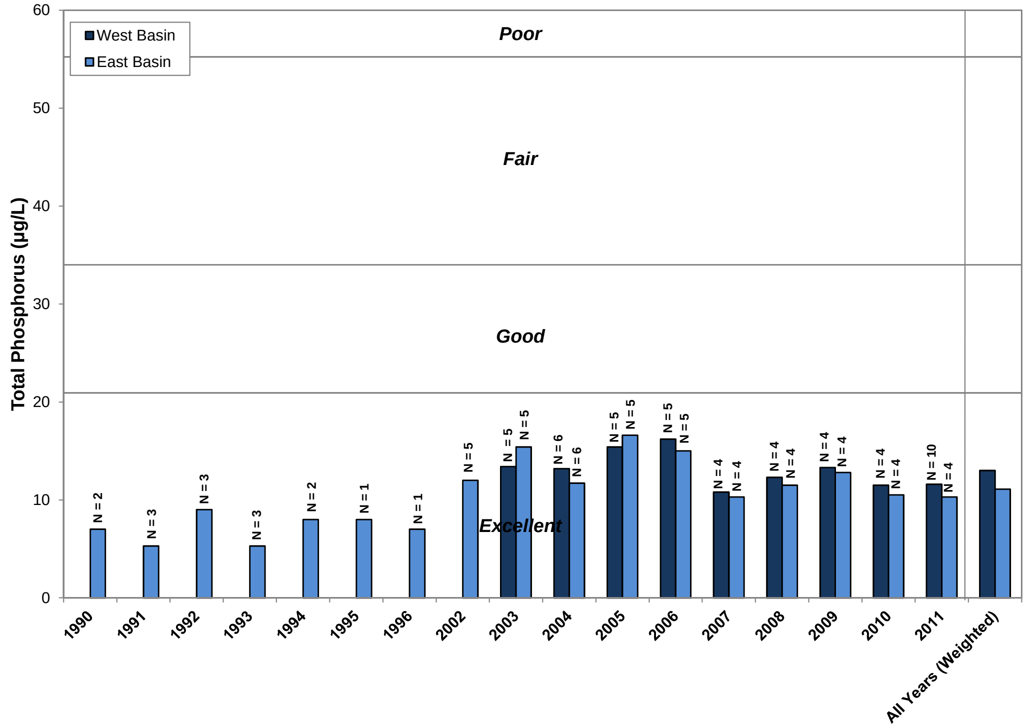


Figure 3.1-4. Two Sisters Lake average growing season total phosphorus concentrations. Values calculated with growing season surface sample data.

Chlorophyll-*a* data are available from both the east and west basins of Two Sisters Lake for nearly the same time period as total phosphorus. Summer chlorophyll-*a* levels in both basins fall well into the *Excellent* category for deep, headwater drainage lakes and are lower than both the medians for deep, headwater drainage lakes state-wide as well as all lake types within the ecoregion (Figure 3.1-5). Growing season chlorophyll-*a* levels are similar to summer values and also fall into the *Excellent* category for deep, headwater drainage lakes (Figure 3.1-6). Both summer and growing season chlorophyll-*a* levels within both basins have remained relative constant over the time period for which data are available, and no apparent trends are occurring at this time.

Statistical analyses (two-sample t-test assuming unequal variance, $\alpha = 0.05$) were also used to determine if there is a statistical difference exists between growing season chlorophyll-*a* values within the east and west basins. These analyses indicate that there is no statistically valid difference between the east and west basins in terms of chlorophyll-*a* concentrations ($\alpha = 0.18$).

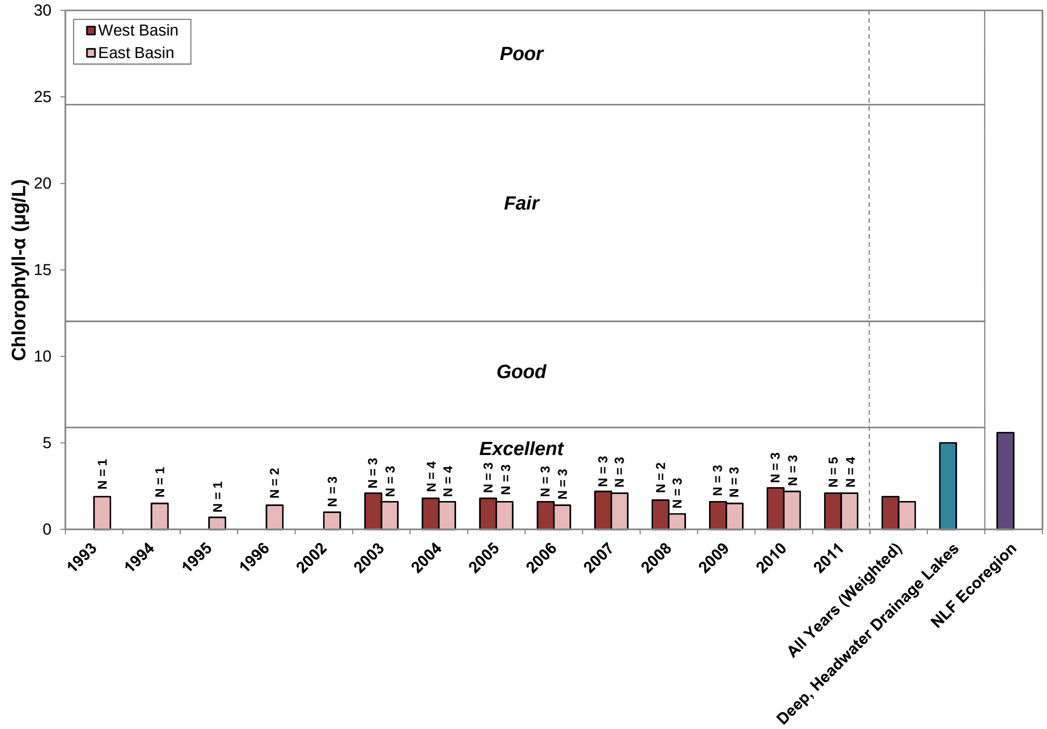


Figure 3.1-5. Two Sisters Lake average summer, and state-wide class two lakes and regional median chlorophyll-*a* concentrations. Values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

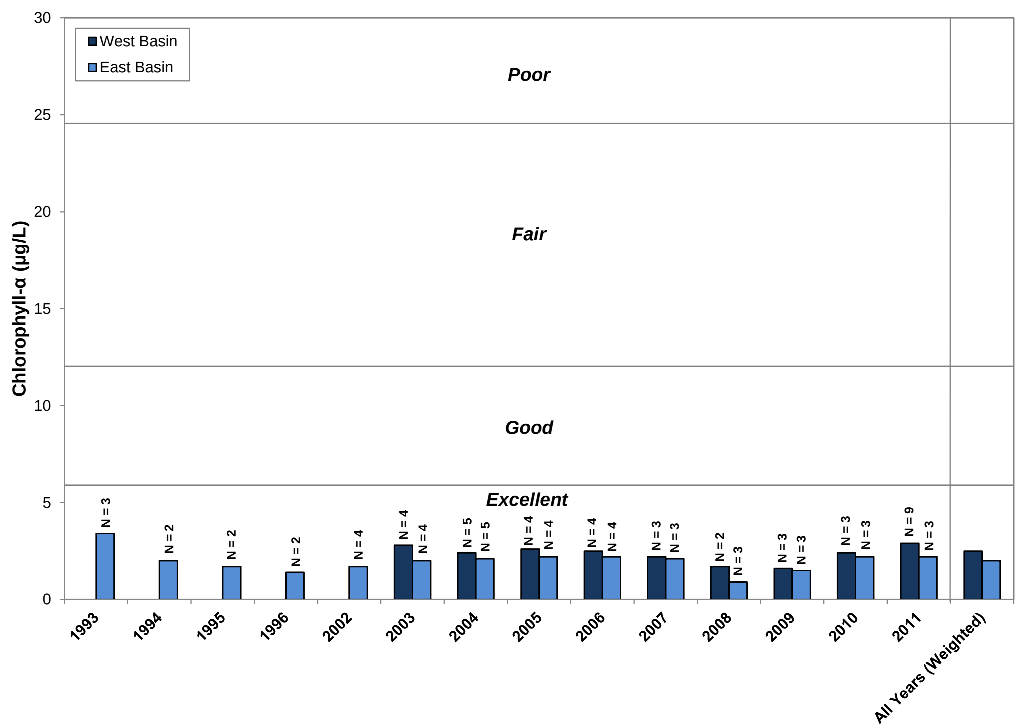


Figure 3.1-6. Two Sisters Lake average growing season chlorophyll-*a* concentrations. Values calculated with growing season surface sample data.

The third primary water quality parameter analyzed in this project, Secchi disk clarity, has been monitored extensively on Two Sisters Lake. Figure 3.1-7 displays Secchi disk clarity collected during the summer months within both the east and west basins, and shows that water clarity values greatly exceed the *Excellent* threshold for deep, headwater drainage lakes. The weighted average for water clarity is nearly twice as high as the median values for statewide deep, headwater drainage lakes and lakes within the Northern Lakes and Forests Ecoregion (Figure 3.1-7).

Water clarity data collected during the growing season on Two Sisters Lake also falls within the *Excellent* category for deep, headwater drainage lakes (Figure 3.1-8). While total phosphorus and chlorophyll-*a* data have varied little in Two Sisters Lake, more variability among years is seen in Secchi disk clarity. This parameter is influenced by many factors, and likely varies due to changes in several environmental conditions such as variations in precipitation. Like total phosphorus, differences in Secchi disk transparency exist from 1986-1996 and 2001-2011. The mean Secchi disk depth from 1986-1996 within the western basin was 19.0 feet compared to 15.0 feet from 2001-2011. In Two Sisters Lake, water clarity is most likely going to be driven by the amount of free-floating algae within the water. As discussed previously, chlorophyll-*a* levels to not appear to have increased over the past two decades. It is believed that the difference in water clarity from 1986-1996 and 2001-2011 is likely due to the number of samples collected (N), which was greater in the most recent decade, or a difference among individuals recording the clarity. As Figures 3.1-7 and 3.1-8 illustrate, Secchi disk clarity was collected nearly twice as much from 2001-2011 compared to 1986-1996, providing a more accurate representation of water clarity within the lake.

Statistical analyses (two-sample t-test assuming equal variance, $\alpha = 0.05$) were also used to determine if a statistical difference exists between growing season water clarity values within the east and west basins. These analyses indicate that there is no statistically valid difference between the east and west basins in terms of water clarity ($\alpha = 0.66$).

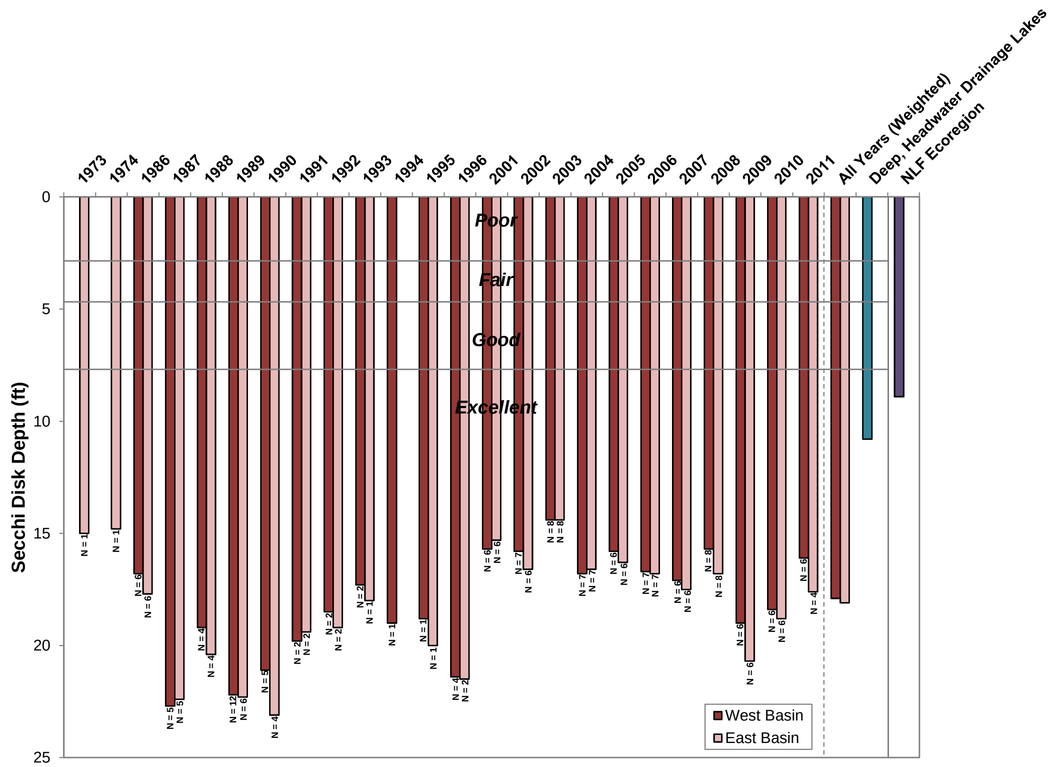


Figure 3.1-7. Two Sisters Lake average summer, state-wide class two lakes and regional median Secchi disk clarity. Water Quality Index values adapted from WDNR PUB WT-913.

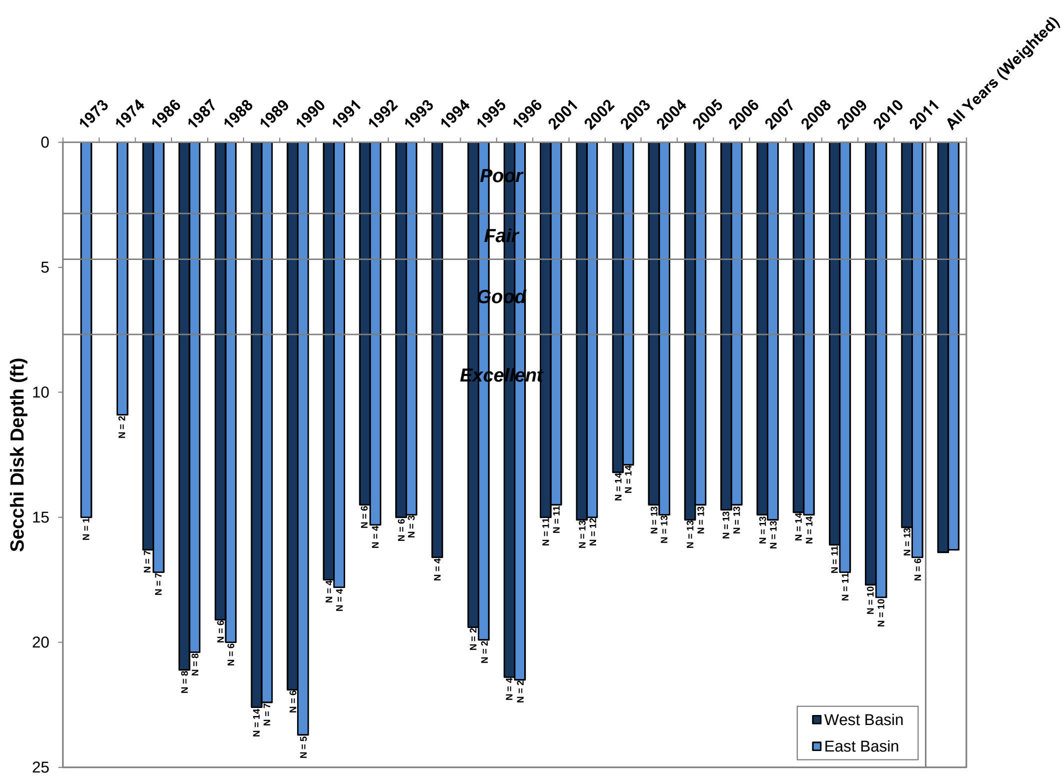


Figure 3.1-8. Two Sisters Lake average growing season Secchi disk clarity.

