# Silver Lake

**Forest County, Wisconsin**

# Comprehensive Management Plan

**January 2016**

Sponsored by:

**Silver Lake Preservation Association, Inc.**

WDNR Grant Program

AEPP-437-14


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Onterra, LLC
Lake Management Planning

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Forest County, Wisconsin

# Comprehensive Management Plan

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Funded by: Silver Lake Preservation Association, Inc.
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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:

### Silver Lake Planning Committee

| | | |
|---|---|---|
| Allen Bluhm | Mary Graham | Greg Helbert |
| Alice Cunningham | John Heeter | Tom Rice |
| George Cunningham | Mike Hess | Erik Roth |
| Dan Graham | Cindy Hilbert | Dan Verbanac |

**Wisconsin Dept. of Natural Resources**

Jim Kreitlow

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# 1.0 INTRODUCTION

Silver Lake, Forest County, is an approximately 320-acre spring lake with a maximum depth of 21 feet and a mean depth of 12 feet (Map 1). This oligo-mesotrophic lake drains into the Rat River which feeds into the Peshtigo River and ultimately Lake Michigan. Silver Lake has a surficial watershed that encompasses approximately 884 acres, yielding a small watershed to lake area ratio of 2:1. In 2014, 37 native aquatic plant species were located, of which the macroalgae stoneworts were the most abundant. The lake also harbors a population of the non-native, invasive plant Eurasian water milfoil.

**Field Survey Notes**

*Silver Lake has high water clarity and supports a large number of native aquatic plant species. The entire lake supports aquatic plant growth, and stoneworts (Nitella spp.) were the most abundant plant encountered during the 2014 surveys. The bay on the southwest side of the lake (pictured) supports a large community of white water lily (Nymphaea odorata) and common bladderwort (Utricularia vulgaris).*

**Photo 1.0-1 Silver Lake, Forest County**

**Lake at a Glance - Silver Lake**

| | |
|---|---|
| **Morphology** | |
| Acreage | 320 |
| Maximum Depth (ft) | 21 |
| Mean Depth (ft) | 12 |
| Shoreline Complexity | 2.5 |
| **Vegetation** | |
| Early-Season AIS Survey Date | June 19, 2014 |
| Comprehensive Survey Date | July 22-23, 2014 |
| Number of Native Species | 37 |
| Threatened/Special Concern Species | 0 |
| Exotic Plant Species | Eurasian water milfoil |
| Simpson's Diversity | 0.85 |
| Average Conservatism | 6.9 |
| **Water Quality/Watershed** | |
| Trophic State | Oligo-Mesotrophic |
| Limiting Nutrient | Phosphorus |
| Water Acidity (pH) | 7.8 |
| Sensitivity to Acid Rain | Not Sensitive |
| Watershed to Lake Area Ratio | 2:1 |

Silver Lake is located in Laona, Wisconsin (Forest County) within the Lake Michigan drainage basin. The non-native, invasive plant Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was first discovered in Silver Lake in 2010. Silver Lake also harbors populations of additional invasive species, including the rusty crayfish (*Orconectes rusticus*), banded mystery snail (*Viviparus georgianus*), and Chinese mystery snail (*Cipangopaludina chinensis*). Following the discovery of EWM in 2010, the Silver Lake Preservation Association, Inc. (SLPA) (formerly the Forest County Silver Lake Association, Inc.) with the assistance of Onterra, LLC was awarded two Wisconsin Department of Natural Resources (WDNR) Aquatic Invasive Species (AIS) Early Detection and Response (EDR) Grants. The SLPA used these state grant funds along with funds provided by the Potawatomi Tribe and the US Forest Service to facilitate volunteer and professional monitoring of EWM, herbicide treatment of EWM, and the development of continued control strategies.

Beyond the issue of developing a management strategy for EWM in Silver Lake, the SLPA wanted to move forward with the creation of a lake management plan in order to ensure the preservation of Silver Lake for future generations. Through the development of a lake management plan, the SLPA wants to assure that they are working to preserve Silver Lake as an ecosystem, not solely a recreational resource. Overall, the SLPA recognized the value of gaining a better understanding of the Silver Lake ecosystem and its current condition. In the end, the information obtained from the studies conducted as part of the lake management plan development will help guide future SLPA plans and programs.

This report discusses the results of the studies conducted on Silver Lake in 2014/2015. These studies included an assessment of Silver Lake's stakeholders through a stakeholder survey, as well as the lake's water quality, watershed, shoreline, and aquatic plant community. Also included is the Implementation Plan which includes goals and actions specific to Silver Lake's current and future management that were developed using the study results by the SLPA Planning Committee and Onterra ecologists.

# 2.0 STAKEHOLDER PARTICIPATION

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

**Kick-off Meeting**
On August 9, 2014 a project kick-off meeting was held at the Laona Community Building to introduce the project to the general public. The meeting was announced through a mailing and personal contact by Silver Lake Association, Inc. board members. Attendees observed a presentation given by Brenton Butterfield, an aquatic ecologist with Onterra. Mr. Butterfield's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

**Planning Committee Meeting I**
On July 9, 2015, Onterra ecologists Brenton Butterfield and Eddie Heath met with members of the Silver Lake Planning Committee. Jim Kreitlow, WDNR Water Resources Management Specialist, was also in attendance. In advance of this meeting, a draft copy of the Results and Discussion Sections were provided to attendees. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including the aquatic plant inventories, water quality analyses, and watershed modeling were presented and discussed. Information regarding moving forward with AIS monitoring and control program was also discussed.

**Planning Committee Meeting II**
On August 27, 2015, Onterra ecologists Brenton Butterfield and Eddie Heath again met with members of the Silver Lake Planning Committee to begin developing management goals and actions for the Silver Lake Comprehensive Lake Management Plan. The primary topic of discussion was the development of a strategy for moving forward with managing the lake's Eurasian water milfoil population.

**Project Wrap-up Meeting**
Planned for summer of 2016.

## Management Plan Review and Adoption Process

Prior to the first planning meeting, the Planning Committee received copies of the Results Section of this report (Section 3.0). Their comments were addressed at this meeting and appropriate changes were incorporated within the management plan. The framework for the Implementation Plan was developed at the second Planning Committee meeting, and the first draft of the Implementation Plan was provided to the Planning Committee in October 2015. Following approval of the Implementation Plan by the Planning Committee, the first official draft of the management plan was sent to the WDNR for review in January of 2016. That same month, Onterra staff discussed and then addressed the WDNR comments. The plan was ultimately approved in January of 2016.

## Stakeholder Survey

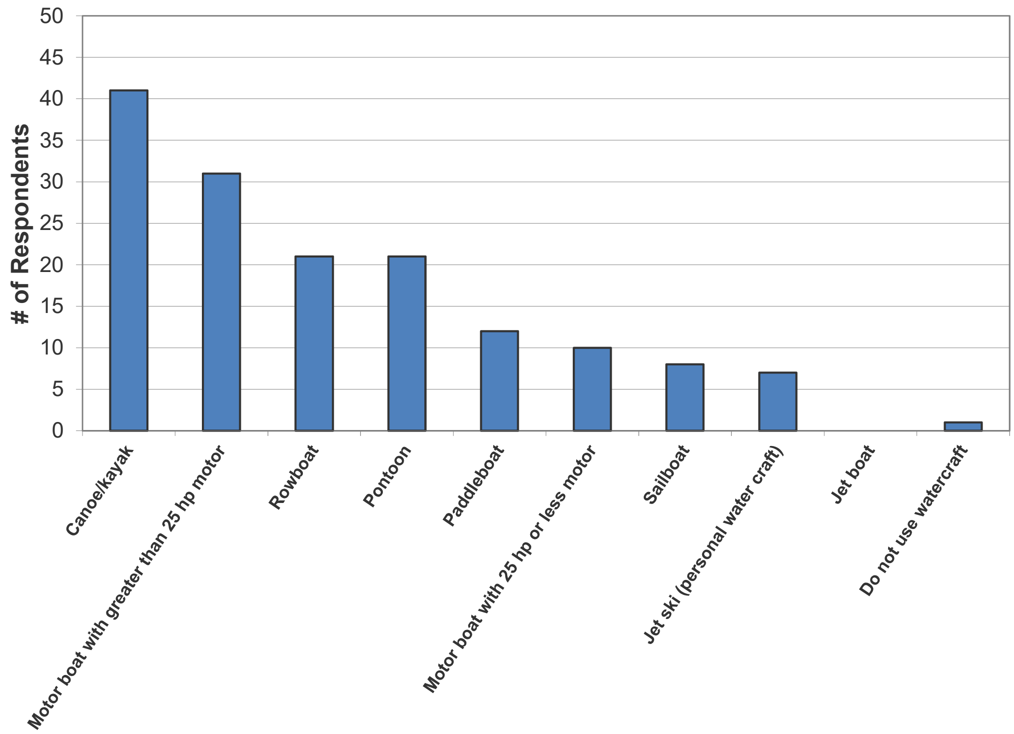
In November 2014, 187 property owners which included all Forest County Silver Lake Association, Inc. members (some on and off the lake) as well as non-member lakefront property owners were notified and asked to participate in a web-based stakeholder survey regarding Silver Lake. Of the 187 property owners contacted, 63 (34%) took the survey. Unfortunately, due to the low response rate, the results of the stakeholder survey should not be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about stakeholder perceptions of Silver Lake, but cannot be stated with any statistical confidence. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of results is integrated within the appropriate sections of the management plan and a general summary is discussed in this section.

The majority of survey respondents (70%) indicated that they use their property on Silver Lake in the summer only or on weekends throughout the year, while 22% live at the lake year round and 3% own undeveloped property (Question 1). Sixty-one percent of respondents have owned their property for over 15 years, while 39% have owned their property for greater than 25 years (Question 3). Ninety-two percent of respondents indicated their property was on Silver Lake, while 8% of respondents did not own property on the lake (Question 4).

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. The majority of survey respondents (67%) indicate that they use a canoe/kayak on the lake, while 51% use a motor boat with greater than 25 mph horsepower (Question 13). The top-rated activity on Silver Lake among survey respondents was relaxing/entertaining with 52% of respondents indicating this was the most important activity (Question 14). Swimming, fishing, and nature viewing were the next top-rated activities amongst survey respondents on Silver Lake, respectively.

When asked to rate the factors that are currently negatively impacting Silver Lake, the majority of survey respondents indicated that the introduction of aquatic invasive species is currently having the greatest negative impact, followed by watercraft traffic, excessive aquatic plant growth, and shoreline development (Question 20).

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




*Question 14: Please rank your top three activities that are important reasons for owning or renting your property on or near Silver Lake.*

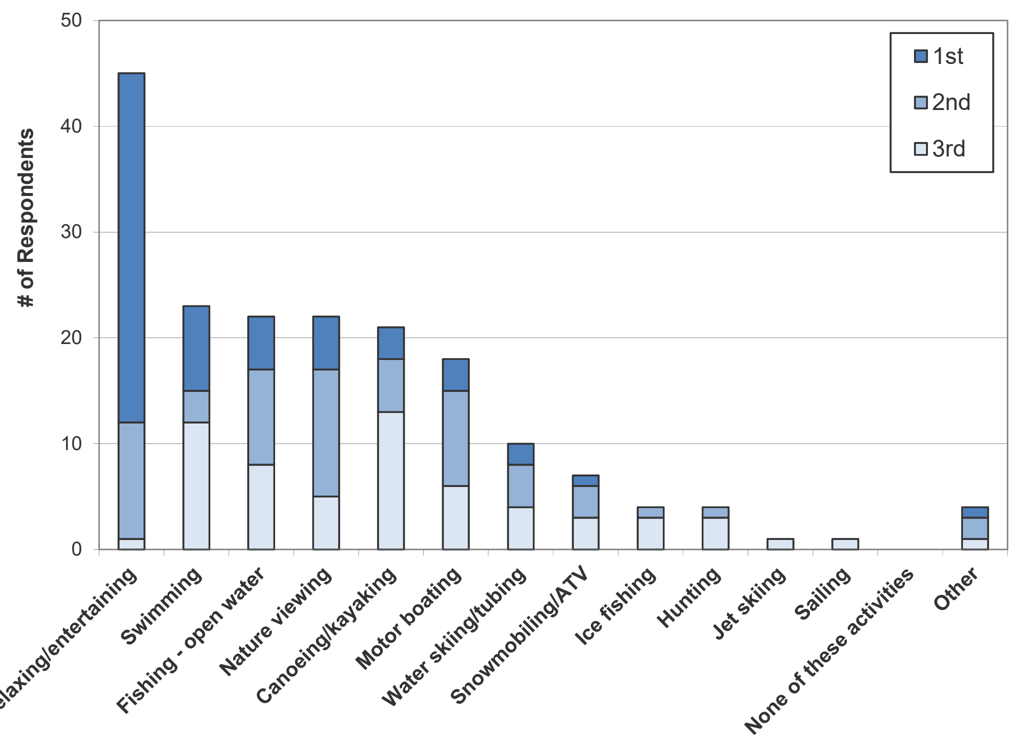
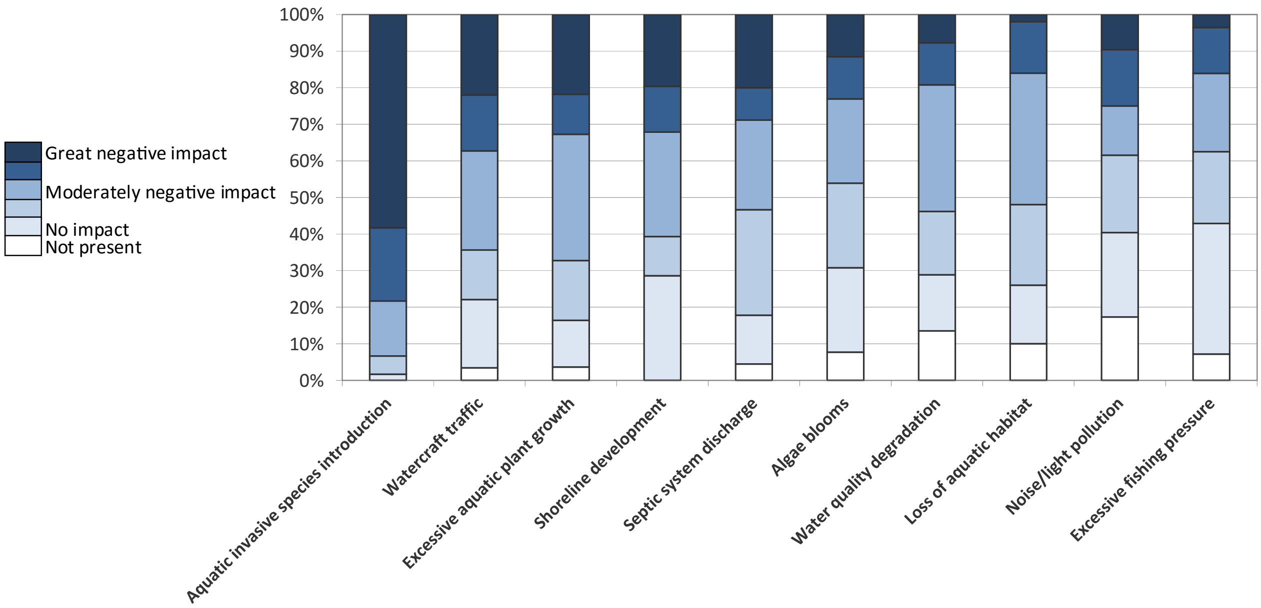



**Figure 2.0-1. Select survey responses from the Silver Lake Stakeholder Survey.** Additional questions and response charts may be found in Appendix B.

*Question 20: To what level do you believe these factors may be negatively impacting Silver Lake?*




*Question 21: Please rank your top three concerns regarding Silver Lake.*

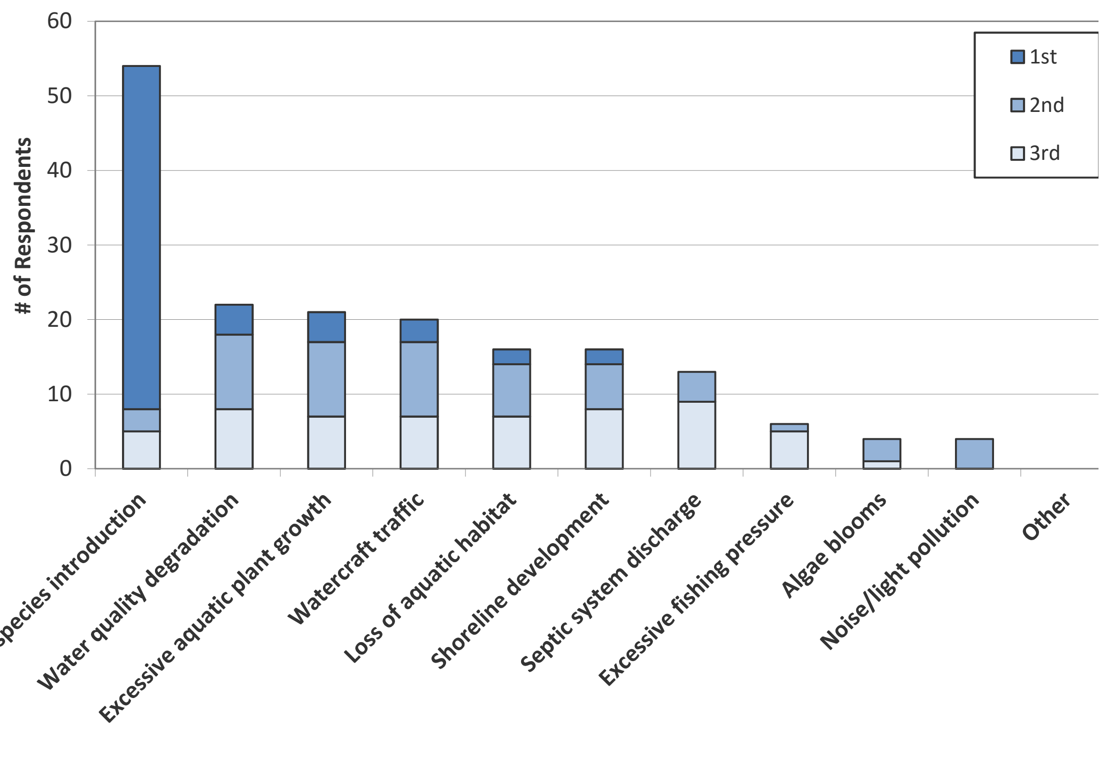



**Figure 2.0-2. Select survey responses from the Silver Lake Stakeholder Survey, continued.** Additional questions and response charts may be found in Appendix B.

# 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 Silver Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Silver 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 document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013A) 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 Silver Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, hydrology. An equation developed by Lathrop and Lillie (1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

Based on Silver Lake's morphology, watershed size (discussed in Watershed Section), and hydrology, using the classification scheme discussed above, Silver Lake is classified as a shallow (mixed), headwater drainage lake (Class 2 in Figure 3.1-1). However, because Silver Lake does not possess a tributary inlet but does possess a tributary outlet, it is technically classified as a spring lake. However, for this analysis, any lake possessing an inlet and/or outlet is classified as a drainage lake.