As discussed in the Water Quality Primer Section, internal nutrient loading is the recycling of nutrients, commonly phosphorus, from lake sediments. If a lake's nutrient-rich bottom sediments are exposed to anoxic (devoid of oxygen) conditions during stratification, the iron that normally holds the phosphorus in the sediments releases it into the hypolimnion (bottom water layer) of the lake. During turnover events, this nutrient-rich water is mixed into surface waters often spurring or maintaining algal blooms. Internal nutrient loading can be a significant source of phosphorus in lakes long after external sources have been minimized. In general, when hypolimnetic phosphorus values exceed 200 µg/L, it is possible internal nutrient loading may be impacting algal production and water clarity.

During 2011, temperature/dissolved oxygen profiles indicated that Two Sisters Lake strongly stratifies during the summer months, forming a distinct epilimnion and hypolimnion. These profiles also indicated that by mid-summer, the hypolimnion (below 35 feet) becomes anoxic. The near-bottom water sample collected in July 2011 had a total phosphorus concentration of 257 µg/L. While this value exceeds the 200 µg/L threshold for potential internal nutrient loading, total phosphorus values recorded near the surface following turnover in the fall did not have elevated phosphorus levels. At this time, it appears the amount of phosphorus being delivered to Two Sisters Lake via internal nutrient loading is negligible, though monitoring should continue in the future.

Limiting Plant Nutrient of Two Sisters Lake

Using midsummer nitrogen and phosphorus concentrations from Two Sisters Lake, a nitrogen:phosphorus ratio of 31:1 was calculated. This finding indicates that Two Sisters Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit algae and macrophyte growth within the lake.

Two Sisters Lake Trophic State

Figures 3.1-9 and 3.1-10 contain the Trophic State Index (TSI) values for both the east and west basins of Two Sisters Lake. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range from oligotrophic to mesotrophic. In general, the best values to use in judging a lake's trophic state are total phosphorus and chlorophyll-*a* TSI values, so it can be concluded that Two Sisters Lake is in a borderline oligotrophic-mesotrophic state.

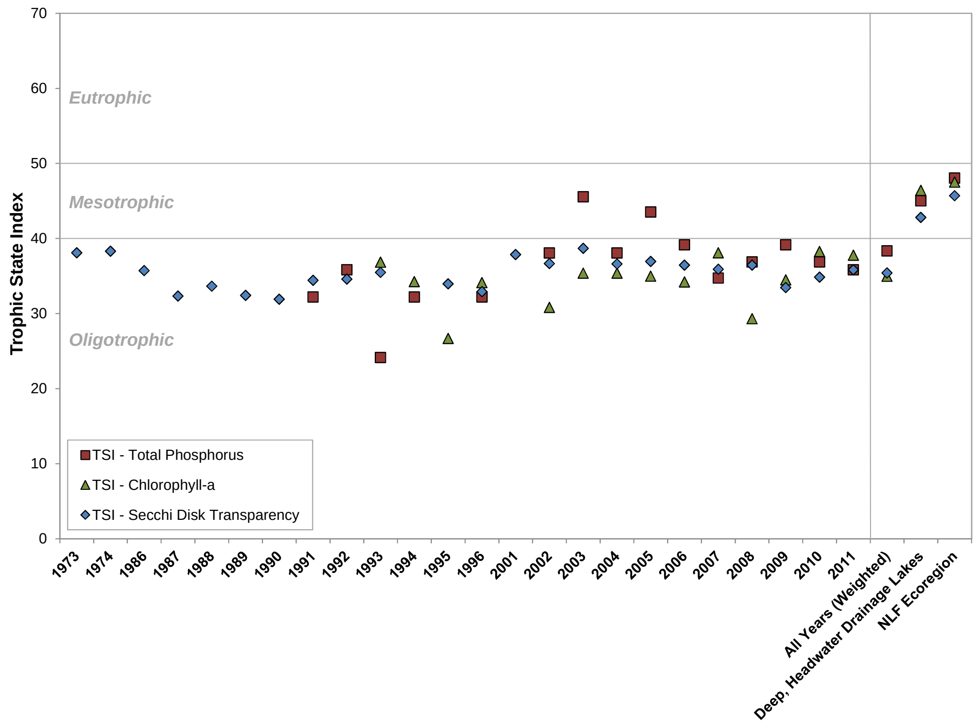


Figure 3.1-9. Two Sisters Lake east basin, state-wide class two lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

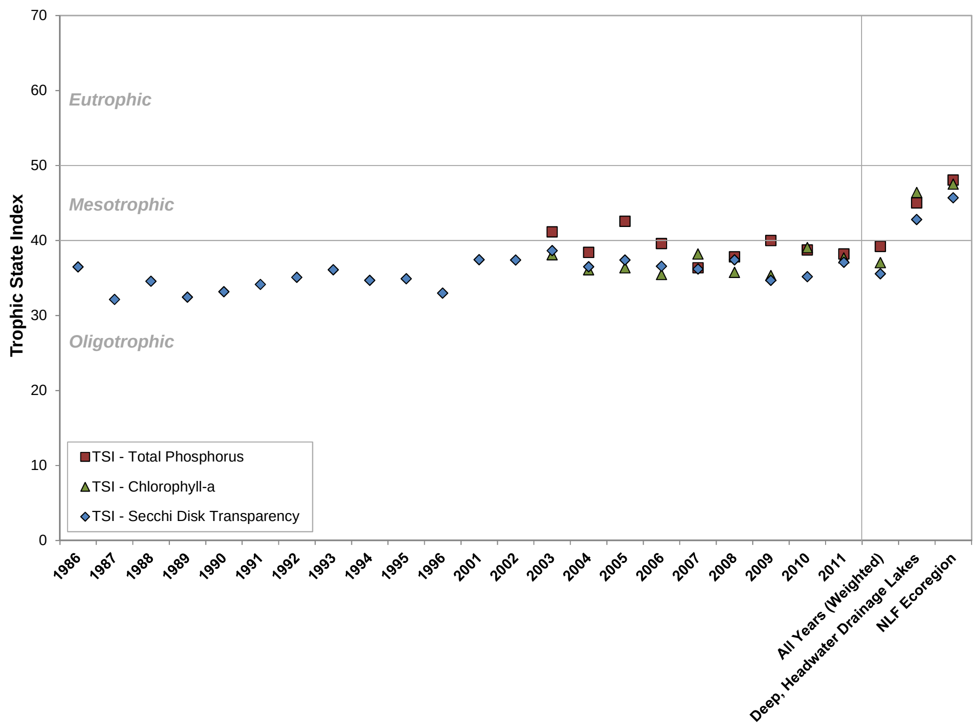


Figure 3.1-10. Two Sisters Lake west basin, state-wide class two lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Two Sisters Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Two Sisters Lake by Onterra staff within the west basin. Profiles depicting these data are displayed in Figure 3.1-11.

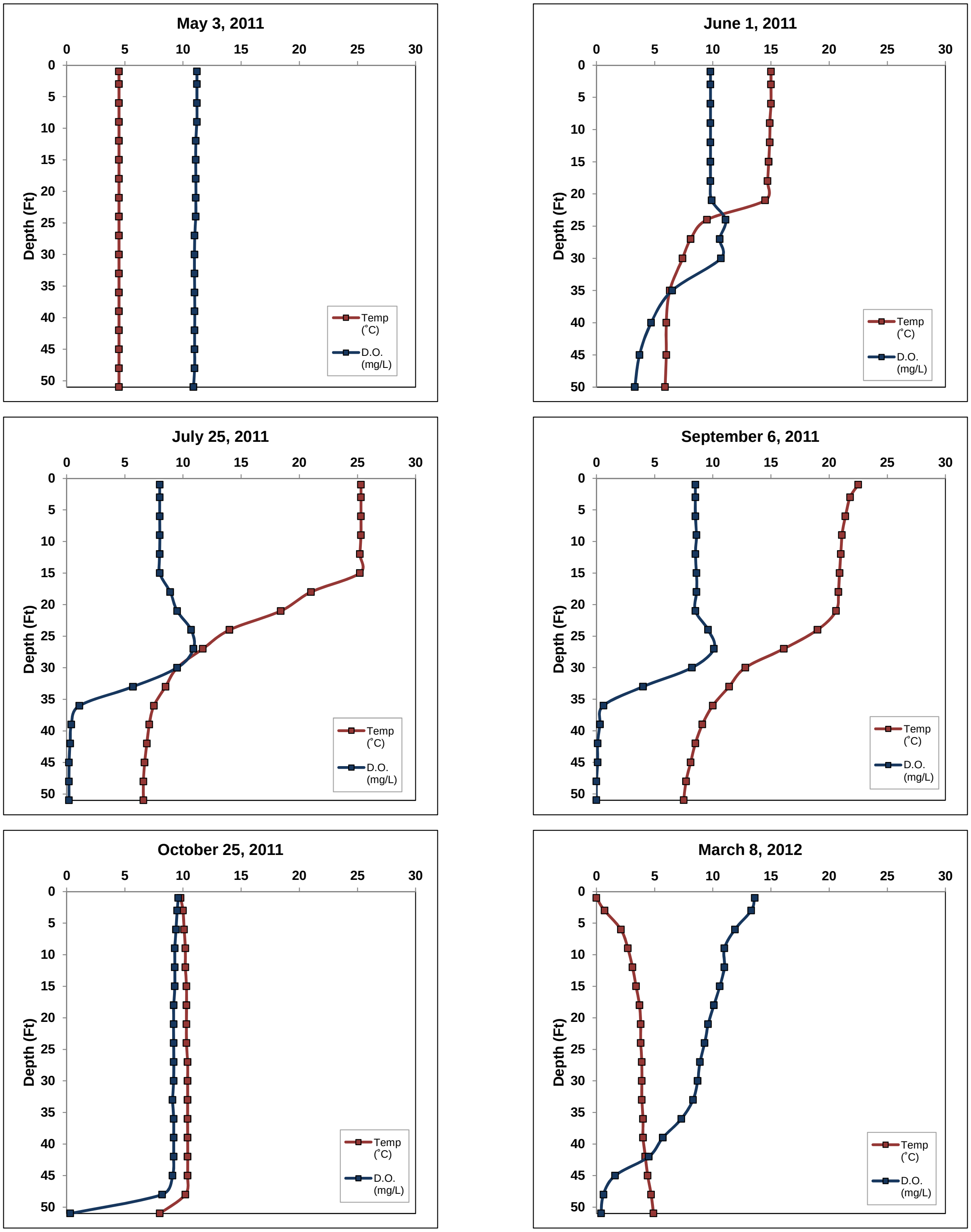


Figure 3.1-11. Two Sisters Lake (West Basin) dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Two Sisters 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 Two Sisters 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 Two Sisters Lake was found to be alkaline with surface values ranging from 7.6 to 8.7.

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 2011, the alkalinity in Two Sisters Lake was approximately 29.0 (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.

The TSLPOA has been collecting alkalinity data in both basins dating back to 1974. These data indicate the lake's alkalinity has been steadily increasing within both basins over time (Figure 3.1-12). Alkalinity is not a direct measure of any one element or compound within the lake, but as discussed previously, it is a measure of a lake's capacity to buffer against acid inputs. In Wisconsin, this buffering capacity is created by limestone-associated minerals dissolved within groundwater entering the lake. The TSLPOA has also collected the concentrations of the limestone-associated elements calcium and magnesium within the water. Figures 3.1-13 and 3.1-14 show that both of these elements have increased in their concentration within both basins over time also. The increase in these elements has also been captured by the water's specific conductivity, or a measure of the water's dissolved ion content (Figure 3.1-15). All of these variables are correlated with one another, and their increase over time is apparent. However, the cause for the observed increases in calcium and magnesium concentrations within the lake is not apparent.

While it is not known why magnesium and calcium concentrations have been increasing in Two Sisters Lake, it may human-induced. Development within the lake's watershed in terms of roads, structures, and manicured lawns increases the amounts of runoff and nutrients to the lake. In some lakes, increased alkalinity over time, or alkalinisation, can occur without seeing increases in phosphorus and nitrogen (Arts 2002).

From an ecological standpoint, the greatest threat alkalinisation poses to lake ecology is a change in aquatic plant species composition (Vestergaard and Sand-Jensen 2000). In summary, as these minerals increase, certain taller species gain a competitive advantage over and displace smaller, turf-forming species. This will be discussed in more detail in the Aquatic Plant Section.

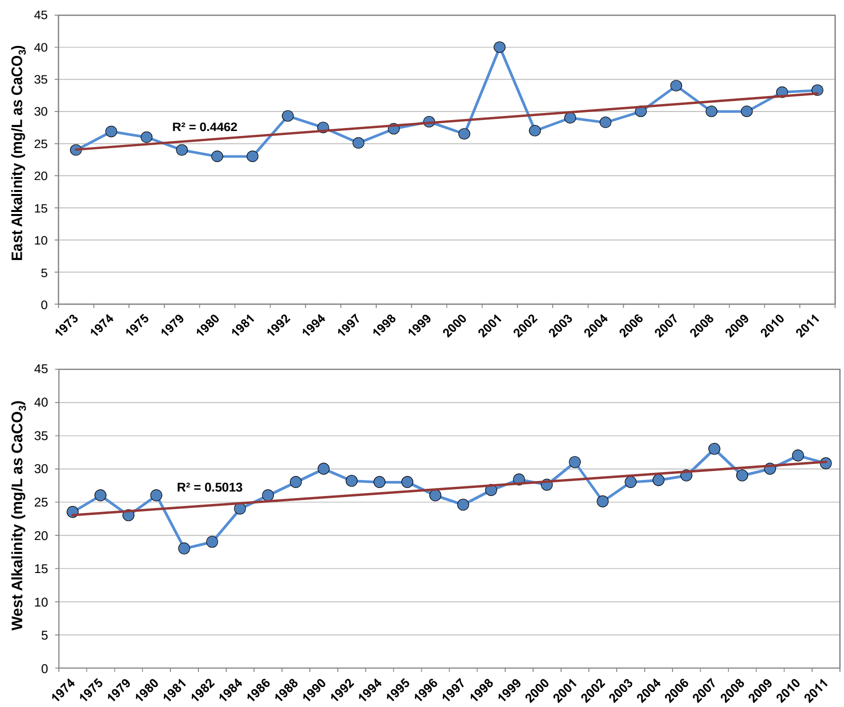


Figure 3.1-12. Two Sisters Lake total alkalinity. Created using data from TSLPOA and Onterra 2011 data.