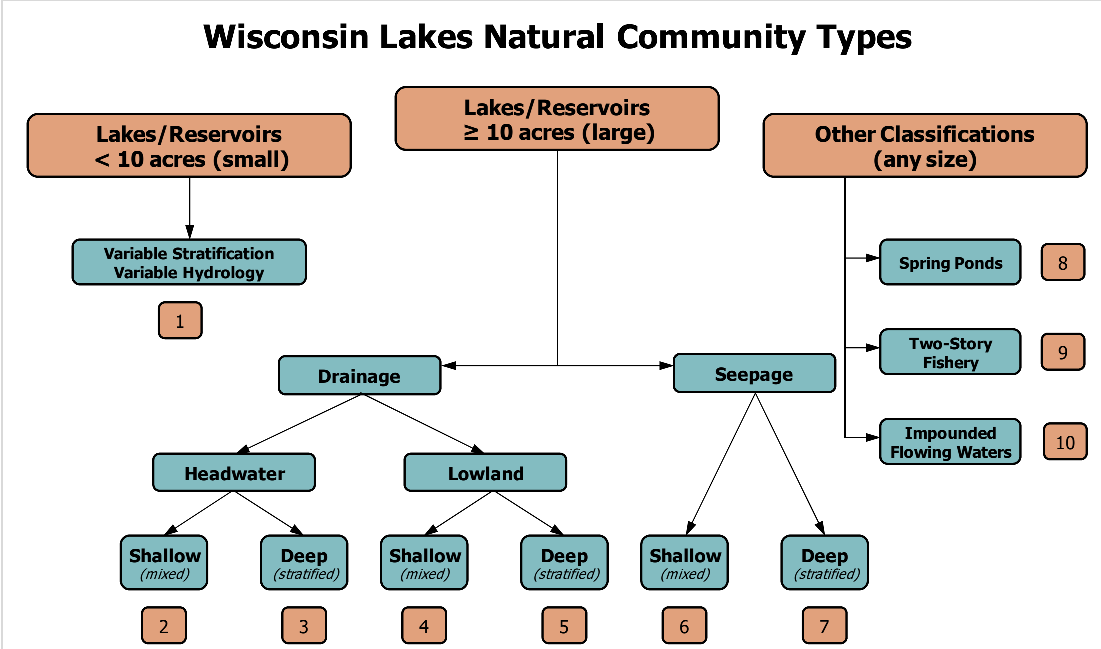



**Figure 3.1-1. Wisconsin Lake Natural Communities.** Adapted from WDNR 2013A. Silver Lake is classified as a Shallow (mixed), Headwater Drainage Lake (Class 2).

Garrison, et. al (2008) developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for six of the lake classifications. Though they did not sample sufficient lakes to create median values for each classification within each of the state's ecoregions, they were able to create median values based on all of the lakes sampled within each ecoregion (Figure 3.1-2). Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Silver Lake is within the Northern Lakes and Forests ecoregion (Figure 3.1-2).

The Wisconsin 2014 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

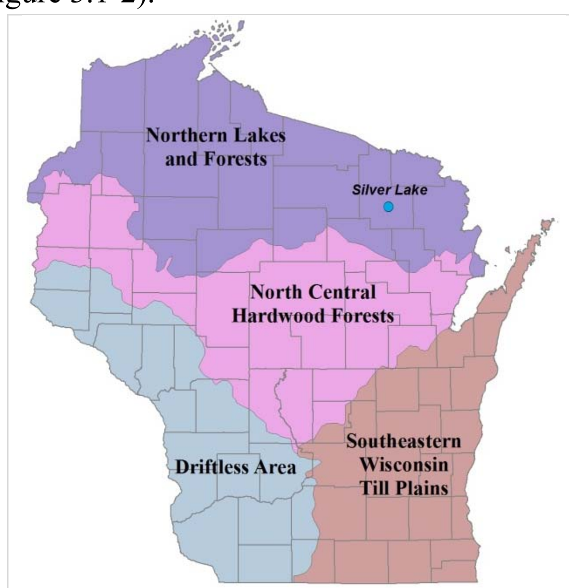



**Figure 3.1-2. Location of Silver Lake within the ecoregions of Wisconsin.** After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Silver Lake is displayed in Figures 3.1-3 - 3.1-9. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

## *Silver Lake Water Quality Analysis*

### Silver Lake Long-term Trends

As a part of this study, Silver Lake stakeholders were asked about their perceptions of the lake's water quality. The majority (82%) of respondents rated the water quality of Silver Lake as *Good* or *Excellent*, 16% rated *Fair*, and 2% rated *Poor* (Appendix B, Question #15). Approximately 47% of survey respondents indicated that the water quality of Silver Lake has *remained the same* since they first visited the lake, while approximately 31% believed the water quality has *somewhat degraded* (Question #16).

Volunteers have been actively collecting water quality data annually on Silver Lake since 1992 through the Citizens Lake Monitoring Network (CLMN) Program. Through this WDNR-sponsored program, volunteers are trained to collect water quality data on their lake. Samples are analyzed through the State Lab of Hygiene in Madison, WI and data are entered into the Surface Water Integrated Monitoring System (SWIMS), an online database which allows for quick access to all current and historical water quality data. This process allows stakeholders to become directly engaged in protecting their lake, while producing reliable and comparable data that managers may recall through a streamlined website.

As discussed previously, three water quality parameters are of most interest when assessing a lake's water quality: total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Volunteers from Silver Lake have been collecting these data on an annual basis since 1992, building a continual dataset that will yield valuable information on Silver Lake's water quality through time.

Near-surface total phosphorus data are available from Silver Lake annually from 1994-2015 (Figure 3.1-3). Since 1994, annual average near-surface total phosphorus concentrations have fallen within the *excellent* category for shallow, headwater drainage lakes in Wisconsin. While annual average growing season near-surface total phosphorus concentrations have ranged from 15.3 µg/L in 1999 to 9.5 µg/L in 1998, A Mann-Kendall Test indicates that there is no significant trend occurring, positive or negative, in near-surface total phosphorus concentrations in Silver Lake over the period for which data are available from 1994-2015. The weighted average summer near-surface total phosphorus concentration using all available data for Silver Lake is 11.7 µg/L, which is significantly lower than the median value of 29.0 µg/L for shallow, headwater drainage lakes throughout Wisconsin and the median value of 21.0 µg/L for all lake types within the Northern Lakes and Forests ecoregion.

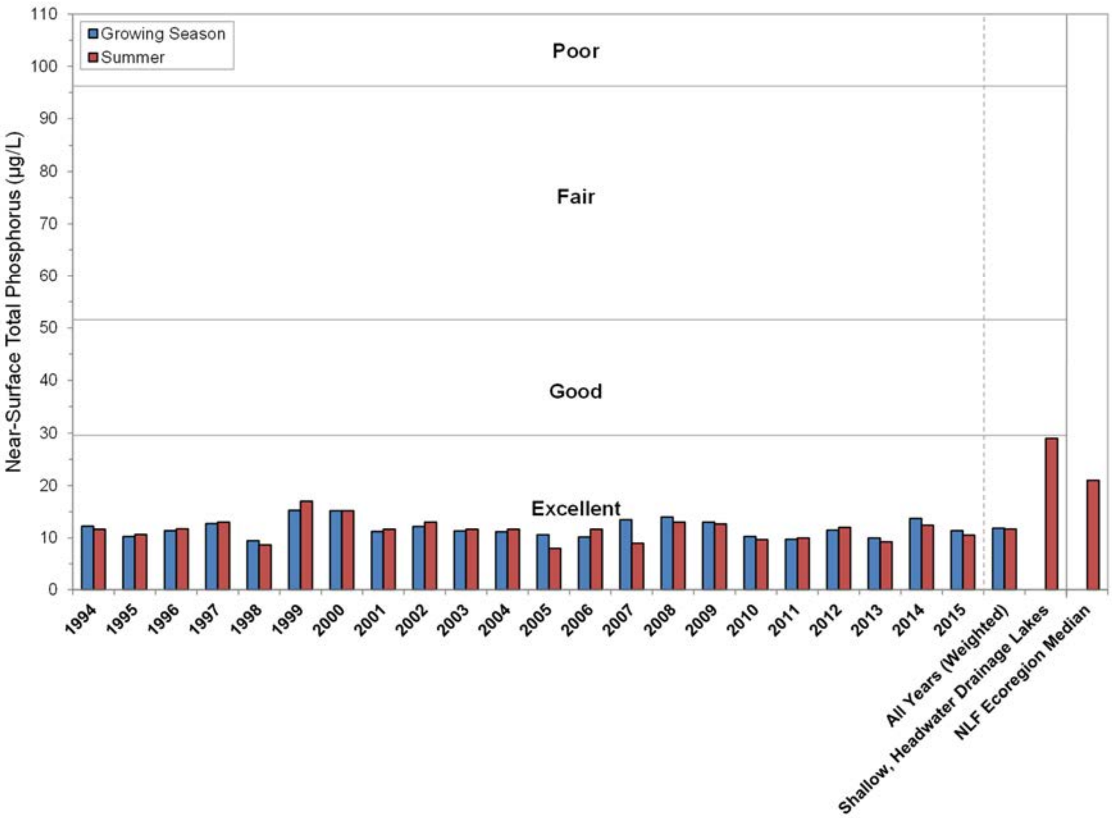



**Figure 3.1-3. Silver Lake average annual near-surface total phosphorus concentrations and median summer near-surface total phosphorus concentrations for Wisconsin shallow, headwater drainage lakes and Northern Lakes and Forests (NLF) ecoregion lakes.** Data collected from historical records (WDNR SWIMS) and Onterra 2014 sampling. Water Quality Index values adapted from WDNR PUB WT-913.

Often, near-surface water samples of phosphorus are analyzed because they are easy to collect and are representative of what is occurring in the littoral zone (sunlit, plant and algae growing area) of a lake. Figure 3.1-3 includes only data collected from the near-surface of Silver Lake. However, comparing surface and bottom phosphorus samples can be advantageous to understanding other nutrient dynamics in lakes, such as internal nutrient loading as discussed previously.

Figure 3.1-4 displays data depicting surface and bottom phosphorus concentrations on dates in which both of these data types were available. During times in which a lake is mixed, we can expect phosphorus concentrations to be similar near the surface and the bottom of the lake. As discussed in the Primer Section, during times when lakes are stratified, the bottom phosphorus concentration may be two to three times or more than what was observed in the surface waters. Under anoxic conditions, phosphorus may be released from the sediments which accounts for the higher concentrations. However, total phosphorus concentrations from Silver Lake indicate that near-surface and near-bottom concentrations are similar throughout the growing season. As will be discussed in the next section, Silver Lake is relatively shallow and does not strongly stratify during the summer, maintaining dissolved oxygen near the bottom. In addition, vegetation grows even in the deepest portions of the lake, and these plants supply oxygen to the water during photosynthesis.