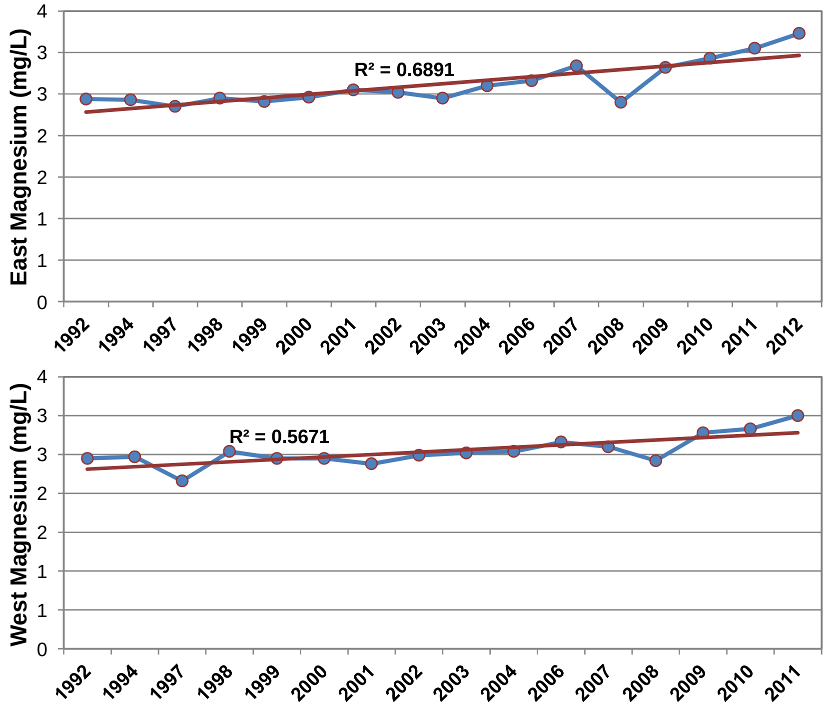


Figure 3.1-13. Two Sisters Lake magnesium concentrations. Created using data from TSLPOA data.

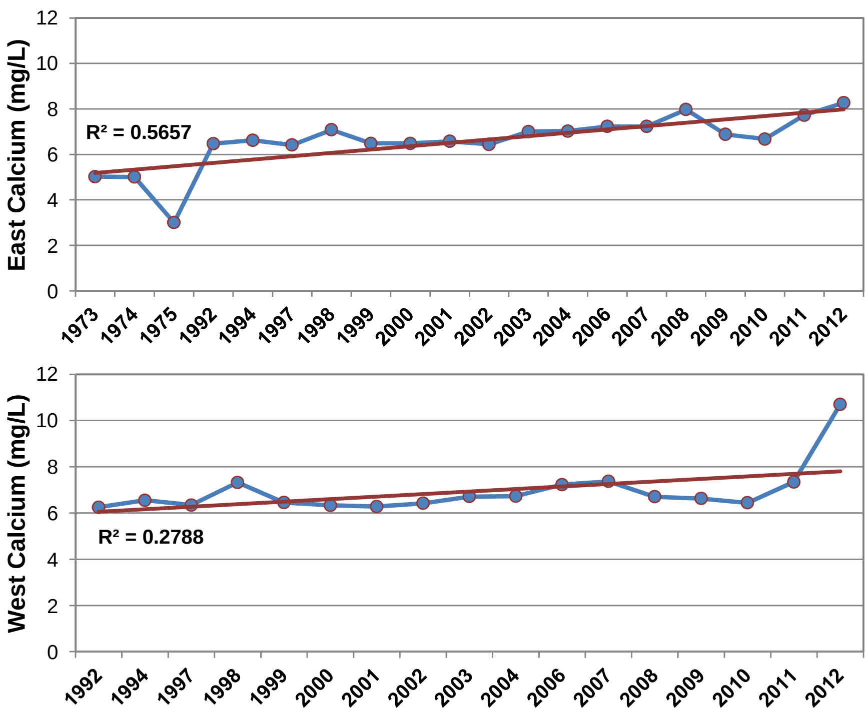


Figure 3.1-14. Two Sisters Lake calcium concentrations. Created using data from TSLPOA data and Onterra 2011 data.

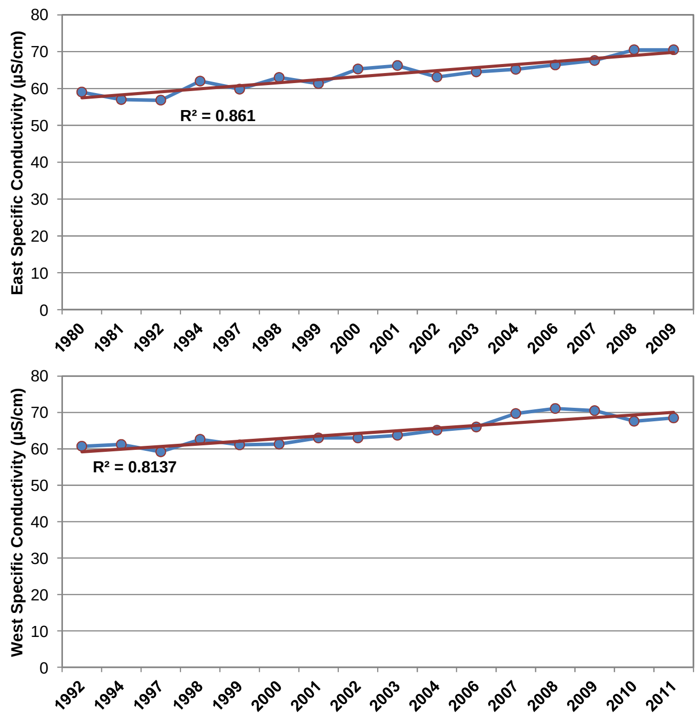


Figure 3.1-15. Two Sisters Lake specific conductivity. Created using from TSLPOA data and Onterra 2011 data.

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 Two Sisters Lake's pH range 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 Two Sisters Lake in 2011 was found to be 7.0 mg/L, indicating a very low susceptibility to zebra mussel establishment.

Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. Their analysis did not find any larval zebra mussels.

Total suspended solids (TSS) are a measure of inorganic and organic particles suspended in the water, and include everything from algae to clay particles. High TSS creates low water clarity, and prevents light from penetrating into the water to support aquatic plant growth. TSS was measured on Two Sisters Lake during every water quality sampling event, and the data indicate that TSS were undetectable during all of the sampling events.

3.2 Watershed Assessment

Watershed Modeling

A lake's **flushing rate** is simply a determination of the time required for the lake's water volume to be completely exchanged. **Residence time** describes how long a volume of water remains in the lake and is expressed in days, months, or years. The parameters are related and both determined by the volume of the lake and the amount of water entering the lake from its watershed. Greater flushing rates equal shorter residence times.

Two aspects of a lake's watershed are the key factors in determining the amount of phosphorus the watershed exports to the lake; 1) the size of the watershed, and 2) the land cover (land use) within the watershed. The impact of the watershed size is dependent on how large it is relative to the size of the lake. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drains to each surface-acre of the lake. Larger ratios result in the watershed having a greater role in the lake's annual water budget and phosphorus load.

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

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

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

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

A reliable and cost-efficient method of creating a general picture of a watershed's affect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface. WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

Two Sisters Lake resides within the Northwoods of Wisconsin. Indeed, the largest portion (44% or 1,056 acres) of land within the lake's watershed is forested (Figure 3.2-1 and Map 2). The surface of Two Sisters Lake is actually the second largest "land" cover type within the watershed, at 705 acres (30% of the watershed), followed by wetlands (20% or 474 acres) and pasture / grass (6% or 139 acres). Overall, the watershed is relatively small in size at 2,374 acres including the surface area of Two Sisters Lake. This makes for a small watershed to lake area ratio at 2:1.

WiLMS was utilized to estimate the annual phosphorus load to Two Sisters Lake. Model results may be viewed in Appendix E. It is difficult to accurately model lakes with no tributary input (spring lakes and seepage lakes), as WiLMS is designed to model drainage systems with an inlet and an outlet most accurately. However, this modeling program may be used to give managers a general idea of the phosphorus load to a spring or seepage lake. Additionally, in-field samples of the lake's water quality may be used to calibrate the model and ensure accuracy. Because water quality data are readily available through the efforts of Two Sisters Lake volunteers and also through this project, these calibrations were able to be made.

The annual phosphorus load to Two Sisters Lake is approximately 353 lbs (Figure 3.2-2). Because of the small watershed, which is also in good condition, the greatest contributor of phosphorus to Two Sisters Lake is actually the lake surface, which collects 190 lbs (54% of the total load) of phosphorus a year through atmospheric deposition. Forested lands, the largest land cover type, contribute 84 lbs (24%), while wetlands (12%) and pasture / grass lands (10%)

export smaller portions of the annual load. The phosphorus load, at 353 lbs, is quite small especially considering the massive size and depth of Two Sisters Lake.

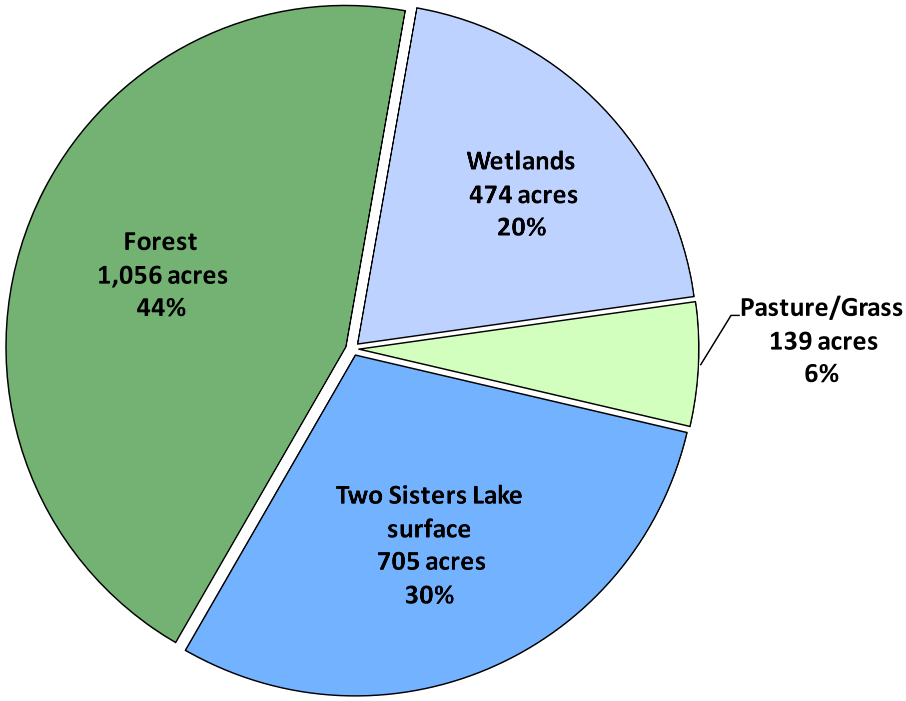


Figure 3.2-1. Two Sisters Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

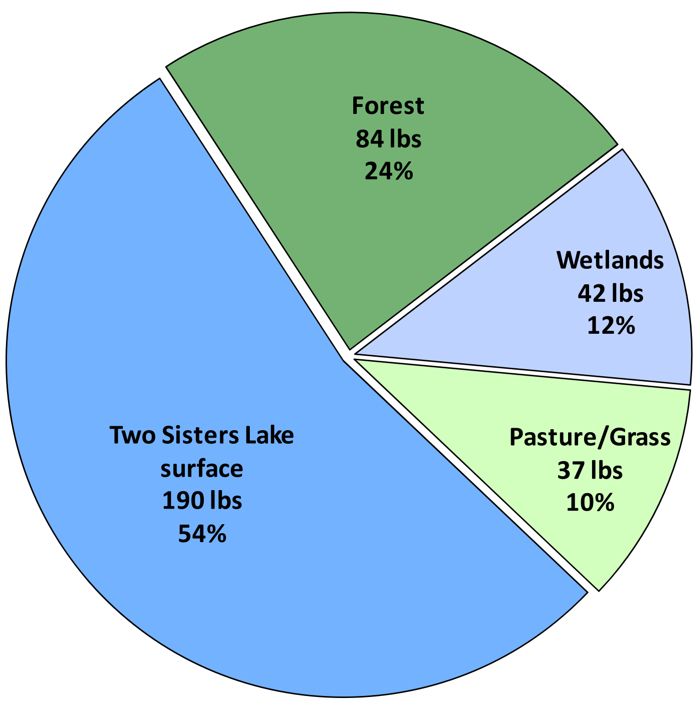


Figure 3.2-2. Two Sisters Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

As previously mentioned, lakes that have a small watershed to lake area ratio are particularly vulnerable to changes that may occur within the watershed. A relatively small conversion of one land cover type to another may have significant impacts, likely not in the short-term, upon the lake. WiLMS was utilized to model a scenario in which 25% (264 acres) of the forested land present in the watershed was converted to a medium density urban classification. This relatively small change in land management resulted in a 28% increase in the annual total phosphorus load to the lake. Using predictive equations from Lillie et al. (1993), this would result in an increase of chlorophyll-*a* from the observed growing season of average of approximately 2.0 µg/L to 6.3 µg/L, and Secchi disk transparency would decline from the observed growing season average of approximately 16 feet to 9 feet. The shoreline of a lake is a critical zone in terms of protecting the health of a lake, but is often subject to modifications which increase the level of unnatural development. This particular area of the watershed is discussed further in the next section.

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:

<u>Wisconsin-NR 115: Wisconsin's Shoreland Protection Program</u>

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, installation of rain gardens, and removal of fire pits and/or 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 or 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 woody habitat and often feed upon many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. Newbrey et al. (2005) found that some fish species prefer different complexity of branching on coarse woody habitat, though in general some degree of branching is preferred over coarse woody habitat that has no branching.

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

Native Species Enhancement

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

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

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

Cost

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

This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

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

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

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

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

Two Sisters Lake Shoreland Zone Condition

Shoreland Development

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

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

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

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

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

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

Figure 3.3-1. Shoreline assessment category descriptions.

On Two Sisters Lake, the development stage of the entire shoreline was surveyed during late summer of 2011, using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

Two Sisters Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.9 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 3.2-4). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.0 mile of urbanized and developed–unnatural shoreline were observed. If restoration of the Two Sisters Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreline lengths around the entire lake.

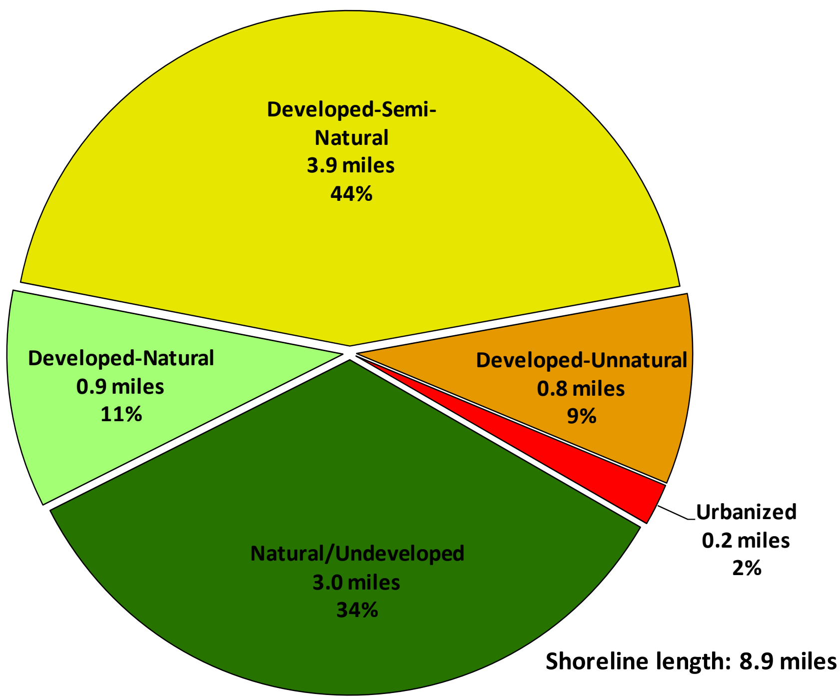


Figure 3.3-2. Two Sisters Lake shoreland categories and total lengths. Based upon a summer 2011 survey. Locations of these categorized shorelands can be found on Map 3.

3.4 Aquatic Plants

Introduction

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

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

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

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

Aquatic Plant Management and Protection

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

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

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that 30 feet. 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 (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*). • Permitting process may require an environmental assessment that may take months to prepare. • Unselective.

Mechanical Harvesting

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

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)
		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; Eurasian water milfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance natives species including duckweeds, trageted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

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

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

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

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

Cost

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

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

Biological Controls

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

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

Cost

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

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

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

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

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

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

Analysis of Current Aquatic Plant Data

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

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

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

Species Diversity and Richness

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Two Sisters Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-2) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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

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

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Two Sisters Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1).

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

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

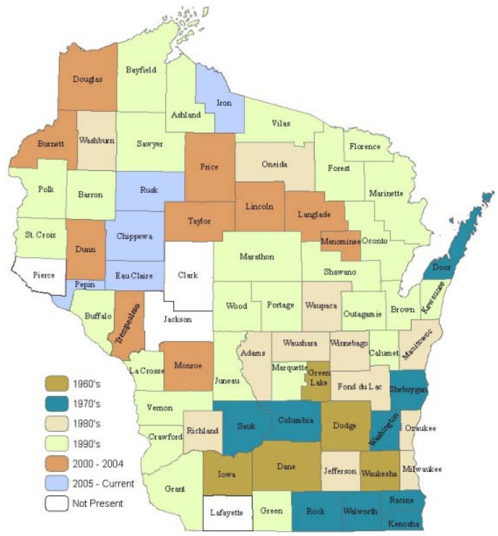


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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 above, numerous plant surveys were completed as a part of this project. On June 23, 2011, a survey was completed on Two Sisters Lake that focused upon locating any potential occurrences of the non-native curly-leaf pondweed. This meander-based survey of the *littoral zone* did not locate any occurrences of this invasive plant. It is believed that this aquatic invasive species is currently not present in Two Sisters Lake or it exists at an undetectable level.

The whole-lake aquatic plant point-intercept and community mapping surveys were conducted on Two Sisters Lake on July 27 and 29, and August 3 and 4, 2011 by Onterra (Appendix F). During these surveys, a total of 61 native aquatic plant species were located; no non-native plants were located during the 2011 surveys. Two species located, Vasey's pondweed (*Potamogeton vaseyi*) and northeastern bladderwort (*Utricularia resupinata*), are listed as species of special concern by the Wisconsin Natural Heritage Inventory (NHI) Program due to uncertainty regarding their population abundance and distribution within Wisconsin (WDNR 2012).

As determined from the point-intercept survey, the majority of the sediment within littoral areas of Two Sisters Lake is comprised of sand (76%), while organic sediments (muck) and rock comprise the remaining 16% and 8%, respectively. Map 5 illustrates that the majority of shallower, near-shore areas of Two Sisters Lake are comprised of sandy substrates, while areas of muck were encountered in the isolated bays. Deeper areas of the littoral zone (>14 feet) are likely comprised of mucky substrates; however, the sediments in these areas were not able to be determined to the deeper depths.

Approximately 61% of the 732 locations sampled within the maximum depth of plant growth (30 feet), or the littoral zone, contained aquatic vegetation. Map 6 shows that the majority of the aquatic vegetation in Two Sisters Lake is located within near-shore areas and shallow bays. The exceptional water clarity in Two Sisters Lake allows aquatic plants to inhabit deeper areas of the lake as they can receive adequate amounts of sunlight to support photosynthesis.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 3.4-1). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

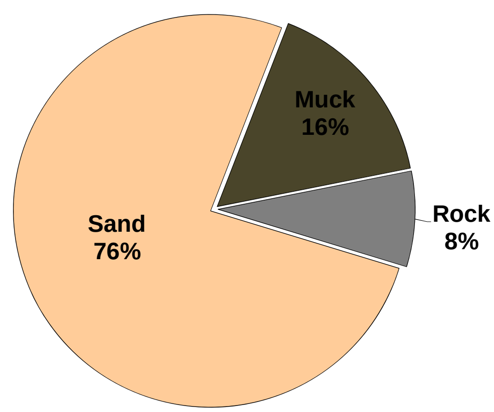


Figure 3.4-2. Two Sisters Lake proportion of substrate types within littoral areas. Created using data from July-August 2011 aquatic plant point-intercept survey.

Table 3.4-1. Aquatic plant species located in Two Sisters Lake during July and August 2011 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2011 (Onterra)
Emergent	*Calla palustris*	Water arum	9	I
	Carex comosa	Bristly sedge	5	I
	Carex lasiocarpa	Woolly-fruit sedge	9	I
	Carex utriculata	Common yellow lake sedge	7	I
	Carex stricta	Common tussock sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	X
	Equisetum fluviatile	Water horsetail	7	I
	Glyceria canadensis	Rattlesnake grass	7	I
	Iris versicolor	Northern blue flag	5	I
	Juncus effusus	Soft rush	4	I
	Lysimachia terrestris	Bulbil loosestrife	7	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Sagittaria rigida	Stiff arrowhead	8	X
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Schoenoplectus tabernaemontani	Softstem bulrush	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 angustifolium*	Narrow-leaf bur-reed	9	X
	Sparganium emersum	Short-stemmed bur-reed	8	I
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elatine minima	Waterwort	9	X
	Elodea canadensis	Common waterweed	3	X
	Eriocaulon aquaticum	Pipewort	9	X
	Gratiola aurea	Golden pert	10	X
	Isoetes spp.	Quillwort species	8	X
	Lobelia dortmanna	Water lobelia	10	X
	Myriophyllum alterniflorum	Alternate-flowered water milfoil	10	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Myriophyllum tenellum	Dwarf water milfoil	10	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton alpinus	Alpine pondweed	9	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton illinoensis	Illinois pondweed	6	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	I
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	X
	*Utricularia resupinata**	Small purple bladderwort	9	X
	Utricularia vulgaris	Common bladderwort	7	I
	Vallisneria americana	Wild celery	6	X
SE	*Eleocharis acicularis*	Needle spikerush	5	X
	Juncus pelocarpus	Brown-fruited rush	8	X
	Sagittaria cuneata	Arum-leaved arrowhead	7	I
	Sagittaria graminea	Grass-leaved arrowhead	9	I
FF	*Lemna turionifera*	Turion duckweed	2	I

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

Photograph 3.4-1. Lake quillwort of the isoetid growth form (left), and alpine pondweed of the elodeid growth form (right).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely familiar with (Photo 3.4-1). It is important to note that these two groups are based solely on morphology and not on species' relationships; for example, dwarf-water milfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum sibiricum*) are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide and must be supplemented from bicarbonate. On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize carbon storage. While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in some lakes, like Two Sisters Lake, alkalinity levels are not too high or too low, and the aquatic plant community is comprised of both isoetids and elodeids.

As was discussed in the Water Quality Section, alkalinity and associated calcium and magnesium have been increasing within Two Sisters Lake over time, but the direct cause of the increase is not yet known. This process of increasing alkalinity within a lake is termed alkalinisation. Studies have documented increased prevalence of elodeids and loss of isoetids over time in lakes that see increases in alkalinity (Borman et al. 2009). Historic aquatic plant data are not available from Two Sisters Lake, so it is not known if elodeids have in fact been increasing over time. The main concern regarding alkalinisation is the long-term viability of isoetid populations; many are listed as special concern or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation. The impact on the overall lake ecology of a shift from isoetids to elodeids is less apparent, but it has been shown that isoetids modify the sediment in a way which essentially traps and immobilizes bioavailable phosphorus within the lake and makes it less available to other plants and free-floating algae (Smolders et al. 2002).

As mentioned previously, Two Sisters Lake contains aquatic plant species of both the isoetid and elodeid growth form. Figure 3.4-3 displays the frequency of occurrence of isoetids and elodeids as well as floating-leaf and emergent aquatic plants across littoral depths of the lake. While isoetids and elodeids co-occurred from 1 to 14 feet, isoetids were dominant in near-shore areas from 1 to 3 feet and elodeids dominated deeper areas (Figure 3.4-3). Floating-leaf and emergent species were restricted to shallower water. Theoretically, if alkalinity continues to increase within the lake, elodeids may out-compete isoetids in deeper water and restrict their growth to shallow, near-shore areas.

Map 7 displays the locations of isoetid, elodeid, and characeans within Two Sisters Lake and displays spatially what Figure 3.4-3 illustrates. Characeans include *Chara* and *Nitella* species which are genre of macroalgae. The map shows that point-intercept locations with just isoetid species were located in very shallow, near-shore areas. Progressing lake-ward into deeper water, both elodeids and isoetids co-occur. And finally, in the deepest areas of the littoral zone, elodeids and characeans dominate.

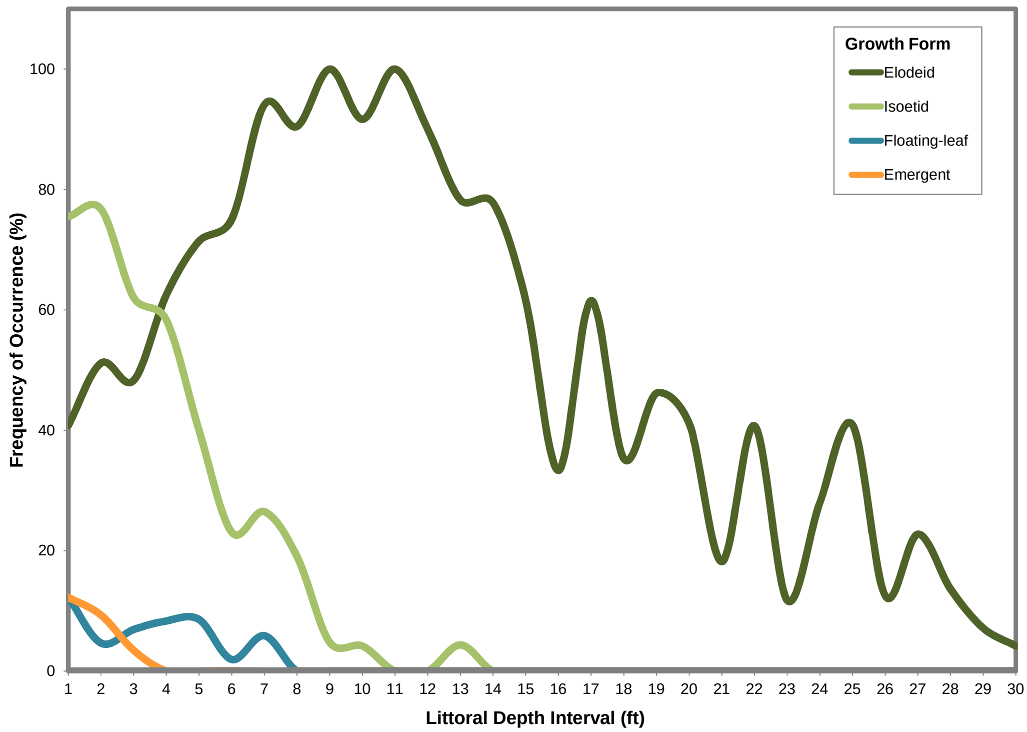


Figure 3.4-3. Frequency of occurrence of isoetids, elodeids, floating-leaf, and emergent aquatic plant species on Two Sisters Lake. Created using data from July-August 2011 aquatic plant point-intercept survey.

Of the 41 aquatic plant species located during the point-intercept survey, fern pondweed, slender naiad, and muskgrasses, were the most prevalent (Figure 3.4-4). Fern pondweed, as its name suggests, has the appearance of a fern's leaf and is a common pondweed found in lakes in northern Wisconsin. In clear lakes, this species can be found growing deeper than many other of the pondweed species. In Two Sisters Lake, fern pondweed was most abundant between 9 and 13 feet, with 70% of the point-intercept locations within these depths containing it. 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.

Slender naiad is one of the more common naiad species found in Wisconsin. This plant is often found growing in sandy areas of lakes and streams. Being an annual, this species produces a large number of seeds which have been shown to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 2007). Their numerous seeds, leaves, and stems all provide sources of food, and their small, condensed network of leaves provide excellent habitat for aquatic organisms.

Muskgrasses resemble other large vascular aquatic plants, but are actually a group of macroalgae. Several species of muskgrasses occur in Wisconsin, and they all exude a strong, skunk-like odor when removed from the water. Often found growing in larger beds, they provide structural habitat and sources of food for aquatic organisms.