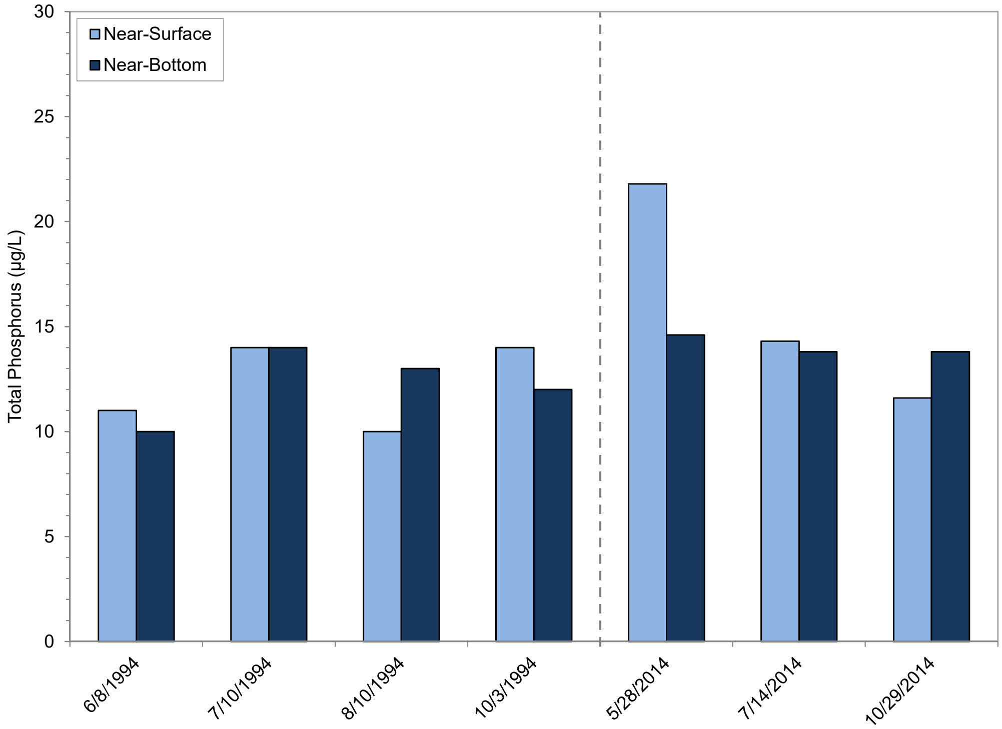



**Figure 3.1-4. Silver Lake near-surface and near-bottom total phosphorus concentrations.** Data collected from historical records (WDNR SWIMS) and Onterra 2014 sampling. All concentrations are actual values, not averages.

As discussed earlier, chlorophyll-*a*, or the measure of free-floating algae within the water column, is usually positively correlated with total phosphorus concentrations. While phosphorus limits the amount of algae growth in the majority of Wisconsin's lakes, other factors also affect the amount of algae produced within the lake. Water temperature, sunlight, and the presence of small crustaceans called zooplankton, which feed on algae, also influence algal abundance. Like total phosphorus data, chlorophyll-*a* concentrations are available from Silver Lake annually from 1994-2015 (Figure 3.1-5).

Average annual growing season chlorophyll-*a* concentrations range from 2.5 µg/L in 2000 and 2005 to 4.3 µg/L in 1996 and 2008, while the weighted growing season average for all years is 3.2 µg/L. The weighted average value for summer chlorophyll-*a* concentrations is 3.1 µg/L and falls into the *excellent* category for shallow, headwater drainage lakes. Chlorophyll-*a* concentrations in Silver Lake are significantly lower than the median values for other shallow, headwater drainage lakes throughout Wisconsin and for all lake types within the NLF ecoregion. A Mann-Kendall Test indicates that there is no significant trend occurring, positive or negative, in chlorophyll-*a* concentrations over the time period from 1994-2015. The low concentration of phosphorus within Silver Lake limits the amount of algae that can be produced, and thus results in low chlorophyll-*a* concentrations.

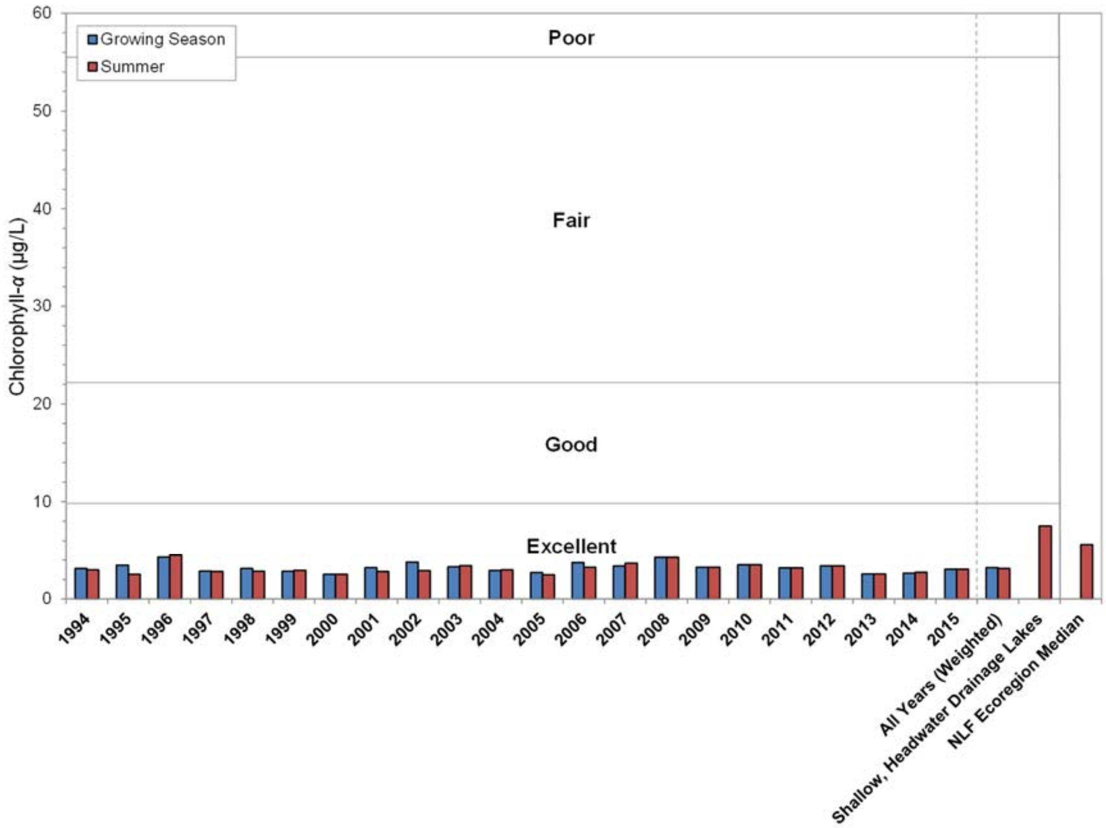



**Figure 3.1-5. Silver Lake average annual near-surface chlorophyll-*α* concentrations and median summer chlorophyll-*α* concentrations for Wisconsin shallow, headwater drainage lakes and Northern Lakes and Forests (NLF) ecoregion lakes.** Data collected from historical records (WDNR SWIMS) and Onterra 2014 sampling. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed previously, water clarity in Wisconsin's lakes is largely driven by the amount of free-floating algae within the water. Because Silver Lake has low concentrations of phosphorus and thus low levels of algae, it would be expected that water clarity would be high. Secchi disk transparency data are available from Silver Lake annually from 1992-2015 (Figure 3.1-6). Average annual growing season Secchi disk transparency values range from 17.1 feet in 2005 to 11.2 in 1999, and all values fall within the *excellent* category for Wisconsin's shallow seepage lakes. The weighted average summer Secchi disk transparency for Silver Lake from 1992-2015 is 12.9 feet, which exceeds the median values of 5.6 feet and 8.9 feet for shallow, headwater drainage lakes throughout Wisconsin and lakes in the NLF ecoregion, respectively.

The Mann-Kendall Test indicated that there is a slight increasing trend in growing season water clarity in Silver Lake from 1992-2015. The average Secchi disk depth from 1992-2002 was 12.5 feet compared to 14.3 feet from 2003-2015. However, it is not believed that water clarity has actually been increasing within Silver Lake over this time period. The higher average water clarity from 2003-2015 is believed to be due to increased sampling events early in the growing season, specifically in April and May when water clarity is highest. From 1992-2002 there were only two Secchi disk depths recorded either in April or May while there have been 13 Secchi disk depths recorded during these two months from 2003-2014. When only summer water clarity values are evaluated, there is no apparent increasing trend in water clarity over time.