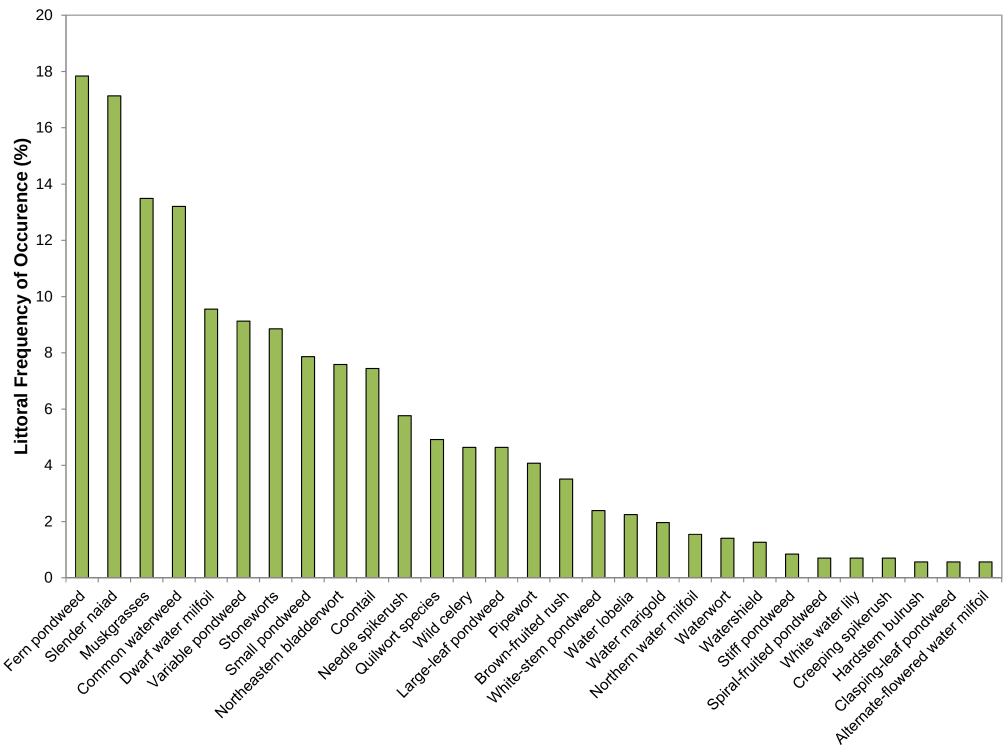


Figure 3.4-4. Two Sisters Lake aquatic plant littoral occurrence analysis. Note: Only species with a littoral occurrence of >1% are displayed. Created using data from July-August 2011 aquatic plant point-intercept survey.

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 61 native aquatic plant species were located in Two Sisters Lake during the 2011 surveys, 41 were encountered on the rake during the point-intercept survey. The native species encountered on the rake and their conservatism values were used to calculate the FQI of Two Sisters Lake's aquatic plant community (equation shown below).

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

Figure 3.4-5 compares the FQI components from Two Sisters Lake calculated from the 2011 point-intercept survey to median values of lakes within the Northern Lakes and Forests Ecoregion in Wisconsin. As displayed in Figure 3.4-5, the native species richness and average conservatism values for Two Sisters Lake exceed median values for both the ecoregion and the state. Combining Two Sisters Lake's native species richness and average conservatism values yields an exceptionally high FQI value of 46.9, greatly exceeding the ecoregional and state medians (Figure 3.4-5). This analysis indicates that the aquatic plant community of Two Sisters Lake is of higher quality than the majority of lakes within the Northern Lakes and Forests Ecoregion and the entire state of Wisconsin.

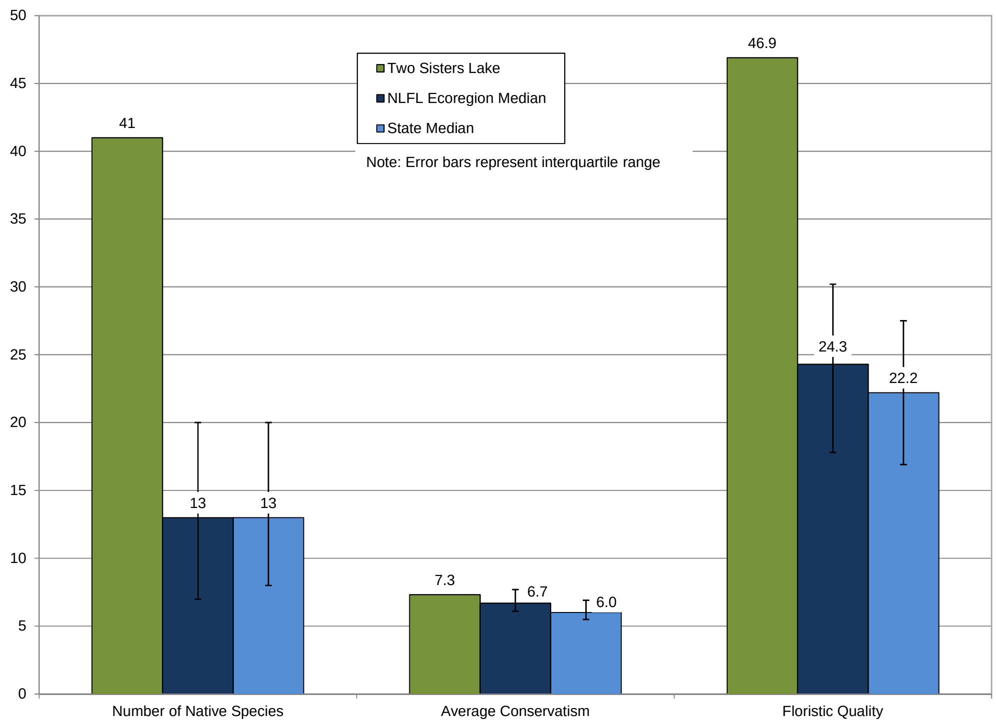


Figure 3.4-5. Two Sisters Lake Floristic Quality Assessment. Created using data from 2011 aquatic plant point-intercept survey.

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 Two Sisters Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Two Sisters Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLFL Ecoregion (Figure 3.4-6). Using the data collected from the 2011 point-intercept survey, Two Sisters Lake's aquatic plant community was shown to have very high species diversity with a Simpson's diversity value of 0.94. This diversity value falls right on the maximum diversity value for lakes sampled within the ecoregion and the state (Figure 3.4-6), meaning that no lakes within the WDNR's surveys had a diversity value greater than 0.94. This value indicates that if two individual aquatic plants were randomly sampled from Two Sisters Lake, there would be a 94% probability that they would be different species.

The littoral frequency of occurrence analysis allows for an understanding of how often each of the plant species is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while fern pondweed was located at approximately 18% of the littoral sampling locations in Two Sisters Lake, its relative frequency of occurrence is 11%. Explained another way, if 100 plants were randomly sampled from Two Sisters Lake, 11 of them would be fern pondweed.

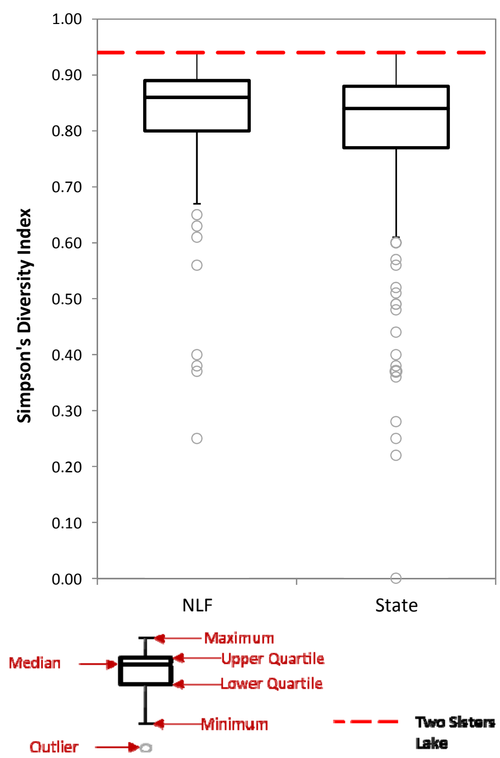


Figure 3.4-6. Two Sisters Lake species diversity index. Created using data from 2011 aquatic plant point-intercept survey.

Figure 3.4-7 displays the relative frequency of occurrence of aquatic plant species in Two Sisters Lake from the 2011 point-intercept survey and illustrates the relatively even distribution of species within the community; the aquatic plant communities are not overly dominated by a single or few species which creates a highly diverse community.

The quality of Two Sisters Lake's aquatic plant community is also indicated by the occurrence of emergent and floating-leaf plant communities that occur in the lakes. The 2011 community map indicates that approximately 26.4 acres (3.7%) of the 705-acre lake contain these types of plant communities (Table 3.4-2). Twenty-three floating-leaf and emergent species were located in Two Sisters Lake (Table 3.4-1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines.

The community map represents a 'snapshot' of the important plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Two Sisters Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. A stakeholder survey of TSLPOA members indicates that motorboats with a 25 horsepower or greater motor are the second-most prevalent watercraft on the lake (Appendix B, Question #14). Additionally, stakeholders indicated throughout the survey that lakeshore development and jet ski/boat traffic are of great concern and may be impacting the lake (Questions #27, #28, General Comments).

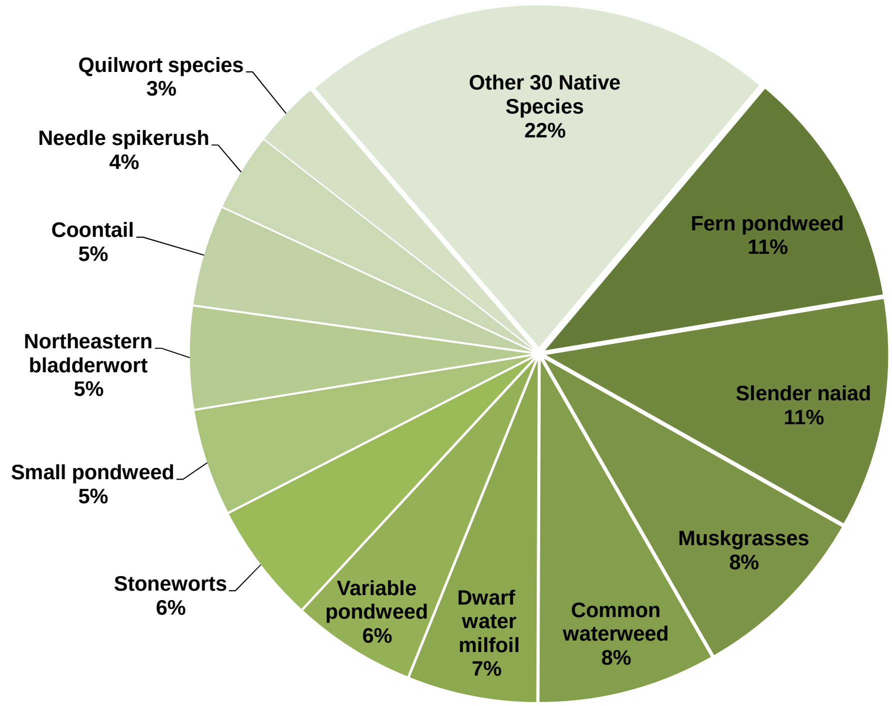


Figure 3.4-7. Two Sisters Lake aquatic plant relative occurrence analysis. Created using data from July-August 2011 aquatic plant point-intercept survey.

Table 3.4-2. Two Sisters Lake acres of floating-leaf and emergent plant communities. Created from the July-August 2011 community mapping survey.

Plant Community	Acres
Floating-leaf	4.1
Emergent	7.8
Floating-leaf & Emergent	14.5
Total	**26.4**

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 are 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 Two Sisters Lake. The goal of this section is to provide an incomplete overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the TSLPOA 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 2012 & GLIFWC 2012A and 2012B).

Two Sisters Lake Fishery

Two Sisters Lake Fish Species and Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was ranked 5th on a list of activities stakeholders participate in on Two Sisters Lake (Question #15). 89% of survey respondents have fished on Two Sisters Lake before, and 38% have been fishing the lake for over 25 years (Questions #9 & #10). Smallmouth bass, bluegill / sunfish and walleye are the species most commonly caught by stakeholders (Question #12). Approximately 78% of respondents believed that the quality of fishing on the lake was fair or good (Question #11); however, 36% believe the quality of fishing has gotten somewhat worse and 40% believe the fishing has remained the same since they began fishing the lake (Question #13).

Table 3.5-1 shows the popular game fish that are present in the system, while Table 3.5-2 displays some of the non-game fish in the 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 Two Sisters Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

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

Table 3.5-1. Gamefish present in Two Sisters Lake with corresponding biological information. Species list from WDNR surveys (WDNR, 2012). Biological information from Becker, 1983.

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead	*Ictalurus melas*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	*Lepomis gibbosus*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass	*Micropterus dolomieu*	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye	*Sander vitreus*	18	Mid April - early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Bullhead	*Ameiurus natalis*	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Table 3.5-2. Non-gamefish present in Two Sisters Lake. Species list from WDNR surveys (WDNR 2012).

Common Name	Scientific Name	Common Name	Scientific Name
Bluntnose minnow	*Pimephales notatus*	Greater redhorse	*Moxostoma valenciennesi*
Cisco	*Coregonus artedi*	Hornyhead chub	*Nocomis biguttatus*
Common shiner	*Luxilus cornutus*	Johnny darter	*Ethostoma nigrum*
Creek chub	*Semotilus atromaculatus*	Mimic shiner	*Notropis volucellus*
Golden shiner	*Notemigonus crysoleucas*	White sucker	*Catostomus commersoni*

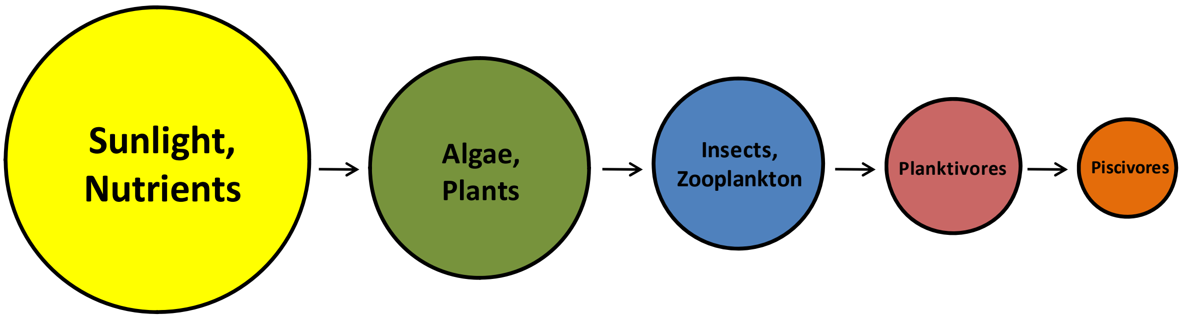


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

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

Two Sisters Lake Spear Harvest Records

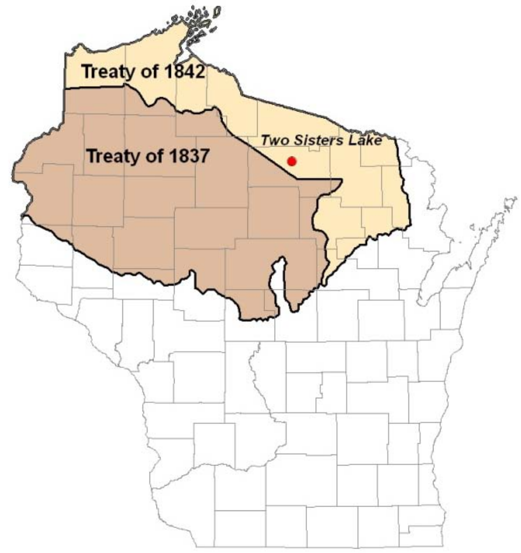


Figure 3.5-2. Location of Two Sisters Lake within the Native American Ceded Territory (GLIFWC 2012A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

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). Two Sisters 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).

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 2012B). 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 quota 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 quota is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller quotas. Starting with the 2011 spear harvest season, on lakes with a harvestable quota of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye open water spear harvest records are provided in Table 3.5-3. One common misconception is that the spear harvest targets the large spawning females. Table 3.5-3 and Figure 3.5-2 clearly show that the opposite is true with only 7.8% of the total walleye harvest (116 fish) since 1998 comprising of female fish on Two Sisters Lake. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIFWC 2012B). This regulation limits the harvest of the larger, spawning female walleye.

Table 3.5-3. Open water spear harvest data of walleye for Two Sisters Lake. Data provided by the WDNR (T. Cichosz, personal communication).

Year	Safe Harvest	Declaration	Harvest	%Male	%Female	%Unknown
1998	80	43	43	83.7	7.0	9.3
1999	167	66	66	95.5	4.5	0.0
2000	144	57	56	98.2	1.8	0.0
2001	292	160	158	93.9	3.0	3.0
2002	291	160	160	87.5	5.6	6.9
2003	332	132	132	93.9	2.3	3.8
2004	285	113	111	92.8	5.4	1.8
2005	279	153	144	74.6	19.6	5.8
2006	245	97	84	91.7	2.4	6.0
2007	210	83	71	76.1	4.2	19.7
2008	280	153	149	94.6	4.0	1.3
2009	242	96	96	86.5	13.5	0.0
2010	207	159	159	87.9	12.1	0.0
2011	283	155	154	75.2	18.3	6.4
2012	143	57	57	91.2	7.0	1.8

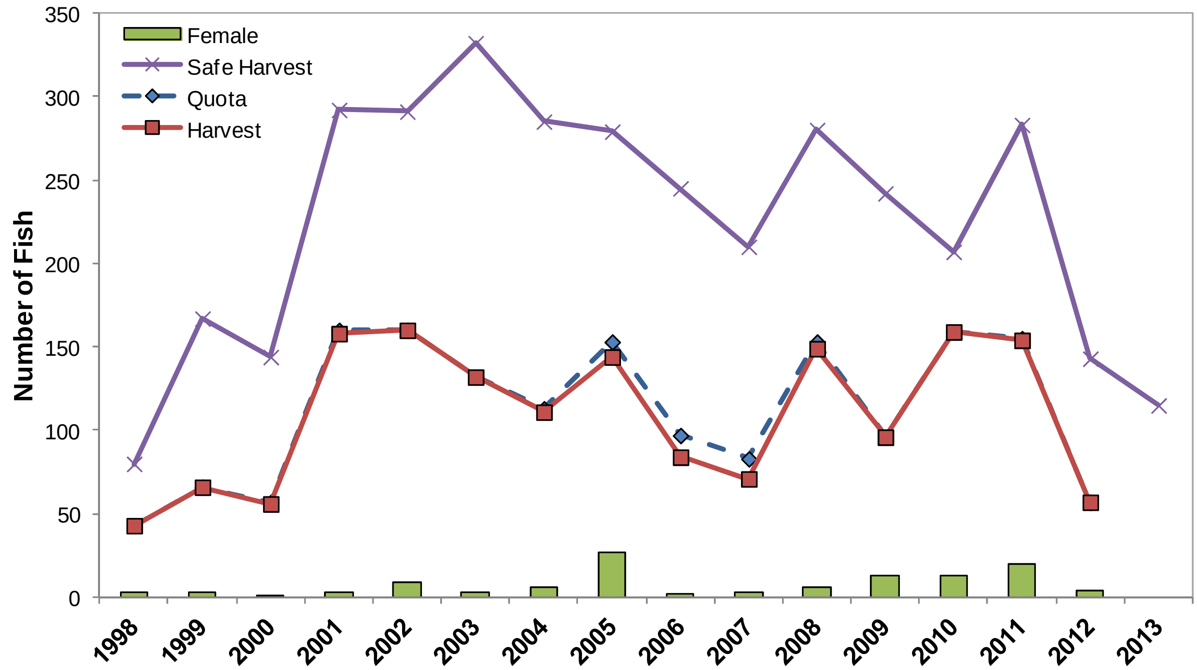


Figure 3.5-3. Open water spear harvest data of walleye for Two Sisters Lake. Annual walleye spear harvest statistics are displayed since 1998 for Two Sisters Lake (T. Cichosz, personal communication).

Table 3.5-4 displays the Native American open water muskellunge spear harvest since 1998. Since 1998, an average of less than two muskellunge per year have been harvested during the open water spear fishery. Between 1998 and 2012, no muskellunge have been speared in seven of the years, while the declared quota has been filled once (2002).

Table 3.5-4. Open water spear harvest data of muskellunge for Two Sisters Lake. Data provided by the WDNR (T. Cichosz, personal communication).

Year	Safe Harvest	Declaration	Harvest
1998	15	7	5
1999	27	13	3
2000	14	7	0
2001	15	7	2
2002	15	7	7
2003	15	7	0
2004	14	7	0
2005	15	8	1
2006	16	9	0
2007	11	6	3
2008	17	10	0
2009	17	10	0
2010	17	10	1
2011	17	10	2
2012	16	9	0

Two Sisters Lake Fishing Regulations

Because Two Sisters Lake is located within ceded territory, special fisheries regulations may occur, specifically in terms of walleye. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which explains the more restrictive bag or length limits that may pertain to Two Sisters Lake. In 2011-2012, the daily bag limit remained at three fish for the lake. The minimum length limit for walleye is 15”.

Statewide or regional regulations apply for all fish species. For bass species, the first Saturday in May through the third Saturday in June is reserved for a catch and release season only. Following the third Saturday in June, five bass of either species may be harvested, with a minimum length of 14”. Two Sisters Lake is in the northern half of the muskellunge and northern pike management zone. Muskellunge must be 40” to be harvested, with a daily bag limit of one fish, while no minimum length limit exists for northern pike and five pike may be kept in a single day.

Two Sisters Lake Fish Stocking

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

Muskellunge were stocked in the lake several times in the 1970’s and 1980’s, and often during the 1990’s (Table 3.5-5). Stocking records for this species end in 2001. Currently, the lake is classified as a Category 1 muskellunge lake, meaning the population is self-sustaining through natural reproduction. Generally, stocking is not necessary to supplement a self-sustaining population.

Walleye were stocked intermittently in the 1970’s and 1980’s, and regularly through the 1990’s and 2000’s (Table 3.5-6). Currently, the lake is stocked every other year with small fingerlings. Most recently, (2009 and 2011) the lake was stocked with walleye at a density of 35 small fingerlings per acre. WDNR regional biologist John Kubisiak noted in personal conversation that although walleye are being stocked with good contribution, WDNR crews have seen good natural reproduction in recent years.

Table 3.5-5. Muskellunge stocking data available from the WDNR. (WDNR 2012).

Year	Age Class	# Stocked	Avg. Length (inches)
1974	Fingerling	1,521	7
1977	Fingerling	1,671	9
1980	Fingerling	1,400	9.5
1983	Fingerling	700	9
1985	Fingerling	1,408	9.5
1990	Fingerling	1370	11
1991	Fingerling	700	11
1992	Fingerling	850	10
1992	Fry	35,750	3.5
1993	Fry	10,500	0.4
1995	Fry	168,000	0.4
1996	Fingerling	2,800	10.7
1996	Fry	100,000	0.5
1998	Fry	56,000	0.5
2000	Fry	62,600	0.5
2001	Fry	162,000	0.5

Table 3.5-6. Walleye stocking data available from the WDNR. Shaded items indicate permitted stocking conducted by the TSLPOA (WDNR 2012).

Year	Age Class	# Stocked	Avg. Length (inches)
1976	Fingerling	20,000	3
1977	Fingerling	35,000	3
1982	Fingerling	12,800	3
1986	Fingerling	35,000	2
1987	Fingerling	124,695	2
1989	Fingerling	49,406	2.67
1991	Fingerling	35,144	2
1992	Fingerling	17,686	2
1992	Fry	688,500	0
1993	Fingerling	30,540	2
1995	Fingerling	36,144	1.9
1995	Fry	1,000,000	0.2
1997	Fry	500,000	0.3
1998	Fry	1,000,000	0.3
1999	Small Fingerling	71,900	1.5
2000	Fry	2,000,000	0.3
2001	Small Fingerling	71,900	1.6
2001	Large Fingerling	700	6.0
2003	Small Fingerling	71,900	1.3
2003	Large Fingerling	1,675	6.5
2005	Small Fingerling	35,947	1.3
2006	Large Fingerling	799	7.5
2007	Small Fingerling	11,392	2.8
2009	Small Fingerling	25,168	1.7
2011	Small Fingerling	25,165	1.8

Two Sisters Lake Substrate Type

According to the point-intercept survey conducted by Onterra, 76% of the substrate sampled in the littoral zone on Two Sisters Lake was sand, while 16% of the substrate was classified as organic muck and 8% was determined to be rock of various size (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.

Two Sisters Lake Fisheries Management

The WDNR considers Two Sisters Lake a “trend” lake, meaning that a comprehensive survey takes place every three years to identify changes in the fish community. Because there are so many lakes in Wisconsin, particularly in the northern ecoregion, many lakes do not receive this much attention from fishery managers with the WDNR.

Two Sisters Lake is currently being managed as a walleye and muskellunge lake by the WDNR. Specifically, because of Two Sisters Lake’s habitat type, water chemistry, and size, the lake is best suited towards management of a walleye and muskellunge fishery with low-density, but high-quality size structure and good trophy potential. Another interesting factor affecting the fishery is the presence of cisco (*Coregonus artedi*) in the lake. Cisco, are now found in about 170 lakes across Wisconsin. Cisco are particularly sensitive to the water quality of the lake; they prefer deep, cold lakes with well oxygenated water. Cisco are a key forage species for walleye, muskellunge and trout species in the Great Lakes as well as inland lakes where they are found.

Numerous types of surveys have taken place on Two Sisters Lake to study the fishery. Because Two Sisters Lake is being studied for long-term trends, the WDNR conducts electrofishing surveys on the lake each fall season. GLIFWC has conducted these surveys in the past as well, and now conducts shoreline surveys to assess the strength of the young (age 0 and age 1) walleye class. Additionally, each year it is active, GLIFWC monitors the spear harvest that occurs on Two Sisters Lake. Data from these surveys help greatly in making future decisions regarding the fishery.

WDNR staff have completed creel surveys on the lake on six occasions since 1992. Creel surveys are a series of short, informal interviews with fisherman and are conducted right on the lake of interest. They provide valuable information on sport angler activities and their impacts on the fish populations of a waterbody. From this data, fisheries managers can determine trends in total catch and harvest for the lake, and also estimate the number of hours it takes anglers to catch a particular species of fish. Creel survey summaries from 1992, 1998, 2002, 2005, 2008 and 2011 are summarized in Table 3.5-7.

Table 3.5-7. Two Sisters Lake WDNR creel survey summary (WDNR 2012).

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch / Acre	Harvest / Acre
Largemouth Bass	1992	26.8	2.9	0.7	0.1
	1998	20.1	2.3	0.3	0
	2002	21.3	2.7	0.7	0
	2005	18.8	1.5	1.8	0
	2008	12.3	1.7	1.7	0
	2011	18.9	2.5	2.5	0.2
Muskellunge	1992	26.8	6	0.2	0
	1998	20.1	6.1	0.2	0
	2002	21.3	6.7	0.2	0
	2005	18.8	5.1	0.2	0
	2008	12.3	2.4	0.1	0
	2011	18.9	5.0	0.1	0
Northern Pike	1992	26.8	2	0.8	0.1
	1998	20.1	0.8	0.5	0
	2002	21.3	1.6	0.5	0
	2005	18.8	0.8	1	0
	2008	12.3	0.5	0.3	0
	2011	18.9	1.4	0.6	0.2
Smallmouth Bass	1992	26.8	6.5	2.7	0.5
	1998	20.1	3.1	1.8	0.1
	2002	21.3	4.4	3.8	0.1
	2005	18.8	2	2.8	0
	2008	12.3	2.3	2.9	0.1
	2011	18.9	3.9	4.8	0.5
Walleye	1992	26.8	18.2	2.3	0.6
	1998	20.1	8.8	1.2	0.2
	2002	21.3	10.1	0.6	0.1
	2005	18.8	8.4	0.6	0.4
	2008	12.3	7.4	0.4	0.3
	2011	18.9	7.9	0.4	0.3

In addition to creel surveys, the WDNR conducts surveys to estimate the adult walleye population in Two Sisters Lake. These surveys have coincided with creel survey efforts (1998, 2002, 2005, 2008 and 2011). Over these years, the estimated walleye population has been between 995 fish, or 1.4 fish per acre and 2,714 fish, or 3.8 fish per acre (WDNR 2012). Fluctuations in population occur both naturally and as a result of harvest efforts, stocking trends, etc. For example, some environmental condition (precipitation, warm/cold weather, etc.) may impact walleye spawning on a given year, resulting in a low year class in terms of young walleye survival.

These survey efforts give managers a good idea of the dynamics and human impacts on the fishery of Two Sisters Lake. One aspect of a fishery is the level of harvest by humans. As previously mentioned, biologists determine the safe harvest level of a lake (the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers) using estimated population data. Following determination of the safe harvest level, tribal spearing quotas and state-licensed angler restrictions are created for that year.

Figure 3.5-4 displays data concerning the harvest of walleye from Two Sisters Lake, compared to the estimated adult population in years 1998, 2002, 2005, 2008 and 2011. In 2011, the most recent year in which these three sources provided data, the walleye population was estimated to be 995 fish. Of this total population, angler harvesting removed 23% (231 fish) and tribal spearing removed 15% (154 fish), leaving 610 adult walleye in that year.