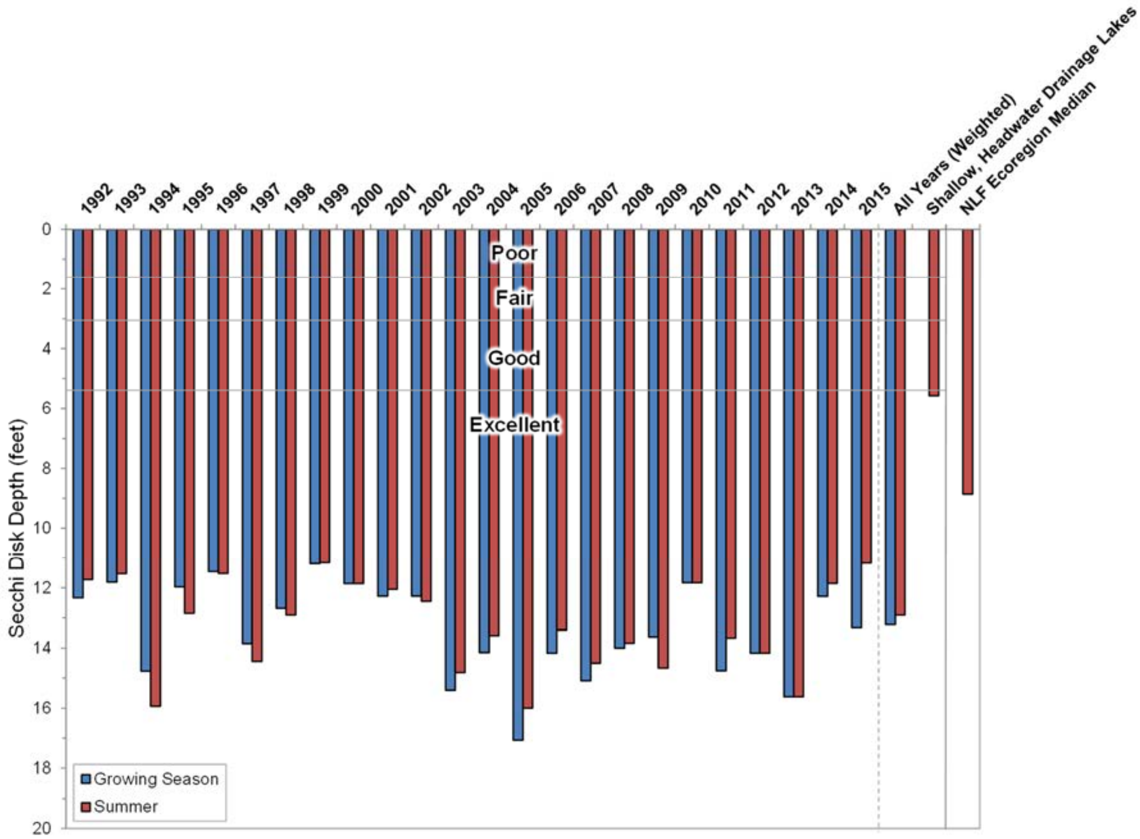



**Figure 3.1-6. Silver Lake average annual Secchi disk transparency and median summer Secchi disk transparency for Wisconsin shallow, headwater drainage lakes and Northern Lakes and Forests (NLF) ecoregion lakes.** Data collected from historical records (WDNR SWIMS) and Onterra 2014 sampling. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed earlier, algae concentrations are relatively low during the summer months on Silver Lake, but there are other factors that can affect a lake's water clarity. These other factors include dissolved organic compounds that originate within wetlands and forests within the lake's watershed and can give the water a stained appearance. These dissolved compounds can be measured through an analysis called *true color*. Water samples collected from Silver Lake in May and July 2014 were measured for true color and were found to be at the lower threshold (<20 Platinum-cobalt units, or PCU) of detection for this analysis, with values of 5.0 and 10.0 PCU, respectively. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having *low* color, 40-100 PCU as *medium* color, and >100 PCU as *high color*. Having little color to the water increases its clarity. This indicates that Silver Lake's water clarity is mainly driven by algae, and because there is relatively low levels of algae and dissolved organic compounds, water clarity is high.

While there are no apparent trends in annual total phosphorus, chlorophyll-*a*, and Secchi disk transparency data in Silver Lake, these parameters exhibit patterns within a single growing season that is typical of many lakes. Figure 3.1-7 illustrates the monthly averages for these three parameters over the time period for which data are available. Water clarity in Silver Lake is highest in April, May, and June, when water temperatures are cooler and algae production is low. Water clarity is lowest in July and August and into the fall when water temperatures and algae production is highest. Total phosphorus concentrations are highest in spring and fall, and decline over the course of the summer. The decline in phosphorus in summer is likely due to decrease runoff from lower rates of precipitation, sedimentation of phosphorus, and increasing growth and uptake by the rooted aquatic plant (macrophyte) community and the periphyton that live on them. In the fall, precipitation and storm events increase which delivers more runoff to the lake and also may increase bottom sediment resuspension. In addition, many of the macrophytes senesce or die back, releasing phosphorus back into the water.

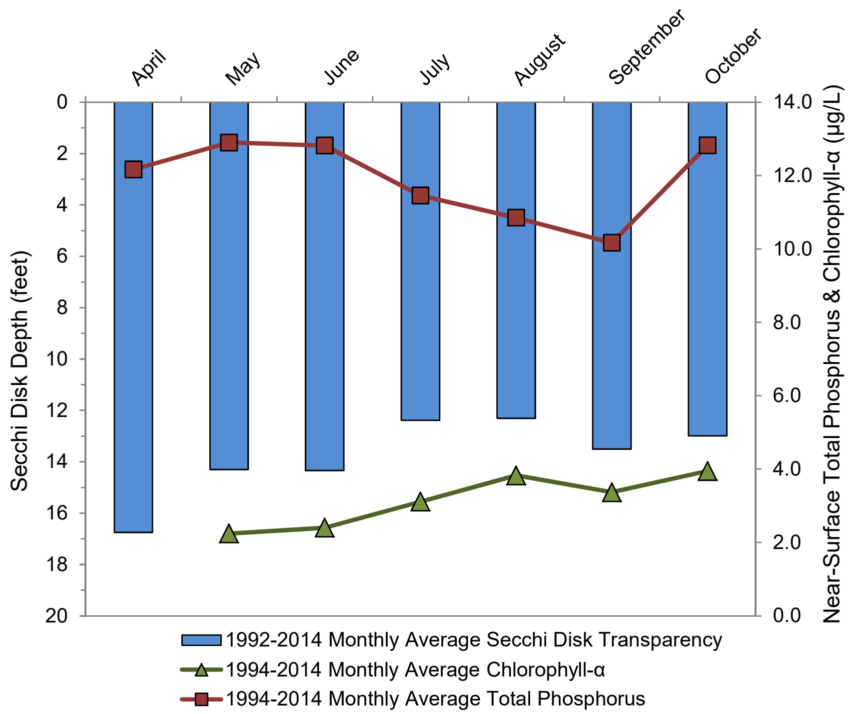



**Figure 3.1-7. Silver Lake monthly average Secchi disk transparency, near-surface total phosphorus, and chlorophyll-α.** Data collected from historical records (WDNR SWIMS) and Onterra 2014 sampling.

In 2014, near-surface total phosphorus concentrations were measured on May 24, 26, and 28 through a combination of the Silver Lake CLMN and Onterra (Figure 3.1-8). On May 24 and 26 near-surface total phosphorus concentrations were 11.8 and 12.2 µg/L, respectively. On May 28, near-surface total phosphorus concentrations had nearly doubled to 21.8 µg/L; however, near-bottom concentrations on May 28 remained relatively low at 14.3 µg/L. A temperature profile collected on May 28 indicated that the lake was stratified, with an epilimnion extending to approximately 7.0 feet. If the data from May 28 are valid, the observed increase in total phosphorus only within the near-surface waters indicates that phosphorus may have been loaded to the lake externally, internally within the epilimnion, or a combination of both.

Precipitation data were obtained from a weather station in Laona, WI. These data indicate that there was a 1.4-inch rainfall even on May 27, which was the largest precipitation event to date of the 2014 open water season in this area. Total suspended solids, a measure of the particulate matter within the water, were also measured from the near-surface on May 28 at 2.0 mg/L indicating a low level of suspended material within the water. It is likely that the combination of 1.4 inches of rain and wind from the May 27 storm event delivered phosphorus from the watershed as well as suspended bottom sediments in shallow areas of the lake. While the exact source of this phosphorus is not known, it did not cause an increase in algae abundance within the lake, and concentrations declined to approximately 14 µg/L by the next sampling event in mid-July. Because of this, this "pulse" of phosphorus measured in late-May is not of great concern.

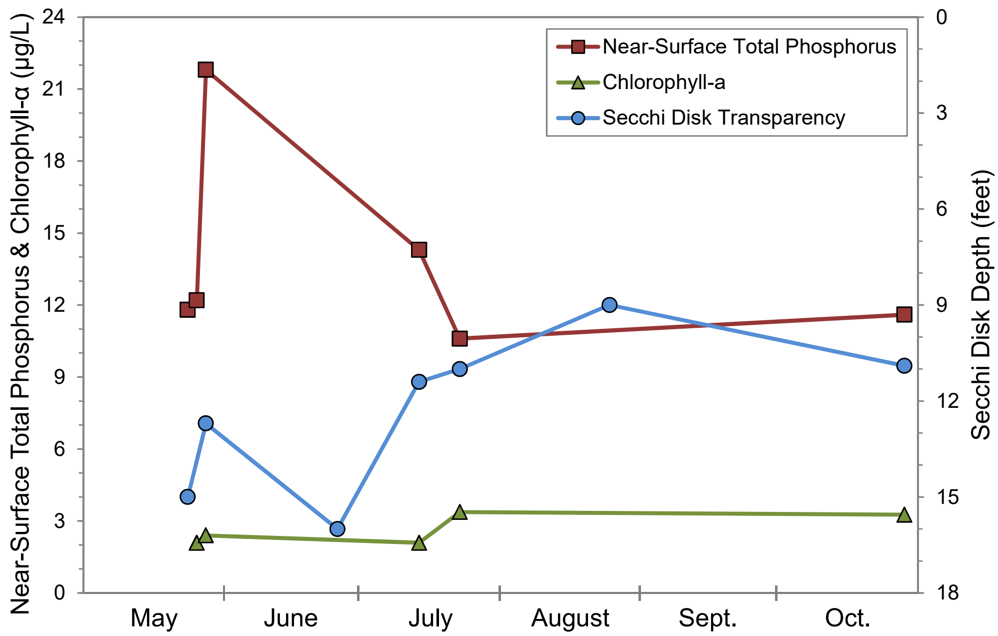



**Figure 3.1-8. Silver Lake 2014 growing season near-surface total phosphorus, chlorophyll-α, and Secchi disk transparency.** Data collected by Silver Lake CLMN volunteer and Onterra ecologists.

## Limiting Plant Nutrient of Silver Lake

Using midsummer nitrogen and phosphorus concentrations from Silver Lake, a nitrogen:phosphorus ratio of 35:1 was calculated. This finding indicates that Silver Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that phosphorus is primary nutrient controlling aquatic macrophyte and algae abundance within Silver Lake.