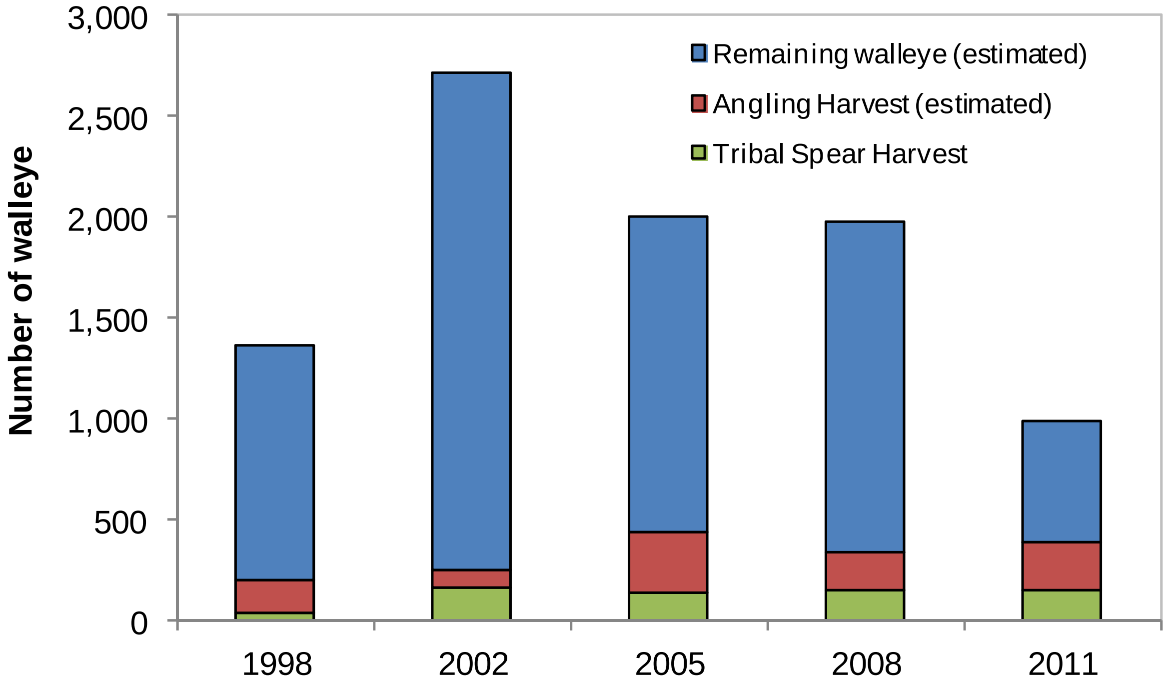


Figure 3.5-4. Walleye population and harvest data. Data includes WDNR population estimates, spear harvest counts and angling creel survey estimates (WDNR 2012 and T. Cichosz, personal communication).

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 Two Sisters Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, if any were found.
3) Collect sociological information from Two Sisters 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 Two Sisters Lake ecosystem, the folks that care about the lake, and what needs to be completed to protect and enhance this important waterbody.

The scientific studies conducted on Two Sisters Lake covered a variety of ecological components, including water quality, watershed and shoreland analysis, aquatic plant surveys, and an integration of available fisheries data. All study results point towards the ultimate conclusion that Two Sisters Lake is in outstanding condition. The water quality analysis included over 20 years of available data for some parameters. This could not have been done without sampling undertaken by volunteers through the Citizens Lake Monitoring Network. The importance in these volunteer efforts is that in building a large database, lake managers are able to determine if trends are occurring for certain, instead of relying upon anecdotal accounts of what is occurring. The CLMN volunteers' work should be commended and actions taken to ensure these efforts continue.

The water quality of Two Sisters Lake was determined to be exceptional, with phosphorus and chlorophyll-*a* values and Secchi disk readings ranking in categories of *Excellent*. These values are above average compared to similar lakes across the state and all lakes within the Northern Lakes and Forests ecoregion as well. The TSLPOA had been collecting water quality data from each of the two basins for a number of years. A side-by-side comparison indicates that water chemistry is essentially the same between these two basins, with no statistically valid difference between all parameters analyzed. In the future, monitoring efforts may be condensed to include only one monitoring site – the deepest location, most-down flow, in the lake which would be within the west basin.

A lake's water chemistry is often a reflection of what is occurring within the surrounding watershed. Lakes with watersheds that are generally smaller and include natural land cover types typically contain less nutrients and exhibit higher water clarity than lakes with larger, human-disturbed watersheds. At a little over 2,300 acres, the watershed draining to Two Sisters Lake is quite small, and the land coverage is mostly natural, which is ideal for the lake ecosystem. The immediate watershed, or shoreland zone, has seen some development and human disturbance, but nearly four miles (45%) of the shoreline remains in a natural or developed but natural state. The TSLPOA may consider potentially restoring several areas of heavily disturbed shoreline, but preserving the natural shoreline that already exists may be of greater or equal importance.

During several aquatic plant surveys that were conducted in 2011, a total of 61 native aquatic plant species were found. This represents an incredible amount of biodiversity; most Northwoods Wisconsin lakes are hard-pressed to contain half this many species. Additionally, two species of special concern were found within the lake. The aquatic plant species present are representative of the high quality conditions found in Two Sisters Lake. Preserving the biodiversity of an aquatic plant community serves several functions. First, the diversity of the community is preferred by a variety of fish, insect, waterfowl and mammal species. Much like a forest ecosystem, which may contain wetlands, upland hardwoods, and areas with thick understory growth, a diverse habitat provides opportunity for a diverse animal community to exist. Secondly, a robust and rich aquatic plant community helps to keep aquatic invasive species from establishing, should they be introduced. Invasive species are termed "pioneer" species because they are adapt at quickly establishing in areas of disturbance. Lastly, a diverse aquatic plant community provides for an educational opportunity that cannot be matched on lakes with only a few aquatic plant species.

Though no fisheries studies were conducted on Two Sisters Lake as a part of this planning project, much was learned and compiled in this report through data provided by the WDNR and GLIFWC. It is difficult to sustain a large fishery with low primary productivity, as is described in the Fisheries Data Integration Section. Though with a variety of substrate type, aquatic plant habitat, and the management approach by the WDNR, GLIFWC and TSLPOA (stocking, surveys, habitat enhancement, etc.), a balanced fishery currently exists. Furthermore, the walleye fishery includes trophy sized fish potential. The key to maintaining the Two Sisters Lake fishery is to foster the existing, productive relationship with the WDNR and GLIFWC, and be proactive about approaches to enhance the habitat or species abundance in the lake.

The Two Sisters Lake ecosystem is in exceptional health. However, this was understood by the TSLPOA before the management planning project studies were conducted. The TSLPOA is a very hard-working, dedicated group that strives to protect their beloved lake. This was also known before the management planning project was begun. What this management planning project has done is quantified the current level of health the lake exhibits and will provide the baseline conditions to which future studies can be compared. This is particularly important in biological assessment/study, where scientific data are the foundation from which decision-making is derived. The planning process culminated with the creation of many management goals for the TSLPOA to pursue. The TSLPOA worked with Onterra staff to determine a reasonable course of action that would lead towards achieving these goals. This, the Implementation Plan of this document, can be found in the next section and outlines the ways in which the TSLPOA will facilitate effective communication through its membership and preserve the lake which it cares so deeply for – Two Sisters Lake.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Two Sisters Lake Planning Committee and ecologist/planners from Onterra. It represents the path the TSLPOA 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 Two Sisters 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: Develop and Maintain Partnerships with Cognizant Organizations

Management Action: Enhance the TSLPOA's involvement with other entities that partake in the management (management units) of Two Sisters Lake.

Timeframe: Continuation of existing efforts.

Facilitator: Board of Directors to appoint TSLOA representative(s).

Description: The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities and agencies. It is important that the TSLPOA actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. While not an inclusive list, the primary management units regarding Two Sisters Lake are the WDNR (fisheries, AIS, and lake management personnel), local school districts, the Newbold Lakes Committee, Oneida County Lakes & Rivers Association (OCLRA), Wisconsin Lakes, and Loon Watch staff. Each entity is specifically addressed in the table on the next page.

Action Steps:

1. See table guidelines on the next page.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
WDNR	Fisheries Biologist (John Kubisiak – 715.365.8919)	Manages the fishery of Two Sisters Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier – 715.365.8937)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Warden (Timothy Ebert – 715.356.5211)	Oversees regulations handed down by the state.	As needed.	Contact regarding suspected violations pertaining to recreational activity on Two Sisters Lake, include fishing, boating safety, ordinance violations, etc.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Late winter: contact to arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
Oneida County	Oneida County AIS Coordinator (Michele Saduaskas – 715.365.2750)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	Spring: AIS training and ID, AIS monitoring techniques Summer: Report activities to Ms. Saduaskas.
Rhinelander School District	Administrative staff - (715.365.9700 – general number)	Educational opportunities for school, volunteers for TSLPOA.	As needed.	Teachers/students may be interested in partnering in educational projects such as CLMN or CBCW.
Nicolet College	Administrative staff (715.365.4410 – general number)	Educational opportunities for school, volunteers for TSLPOA.	As needed.	Teachers/students may be interested in partnering in educational projects such as CLMN or CBCW.
Newbold Lakes Committee	Committee Chair (Scott Eshelman – 715.804.4403)	Coordinates efforts between lake groups in the Town of Newbold	As needed.	Attend meetings, check website (http://newboldlakes.blogspot.com) to learn of matters pertaining to area lakes.
Oneida County Lakes & Rivers Association (OCLRA)	Secretary (Connie Anderson – 715.282.5798)	Protects Oneida Co. waters through facilitating discussion and education.	Twice a year or as needed.	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Oneida Co. waterways.
Loon Watch	Contact person (Erica LeMoine – 715.682.1220)	Protects loons through education, monitoring and research.	As needed.	To assist in loon preservation, through loon monitoring and habitat enhancements. Data collected should be forwarded to the institute.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	TSLPOA members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

Management Goal 2: Develop a Succession Plan for the TSLPOA

<u>Management Action:</u> Review by-laws to determine applicability of individuals to Board of Directors.

Timeframe: Initiate winter of 2012-2013.

Facilitator: Board of Directors.

Description: The current TSLPOA Board of Directors is very active in matters pertaining to the preservation of Two Sisters Lake, as well matters involving the TSLPOA. Currently, there is concern that the level of quality work will not continue into the future if the current level of dedication of the association's board cannot be sustained. There is also uncertainty as to who is and who is not eligible to participate on the board. The board of directors will review the by-laws of the TSLPOA to develop a better understanding of who can and who cannot become a board member. The board will also identify prospective board members who will or will not be eligible to serve on the board.

Using this information, the current board of directors would recommend appropriate changes to the association by-laws that would potentially widen the field of perspective board members. Furthermore, if certain aspects of being a board member may preclude quality prospectives from participating, the board would also consider changes to responsibilities, numbers of board members, meeting schedules, etc. to make participation in the board more inviting.

Action Steps:

1. See description above.

Management Goal 3: Foster a Quality Fishery in Two Sisters Lake

<u>Management Action:</u> Work with fisheries managers to enhance the fishery on Two Sisters Lake.

Timeframe: Ongoing.

Facilitator: Board of Directors to appoint TSLOA representative.

Description: The results of the stakeholder survey associated with this project show that Two Sisters Lake stakeholders feel the fishery is currently fair to good (Appendix B, Question #11). Though there is a positive mentality about the fishery, most stakeholders do believe it has either remained the same or gotten worse (Question #13) since they started fishing the lake. The TSLPOA has (with WDNR permission) conducted private stocking of walleye in the past to bolster the fishery and are currently seeking ways to maximize the lake's fishery potential.

Understanding the limitations and stresses on the Two Sisters Lake ecosystem is the first step in developing a solution to angler concerns. From here, realistic goals and actions may be developed. Two Sisters Lake is currently overseen by WDNR fisheries biologist John Kubisiak (715.365.8919). In order to keep informed of studies that are occurring on Two Sisters Lake, a volunteer from the TSLPOA should contact Mr. Kubisiak at least once a year (perhaps during the winter months when field work is not occurring) for a brief summary of activities.

Additionally, the TSLPOA may discuss options for improving the fishery in Two Sisters Lake, which may include changes in stocking or habitat enhancements.

Action Steps:

1. See description above.

Management Goal 4: Increase Understanding of Shoreland Zoning Around Two Sisters Lake

Management Action: Assemble shoreland zoning regulations for Oneida County.
Timeframe: Begin winter of 2012-2013.
Facilitator: Board of Directors to appoint TSLOA subcommittee.
Description: County and state shoreland ordinances are designed to protect the valuable shorelines and associated habitat of our state's lakes and rivers. While it is not essential that every riparian property owner completely understand the ordinances, it is a benefit to the lake and its shoreland owners to have a basic understanding of the do's and don'ts associated with their property.

In order for TSLPOA members and other Two Sisters Lake property owners to have an understanding about how shorelines can or cannot be managed, the TSLPOA will appoint representative subcommittee to assemble shoreland zoning regulations for Oneida County. This will be done through an internet search of current regulations, supplemented with conversations with Karl Jennrich, Oneida County Planning and Zoning Administrator.

Action Steps:

1. See description above.

Management Action: Provide distilled shoreland zoning information to stakeholders.
Timeframe: Following completion of first Management Action.
Facilitator: Board of Directors to appoint TSLPOA representative.
Description: Once the Board of Directors has a better understanding of the shoreland zoning regulations for Oneida County, it will be important to condense this information into a useable form that all TSLPOA stakeholders will understand. A representative of the TSLPOA will distill information obtained through the regulation research aspect of this Management Goal, and provide it to the TSLPOA in a "user-friendly" format. This distilled version of the regulations may be included within a special mailing, incorporated into an email, or newsletter and distributed to all TSLPOA stakeholders.

Action Steps:

1. See description above.

Management Action: Make contact with large-tract property owners to discuss their options.
Timeframe: Following completion of first and second Management Action.
Facilitator: Board of Directors to appoint TSLPOA representative.
Description: There are several property owners along Two Sisters Lake which have sizable parcels of land. Currently, these properties are minimally developed which is beneficial to the serene nature of Two Sisters Lake, as well as the ecology of the

waterbody. As time goes on, changes may occur with property management or ownership of these parcels. These changes could potentially impact the quiet atmosphere and lake environment; therefore, it was discussed during the planning meetings that the TSLPOA make contact with large property owners to share several options for management of their property. Ideally, owners of large properties along the lake would make decisions that would ensure their property is kept in a natural state, instead of opening up opportunities for large-scale development. A representative from the TSLPOA will contact these large property owners for a discussion of options for property management.

Action Steps:

1. See description above.

<u>Management Action:</u> Develop policy for shoreland violations.
Timeframe: Following completion of first and second Management Action.
Facilitator: Board of Directors.
Description: As previously mentioned, shoreline regulations exist for Two Sisters Lake that have been declared by both the State and County legislatures. Local law enforcement and conservation wardens serve as the enforcement bodies overseeing these rules. As an influential and important management entity overseeing Two Sisters Lake, the TSLPOA is at times put in a position of supposed authority as well. It is natural for an association that has such good relations and communication with its members to hear about the good, and the bad, events that are occurring in and around the lake. When lake stakeholders share information about a potential violation with the TSLPOA, this creates a very difficult and potentially controversial decision for TSLPOA officials to make. On one hand, the association is there to serve the wishes of its members. On the other hand, the association must be responsible lake stewards as well. Opinions have differed amongst stakeholders as to what role the association should play in this scenario – should officials contact the suspected violator, refer the person who observed the violation to the proper authorities, contact the proper authorities themselves, or provide no response at all? In a survey distributed to lake stakeholders, 53% responded that the TSLPOA should "Request the proper authority to investigate the possible violation" (Appendix B, Question #37). To provide consistency, clarity and documentation on this position, the Board of Directors will develop an official policy and procedural mechanism to request the proper authority to investigate possible violations that may occur in the future.

Action Steps:

1. See description above.

Management Goal 5: Maintain Current Water Quality Conditions

<u>Management Action:</u> Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe: Continuation of current effort.
Facilitator: Board of Directors
Description: Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the

management of the lake by building a database that can be used for long-term trend analysis. In fact, within this document a more complete analysis was able to be conducted on Two Sisters Lake's water quality because of the extended dataset that is available. Early discovery of negative trends may lead to the reason as of why the trend is developing. Volunteers from the TSLPOA have collected Secchi disk clarities and water chemistry samples during this project and in the past through the WDNR Citizens Lake Monitoring Network (CLMN). Stability will be added to the program by selecting an individual from the TSLPOA to coordinate the lake's volunteer efforts and to recruit additional volunteers to keep the program fresh. In coordination with Management Goal 1, CLMN volunteers may coordinate with local schools to provide an educational opportunity for students wishing to learn about lake water chemistry and sampling methodology.

In the past, sampling was also conducted on Labor Day each year in both basins of Two Sisters Lake and analysis were conducted by an independent lab in Wausau. It was learned through the course of this project that the lab processing the samples did not utilize analysis methodology that was sensitive enough to accurately measure the relatively low amounts of phosphorus and other constituents present in Two Sisters Lake. Because of this, the data was not able to be integrated into this analysis. Therefore, the TSLPOA conduct CLMN approved monitoring from here on out to ensure results are comparable over time.

Action Steps:

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

Management Action: Investigate feasibility of shoreland restoration project on Two Sisters Lake.

Timeframe: Initiate in 2013.

Facilitator: Board of Directors

Description: As mentioned within the Shoreland Condition Assessment Section, much research has shown that the shoreland zone of a lake plays a vital role in providing habitat for wildlife and also retaining nutrients, sediments and pollutants from reaching the lake. The National Lakes Assessment report (USEPA 2009) states that lakes with impaired shorelands are three times more likely to display biological impairment. With much of the Two Sisters Lake watershed in great condition, the immediate shoreland zone is likely the best area the TSLPOA can concentrate efforts on to improving the lake. While the TSLPOA has committed to investigating ways to keep natural areas from becoming developed (discussed in Management Goal 4), it is also crucial for the group to look at restoring developed areas of the shoreland.

Many misconceptions are held regarding a natural shoreland. The costs involved, the level of work required for restoration, the visual aspects of the end product; these elements are largely unknown to most lake residents. Oneida County conservation specialists have much experience with this matter, and while their ability to answer questions and describe what a restored shoreland site might feature is useful, few things are as effective as a physical demonstration site. If the TSLPOA were to implement a single shoreland restoration site, it could be used as a demonstration tool to inform other riparian property owners about the costs.

The TSLPOA will investigate the feasibility of conducting a shoreland restoration project on Two Sisters Lake, including seeking out a willing private property owner, working with Oneida County conservation specialists to determine site suitability, etc. Priority will be given to areas depicted on Map 3 as being developed. If a successful shoreland restoration project is completed, it would be highlighted by the TSLPOA as a demonstration site. Pictures, educational material and site field trips, with property owner permission (if applicable), would be promoted by the association to inform other property owners of the shoreland restoration process. This in turn would hopefully spur further shoreland restoration actions on Two Sisters Lake.

Action Steps:

1. TSLPOA Board of Directors will seek out a willing riparian property owner for restoration work. Priority should be given to those properties identified as Urbanized, Developed-Unnatural or Developed-Semi-Natural as indicated on Map 3.
2. Using Appendix G, work with Oneida County Conservation Specialist to determine site suitability at applicable Two Sisters Lake locations.
3. Upon completion of project, highlight efforts of process in newsletter, on website or through other means as determined appropriate by the TSLPOA Board of Directors.

Management Goal 6: Maintain Water Levels on Two Sisters Lake

Management Action: Maintain Contingency Fund.
Timeframe: Continuation of current effort.
Facilitator: Board of Directors
Description: Water levels of spring and seepage lakes are subject to fluctuations based upon climatic conditions, much more so than lakes having tributary inputs (drainage lakes). Droughts that have been occurring in northern Wisconsin have lowered many natural spring and seepage lakes substantially as the water released through outlet streams, the ground water table and evaporation have failed to be replaced by precipitation. The water levels of several Town of Newbold lakes, including Two Sisters Lake, have been affected as well. The water level in Two Sisters Lake is maintained by a low head water level structure that is owned by the Town of Newbold. This structure is currently sound, however in the event that extensive repairs are required, the Town of Newbold may not be willing to pay for these repairs. Because this water level structure's purpose is strictly for recreation, and not for water consumption or energy generation, it is not critical that the water level structure be in operation. However, Two Sisters Lake residents support the existence of the water level structure as it keeps their water levels several feet higher, which would not occur if the water level structure was

removed. The TSLPOA will continue to build a contingency fund that may be used, to assist the Town of Newbold with water level structure repair fees if necessary.

Action Steps:

1. See description above.

Management Goal 7: Prevent Introduction of Aquatic Invasive Species to Two Sisters Lake

<u>Management Action:</u> Continue Clean Boats/Clean Waters inspections.
Timeframe: Continuation of current effort.
Facilitator: Board of Directors designee
Description: Members of the TSLPOA have been trained on Clean Boats Clean Waters (CBCW) protocols and complete boat inspections at the public landings on a regular basis. These volunteers have monitored the public boat launch since 2006. Because this system is currently free of exotic plant species, the intent of the boat inspections is to prevent additional invasives from entering the lake through its public access point. The goal would be to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of aquatic invasive species on our lakes and educating people about how they are the primary vector of aquatic invasive species spread. In 2011, 556 boats were inspected and 1,211 people contacted during over 734 hours of watercraft inspections.

This aggressive approach to informing lake users about the dangers of aquatic invasive species has proven to be quite effective, and has likely helped to keep Two Sisters Lake free of exotic plants such as Eurasian water milfoil and curly-leaf pondweed. The TSLPOA will continue CBCW inspections at the public landing, and will more importantly continue to pursue volunteers through its membership and partnering organizations to staff the public landing for this effort.

Action Steps:

1. Members of association continue to attend Clean Boats/Clean Waters training session through the Oneida County AIS Coordinator (Michele Saduaskas – 715.365.2750) to update their skills to current standards.
2. Training of additional volunteers completed by those trained during the summer of 2012.
3. Continue to conduct inspections during weekends of high usage.
4. Continue to report results to WDNR and TSLPOA
5. Promote enlistment and training of new of volunteers to keep program fresh.

<u>Management Action:</u> Coordinate annual volunteer monitoring for aquatic invasive species
Timeframe: Begin summer of 2012
Facilitator: Board of Directors designee
Description: In lakes without Eurasian water milfoil and other invasive species, early detection of pioneer colonies commonly leads to successful control and in cases of very small infestations, possibly even eradication. One way in which lake residents can spot early infestations of aquatic invasive species is through conducting

"Lake Sweeps" on their lake. During a lake sweep, volunteers monitor the entire area of the system in which plants grow (littoral zone) annually in search of non-native plant species, and these surveys are typically conducted twice during the growing season.

In order for accurate data to be collected during these sweeps, 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. To assist association members in these identification skills, Oneida County AIS Coordinator Michele Saduaskas may be contacted to arrange a plant identification workshop. Ms. Saduaskas will help volunteers positively identify native and non-native plants, as well as assist with plant collection and lake monitoring techniques/methodology. Collecting a specimen of suspicious looking plants is important for verification purposes. Additionally, if possible, GPS coordinates should be collected if suspicious looking plants are found on Two Sisters Lake.

Action Steps:

1. Volunteers from the TSLPOA continue to update their skills by attending a training session conducted by the Oneida County AIS Coordinator (Michele Saduaskas – 715.365.2750).
2. Trained volunteers recruit and train additional association members.
3. Continue to complete lake surveys following protocols.
4. Continue to report results to WDNR and TSLPOA.

<u>Management Action:</u> Investigate mandatory-use watercraft washing station and other preventative alternatives.

Timeframe: Initiate winter of 2012-2013.

Facilitator: Board of Directors designee.

Description: The battle against aquatic invasive species has been met with many "tools" by lake managers, state legislators, and lake stakeholders alike. As a result of the spread of these species, programs such as CBCW have developed, educational media such as signs, posters, billboards and television commercials have been crafted, and laws have been generated to reduce the spread of these species via boat trailers. Some programs have been developed to take another step in stopping the spread of aquatic invasives – providing either voluntary or mandatory boat and trailer washing stations at public boat landings.

This concept is not new, but has been somewhat controversial and difficult to implement. Some programs have seen opposition from watercraft operators in utilizing the washing stations. Several programs began, but lacked funding or staff to continue. Others did not meet the demand to provide complete, 24/7 coverage for a waterbody and thus were deemed ineffective.

There has been interest amongst several TSLPOA members in pursuing a boat washing station at the public landing. Before a plan to implement a washing station is pursued, a thorough review of other programs must be completed first, and design of a program that would fit the needs of Two Sisters Lake be developed. A representative of the TSLPOA will be appointed to research boat washing programs. Assistance may be provided by the Oneida County AIS Coordinator, the WDNR, or UW-Extension staff. Alternatives to this plan may be researched as well, such as Lake Champlain's program which instead of providing wash stations at boat landings provides information to boaters to find local car wash stations that can be used to wash boats, trailers and other equipment. More information on this program can be obtained on the Lake Champlain Basin Program website: http://www.lcbp.org/boatwash.htm.

Action Steps:

1. Appointed volunteer researches current or past boat washing programs, determining positive and negative aspects and applicability to Two Sisters Lake.
2. Volunteer reaches alternative programs uncovered during research.
3. Volunteer provides a summary report to Board of Directors.
4. Based upon report findings, Board may decide to pursue one or several options.
5. Volunteer to determine if AIS grant through state of Wisconsin is applicable to any proposed projects.

Management Action: Continue education on AIS-related topics.

Timeframe: Continuation of current effort.

Facilitator: Board of Directors designee.

Description: Education represents an effective tool to address what is known to be a large threat to Wisconsin lakes – aquatic invasive species. Currently, the TSLPOA has a good level of communication with lake stakeholders that is facilitated through a newsletter that is regularly distributed to association members. This level of communication is important within a management group because it builds a sense of community while facilitating the spread of important news pertaining to AIS including coordination and results of monitoring activities, notice of workshops, etc. It also provides a medium for the recruitment and recognition of volunteers. Regular dispersal of a newsletter or brochures can help TSLPOA operations by ensuring that meetings can be conducted more efficiently and misunderstandings based upon misinformation can be avoided.

Education representatives, appointed by the Board of Directors, will prepare articles or monitoring results summaries for inclusion in TSLPOA newsletters, emails or brochures. Assistance may be available through the Oneida County AIS Coordinator, WDNR, Wisconsin Lakes or UW-Extension.

Action Steps:

1. See description above.

Management Action: Maintain strong relationship with Oneida County AIS Coordinator.

Timeframe: Continuation of current effort.

Facilitator: Board of Directors designee.

Description: The Oneida County AIS Coordinator, Michele Saduaskas, has a unique position and job description. The role of an AIS Coordinator is exactly as it sounds: to coordinate efforts between agencies, lake residents and state employees in the battle against aquatic invasive species. The AIS Coordinator is always up-to-date on the latest in strategies and techniques to monitor, manage, and prevent these exotic species. This position entails disseminating this information to stakeholders as it is received, and assisting lake groups in strategies best suited for their situation.

As a person in-the-know, whose job is to continuously network with those dealing with aquatic invasive species issues, the AIS Coordinator should be a priority contact for every lake association. The TSLPOA will develop a good working relationship with Ms. Saduaskas through a variety of aquatic invasive species related projects, including CBCW, lake sweeps, plant identification, a potential boat washing station, and other projects that may develop.

Action Steps:

1. See description above.

Management Goal 8: Continue Transfer of Education and Information from TSLPOA to Lake Stakeholders

Management Action: Continue TSLPOA newsletter.
Timeframe: Continuation of current effort.
Facilitator: Board of Directors to appoint education representative(s).
Description: Education represents an effective tool to address not only issues pertaining to aquatic invasive species, but also lake ecology issues such as lake shore development, lawn fertilization, and other issues such as air quality, noise pollution, and boating safety. One of the best methods of continuing to build stakeholders knowledge of lake issues is through a regularly published newsletter. The TSLPOA will continue this newsletter, and make a determination of who exactly receives the letter (members only, all riparian property owners, etc.). An appointed education representative or representatives will be in charge of pulling together content for the newsletter. As with the 4th Management Action in Management Goal #7, there are a number of resources the representative(s) may contact for newsletter content including the Oneida County AIS Coordinator, WDNR, Wisconsin Lakes or UW-Extension. In addition to creating regularly published association newsletter a variety of educational efforts will be initiated by the Education representatives. These may include educational materials, awareness events and demonstrations for lake users as well as activities which solicit local and state government support.

Example Educational Topics:

- Aquatic invasive species monitoring updates
- Boating safety and ordinances (slow-no-wake zones and hours)
- Catch and release fishing
- Littering (particularly on ice)
- Noise, air, and light pollution
- Shoreland restoration, regulations and protection
- Septic system maintenance
- Fishing Rules
- Loon Watch program and loon habitat
- Specific topics brought forth in other management actions

Action Steps:

1. See description above.

Management Action: Create TSLPOA website.
Timeframe: Initiate winter of 2012-2013.
Facilitator: Board of Directors
Description: Continuing the TSLPOA's goal of increasing the level of communication with lake stakeholders, the association will begin to post activities and information on the Internet for interested parties to view. The Internet has quickly become a primary method of retrieving information and communicating with others. While it is understandable that some TSLPOA members may not prefer utilizing the internet or receiving information this way, many will appreciate this effort to increase communication. The Board of Directors will seek a capable volunteer for creating a website, or decide to allocate funds towards hiring of a web designer. The education representative(s) will be the primary source of information for inclusion on the TSLPOA website, and will be contacted for content to include.
Action Steps:

1. See description above.

Management Action: Continue email notifications.
Timeframe: Continuation of current effort.
Facilitator: Board of Directors to appoint education representative(s).
Description: The TSLPOA currently sends email notifications to members wishing to receive information regarding studies or programs being conducted, special announcements or notification of events occurring around the lake. These special bulletins will be continued by the education representatives to ensure that lake stakeholders are kept up-to-date on important lake-related matters.
Action Steps:

1. See description above.

6.0 METHODS

Lake Water Quality

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

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

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

Watershed Analysis

The watershed analysis began with an accurate delineation of Two Sisters 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 Two Sisters Lake during a June 23, 2011 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 Two Sisters Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, *Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications* (WDNR PUB-SS-1068 2010) was used to complete this study on July 27 and 29, 2011. A point spacing of 41 meters was used resulting in approximately 1,735 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Two Sisters 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 verified by Dr. Robert Freckmann at the University of Wisconsin – Stevens Point Herbarium. A set of samples was also provided to the TSLPOA.

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