## Silver Lake Trophic State

Figure 3.1-9 contains the Trophic State Index (TSI) values for Silver Lake. In general, the best values to use in judging a lake's trophic state are total phosphorus and chlorophyll-*a*, as other factors other than algal abundance can affect a lake's water clarity. The weighted average TSI values for total phosphorus and chlorophyll-*a* indicate that Silver Lake is currently in an oligo-mesotrophic state; falling on the threshold between oligotrophic and mesotrophic states. However, much of Silver Lake's productivity exists within its aquatic macrophyte community which is not taken into account in the TSI analysis. Given Silver Lake's abundant aquatic macrophyte growth, it's more likely that Silver Lake is in a mesotrophic state.

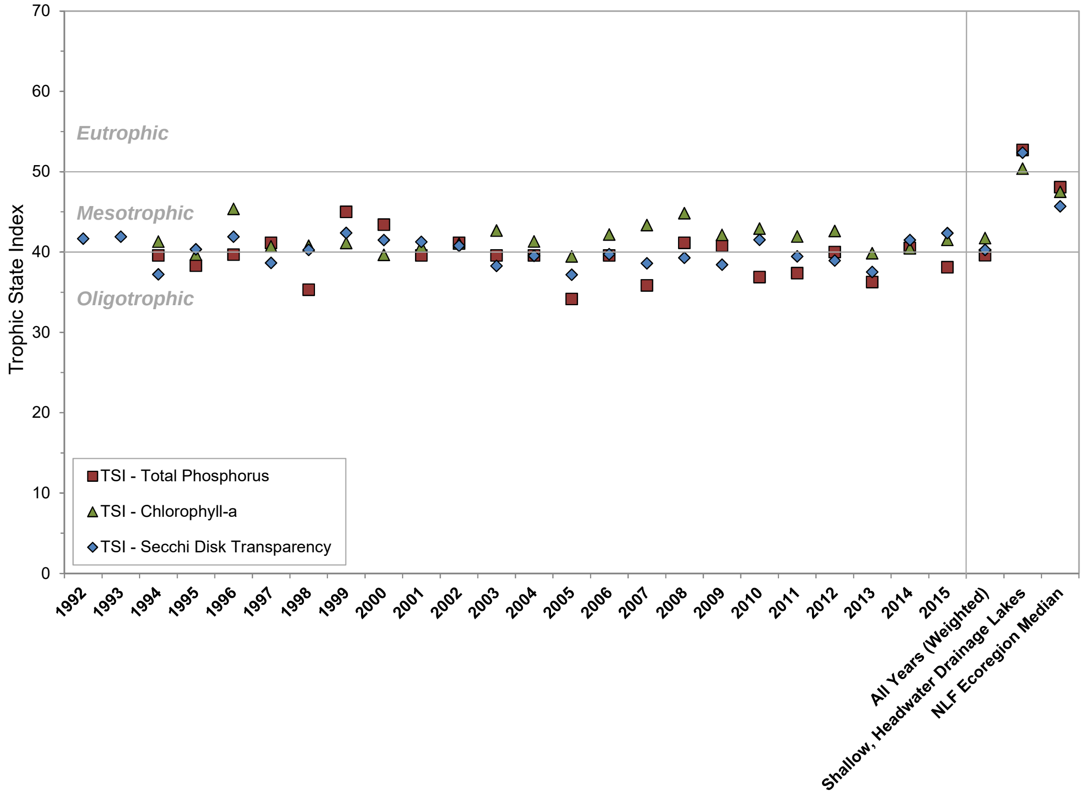



**Figure 3.1-9. Silver Lake annual average Trophic State Index values and median Trophic State Index values for shallow, headwater drainage lakes in Wisconsin and lakes within the Northern Lakes and Forests (NLF) ecoregion.** Values calculated with summer month surface sample data using WDNR PUB-WT-193.

## Dissolved Oxygen and Temperature in Silver Lake

Dissolved oxygen and temperature were measured at regular depth intervals during water quality sampling visits to Silver Lake by Onterra staff and the Silver Lake CLMN volunteer. Profiles depicting these data are displayed in Figure 3.1-10. These data indicate that Silver Lake was weakly stratified in late May. However, by late-June, water temperatures near the bottom increased indicating complete mixing of the water column had occurred, and the more defined stratification observed in late-May was no longer present. Similarly in late-July, near-bottom water temperatures increased again, indicating mixing. During this time, the lake was very weakly stratified with nearly uniform temperatures of approximately 73°F from the surface to approximately 15 feet; below 15 feet, water temperatures gradually declined to 68°F. Dissolved oxygen levels in late-July were approximately 8.0 mg/L from the surface to 15 feet and gradually declined to 3.5 mg/L from 15 feet to 21 feet.

In late-August, water temperatures throughout the water column were nearly uniform, ranging from approximately 72°F at the surface to approximately 70°F near the bottom. The continual increase in near-bottom temperatures over the course of the summer in Silver Lake is an indication of mixing, or warmer surface waters being driven deeper over the course of the summer. The lake's relatively shallow nature allows wind-driven water movement to thoroughly mix the entire water column and maintain dissolved oxygen in near-bottom waters over the course of the summer.

In addition, aquatic vegetation also grows in the deepest areas of Silver Lake, and these plants supply oxygen to these waters through photosynthesis during the day. By late-October, water temperatures throughout the water column had cooled to approximately 47°F, and dissolved oxygen was approximately 10.0 mg/L throughout the water column. In mid-February, the lake was inversely stratified, with the coldest water near the surface and the warmest water of approximately 41°F near the bottom. Sufficient dissolved oxygen was present throughout the majority of the water column, and fish kills due to low levels of oxygen in the winter is likely not a concern on Silver Lake.

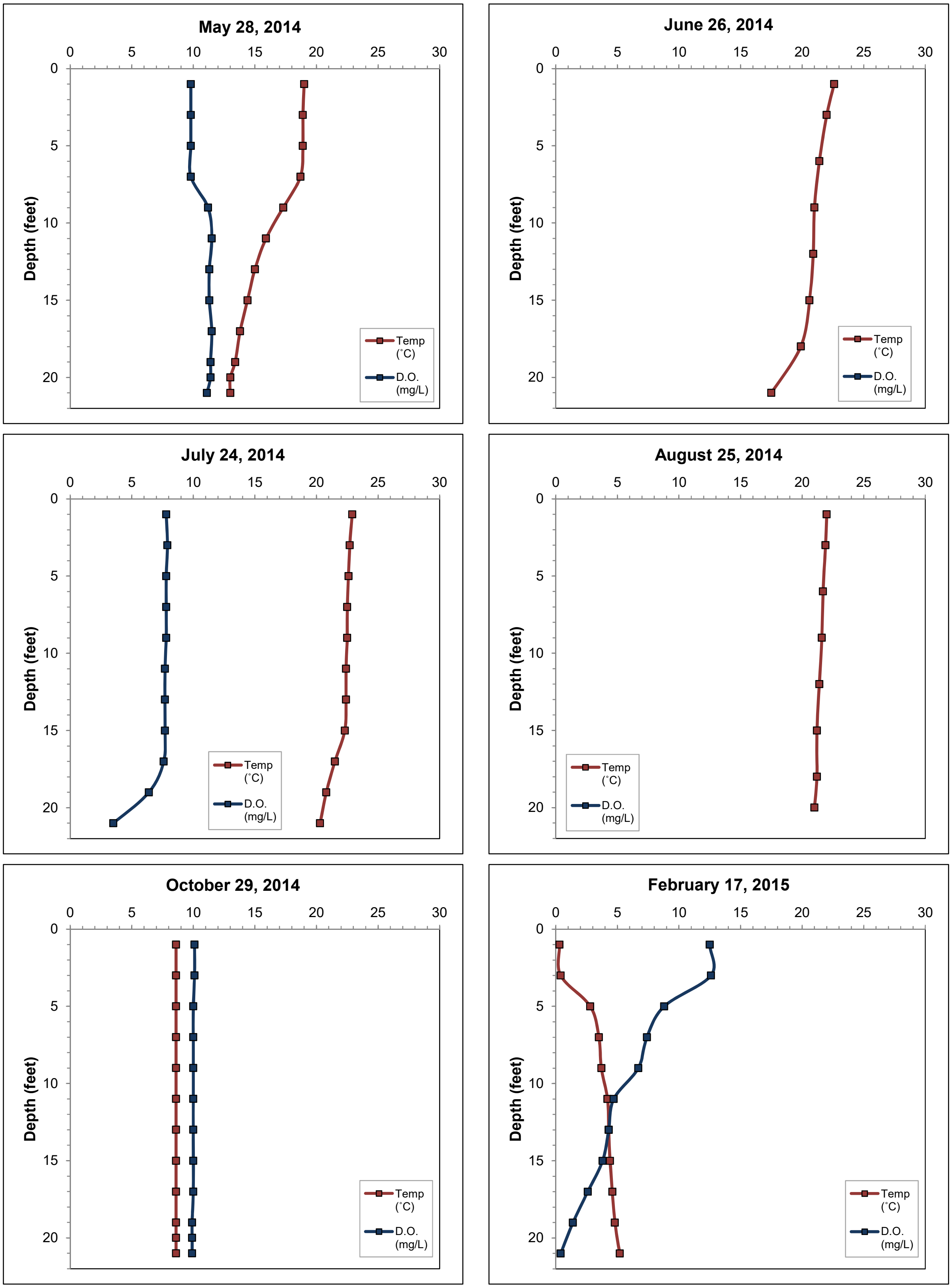



**Figure 3.1-10. Dissolved oxygen and temperature profiles from Silver Lake.** May, July, October, and February profiles collected by Onterra; June and August profiles collected by Silver Lake CLMN volunteer.

## Additional Water Quality Data Collected at Silver Lake

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions ($OH^-$), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius, 1985). The pH of the water in Silver Lake in 2014 was found to be slightly alkaline with near-surface values of around 7.8, falling within the normal range for Wisconsin's lakes.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate ($HCO_3^-$) and carbonate ($CO_3^{2-}$), 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 2014, the alkalinity in Silver Lake was approximately 32.4 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can sustain zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, and Silver Lake's pH of 7.8 falls within this range. Lakes with calcium concentrations of less than 10 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Silver Lake was found to be 6.8 mg/L in 2014, falling in the *low susceptibility* category for zebra mussel establishment. Onterra ecologists conducted plankton tow samples from three locations in Silver Lake in 2014 in an effort to collect any potential larval zebra mussels called veligers, which are pelagic. The samples were analyzed by the WDNR and the results were negative for zebra mussel veligers.

## 3.2 Watershed Assessment

### *Watershed Modeling*

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

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

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

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

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

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

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

### *Silver Lake Watershed Assessment*

Silver Lake's surface watershed (including the lake's surface) encompasses approximately 884 acres (Map 2), yielding a small watershed to lake area ratio of 2:1. WiLMS estimated that Silver Lake has a water residence time of approximately five years. The majority of Silver Lake's watershed (397 acres or 45%) is comprised of forests, 320 acres (36%) is comprised of the lake surface itself, 96 acres (11%) is comprised of rural residential areas, 35 acres (4%) is comprised of pasture/grass and rural open space, 35 acres (4%) is comprised of wetlands, and 2 acres (<1%) are comprised of row crop agriculture (Figure 3.2-1).

Using the land cover types and their acreages within Silver Lake's watershed, WiLMS was utilized to estimate the potential amount of phosphorus delivered to the lake from the watershed annually. The model estimated that approximately 140 pounds of phosphorus are delivered to the lake annually from the watershed. The majority (61%) of this phosphorus is estimated to be due to direct atmospheric deposition onto the lake surface itself, 22% is estimated to be delivered from forested areas, 6% from areas of pasture/grass and rural open space, 6% from rural residential areas, 2% from wetlands, and 2% from row crop agriculture (Figure 3.2-2).

The stakeholder survey indicated that the residences of approximately 60% of the respondents are on municipal sewer while approximately 32% of residences have conventional septic systems. Using data obtained from the stakeholder survey regarding the number of residences with septic systems and the amount of time spent at each residence each year, an estimate of phosphorus loading from septic sources was also calculated. Using the data from Silver Lake stakeholders, WiLMS predicted that approximately 1 pound (1%) of the annual phosphorus load may originate from septic systems.

It is important to note that a failing septic system may not necessarily be impacting the lake if it is located in an area where groundwater is leaving the lake, while a properly functioning septic system may impact the lake if groundwater is passing through it and into the lake. This estimate did not take into account the location of the septic systems and flow of groundwater into and out of Silver Lake. While it is important that riparians with septic systems conduct routine maintenance and inspections, this analysis indicates that septic systems around Silver Lake are currently not having a detectable impact on the lake's water quality.

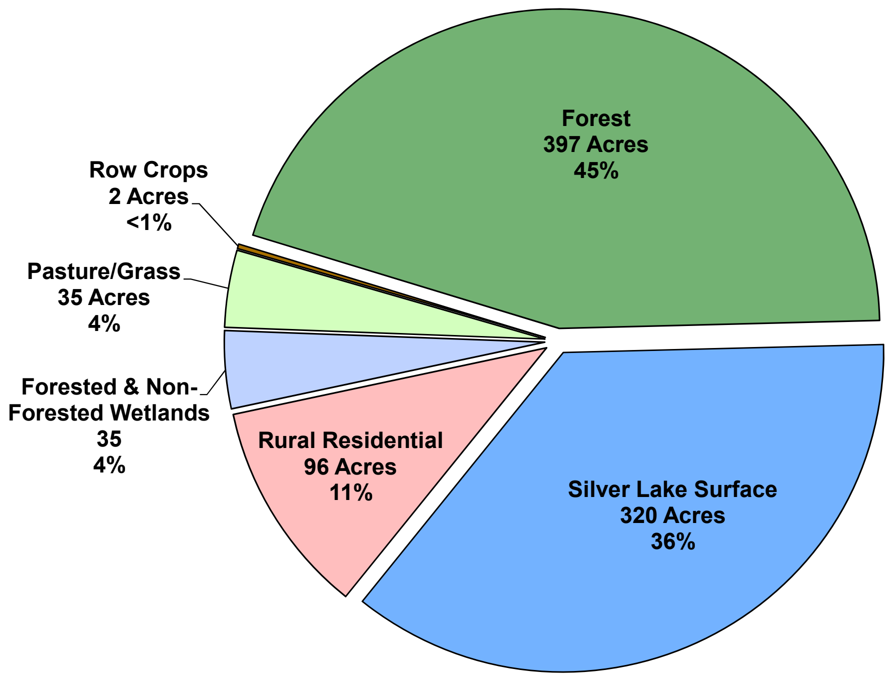



**Figure 3.2-1. Silver Lake watershed land cover types in acres.** Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Based upon the predicted phosphorus load to Silver Lake, WiLMS predicted a within-lake growing season total phosphorus concentration of 19 µg/L, which is approximately 7 µg/L higher than the measured growing season mean total phosphorus concentration of 11.9 µg/L. This overestimation of phosphorus by the model is likely due to the limitations of WiLMS when modeling lakes without a tributary inlet. The model is more adapt at predicting phosphorus loading in lakes that receive larger amounts of inputs from surface water. It must be assumed here that the watershed delivers much less than the 140 lbs of phosphorus predicted by WiLMS to annually enter the lake. The fact that Silver Lake is not fed via a perennial tributary is an indication that there is not enough overland flow of water within the watershed to create one. Overland flow of water from precipitation to Silver Lake likely only occurs from land immediately adjacent to the lake.

Overall, the WiLMS modeling indicates that there are no unaccounted sources of phosphorus entering Silver Lake (e.g. septic system loading). Being a spring lake, groundwater quality and land use within the immediate shoreline areas are going to have the largest influence over Silver Lake's water quality. There are no groundwater models that can currently be applied to Silver Lake, and a groundwater study would have to be conducted to determine the amount of nutrients being delivered to the lake via groundwater. However, because Silver Lake has relatively low nutrient concentrations, nutrient input from groundwater sources is likely low and not a concern at this time.

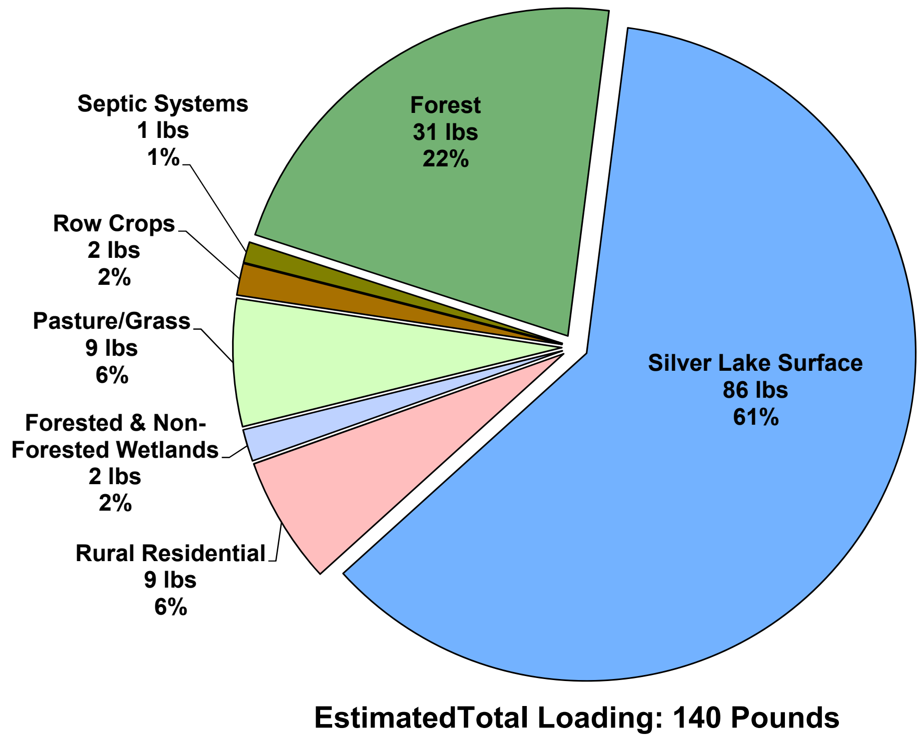



**Figure 3.2-2. Silver Lake estimated annual watershed phosphorus loading in pounds.** Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates. Please note that these phosphorus values are likely overestimated.

## 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) effects on the lake is important in maintaining the quality of the lake's water and habitat.

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

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

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

### Shoreland Zone Regulations

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

**Wisconsin-NR 115: Wisconsin's Shoreland Protection Program**

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted more strict shoreland ordinances. Passed in February of 2010, a revised 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. The revised NR 115 was once again examined in 2012 after some Wisconsin counties identified some provisions that were unclear or challenging to implement. The revisions proposed through Board Order WT-06-12 went into effect in December of 2013. These policy regulations require each county a ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows:

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: 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. No permit is required for removal of vegetation that meets any of the above criteria. 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 entirely within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface on a residential lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner. Counties may develop an ordinance, providing higher impervious surface standards, for highly developed shorelines.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. New language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
  - No expansion or complete reconstruction within 0-35 feet of shoreline
  - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
  - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
  - Vertical expansion cannot exceed 35 feet

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

- For county-specific requirements on this topic, it is recommended that lake property owners contact the county's regulations/zoning department.

**Wisconsin Act 31**

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

## Shoreland Research

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

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

Shorelands provide much in terms of nutrient retention and mitigation, but also play an important role in wildlife habitat. Woodford and Meyer (2003) found that green frog density was negatively correlated with development density in Wisconsin lakes. As development increased, the habitat for green frogs decreased and thus populations became significantly lower. Common loons, a bird species notorious for its haunting call that echoes across Wisconsin lakes, are often associated more so with undeveloped lakes than developed lakes (Lindsay et al. 2002). And studies on shoreland development and fish nests show that undeveloped shorelands are preferred as well. In a study conducted on three Minnesota lakes, researchers found that only 74 of 852 black crappie nests were found near shorelines that had any type of dwelling on it (Reed, 2001). The remaining nests were all located along undeveloped shoreland.


**Photo 3.3-1. Example of a coarse woody habitat along natural lakeshore**

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

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

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

## National Lakes Assessment

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

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

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

### Native Species Enhancement

**Photo 3.3-2. Example of a biolog restoration site.**

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 not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owners should contact the county's regulations/zoning department for all minimum requirements. The single site used for the estimate indicated above has the following characteristics:

- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq ft and 2 shrubs/100 sq ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5' x 35' areas.

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

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

## Silver Lake Shoreland Zone Condition

### Shoreland Development

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


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

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

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

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

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

**Figure 3.1-1. Shoreline assessment category descriptions.**

On Silver Lake, the development stage of the entire shoreland was surveyed during the fall of 2014, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

Silver Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.1 miles (52%) of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.8 miles (20%) of urbanized and developed–unnatural shoreland were observed. If restoration of the Silver Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

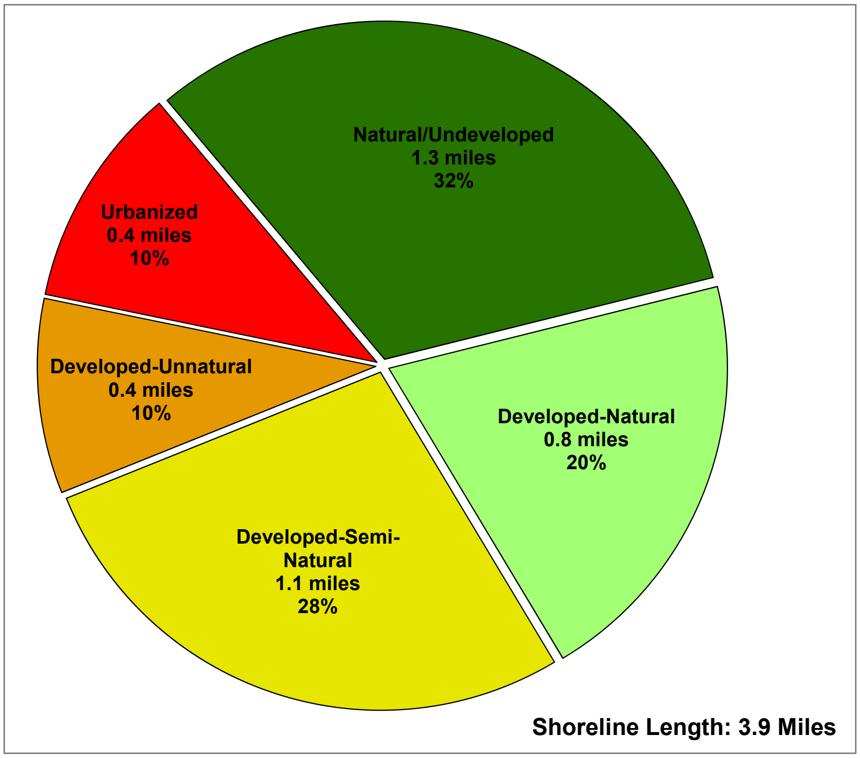



**Figure 3.3-2. Silver Lake shoreland categories and total lengths.** Based upon a fall 2014 survey. Locations of these categorized shorelands can be found on Map 3.

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

## Coarse Woody Habitat

Silver Lake was also surveyed in the fall of 2014 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 115 total pieces of coarse woody habitat were observed along 3.9 miles of shoreline, which gives Silver Lake a coarse woody habitat to shoreline mile ratio of 29:1. Locations of coarse woody habitat are displayed on Map 4. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). However, Onterra ecologists have been conducting coarse woody habitat surveys since 2012, and Silver Lake has the highest coarse woody habitat to shoreline mile ratio of any Onterra-surveyed lakes thus far.

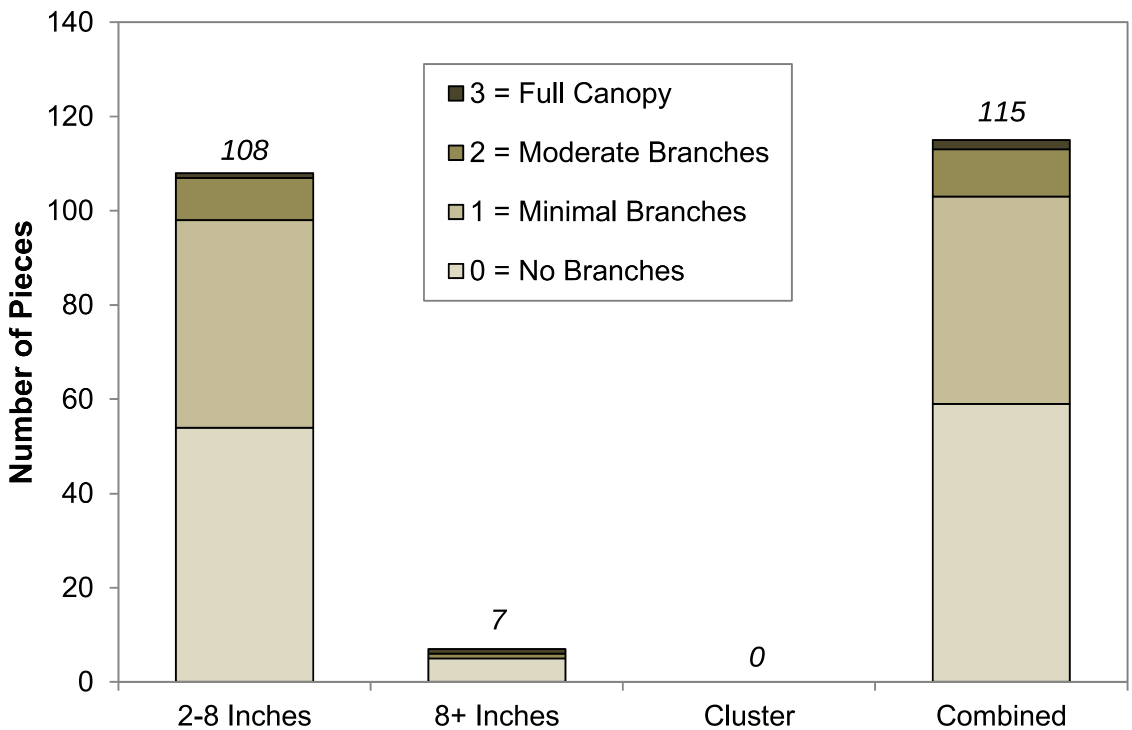



**Figure 3.3-3. Silver Lake coarse woody habitat survey results.** Based upon a fall 2014 survey. Locations of Silver Lake coarse woody habitat can be found on Map 4.

# 3.4 Aquatic Plants

## *Introduction*

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

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

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

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

## Aquatic Plant Management and Protection

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

**Important Note:**
Even though most of these techniques are not applicable to Silver 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 reasons why these techniques are applicable or not applicable to Silver Lake are discussed within each of these sections, as well as in Summary and Conclusions section and the Implementation Plan found near the end of this document.

### Permits

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

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

## Manual Removal

### General Manual Removal Techniques

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.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and piling of fragments on shore. 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 15$^{th}$.

**Important Note:**
Silver Lake does not contain nuisance levels of native aquatic plants that require manual removal, and as will be discussed in the Aquatic Plant Survey Results Section, the lake contains a very high-quality native aquatic plant community. Efforts should be taken to enhance and protect the lake's native aquatic plant community, and any manual removal efforts discussed in this section should focus upon non-native aquatic plants like Eurasian water milfoil.

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

#### *Application to Silver Lake*

As will be discussed in the Aquatic Plant Survey Results Section, Silver Lake has a very high-quality native aquatic plant community. There are no areas within the lake that contain nuisance levels of native aquatic plants that would require manual removal for navigation purposes. However, a small population of the non-native, invasive plant species Eurasian water milfoil was discovered in Silver Lake in 2010. While herbicide applications were utilized to control larger areas of this plant in Silver Lake, volunteers have initiated hand-harvesting efforts to remove any plants that remain following the treatment.

## 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 mainly 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.

### *Application to Silver Lake*

Silver Lake is a natural seepage lake lacking both a defined inlet and outlet, and water levels are primarily dictated by groundwater levels and not via a control structure such as a dam. Therefore, a water level drawdown to control Eurasian water milfoil would not be an applicable management strategy for Silver Lake.

## Mechanical Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants in areas where navigation may be hindered, 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.

In addition to larger mechanical harvesting 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.

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

### *Application to Silver Lake*

As discussed previously, Silver Lake does not contain any areas where native and/or non-native aquatic plants inhibit navigation within the lake. Because of this, mechanical harvesting of aquatic plants is not an applicable management strategy for Silver Lake.

## 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, targeted AIS control when exposure times are low |
| Systemic | Auxin Mimics | 2,4-D | auxin mimic, plant growth regulator | Submersed species, largely for Eurasian water milfoil |
| | | Triclopyr | auxin mimic, plant growth regulator | Submersed species, largely for Eurasian water milfoil |
| | In Water Use Only | Fluridone | Inhibits plant specific enzyme, new growth bleached | Submersed species, largely for Eurasian water milfoil |
| | Enzyme Specific (ALS) | Penoxsulam | Inhibits plant-specific enzyme (ALS), new growth stunted | New to WI, potential for submergent and floating-leaf species |
| | | Imazamox | Inhibits plant-specific enzyme (ALS), new growth stunted | New to WI, potential for submergent and floating-leaf species |
| | Enzyme Specific (foliar use only) | Glyphosate | Inhibits plant-specific enzyme (ALS) | Emergent species, including purple loosestrife |
| | | Imazapyr | Inhibits plant-specific enzyme (EPSP) | Hardy emergent species, including common reed |

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

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

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

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

| ***Advantages*** | ***Disadvantages*** |
|---|---|
| • Herbicides are easily applied in restricted areas, like around docks and boatlifts.<br>• Herbicides can target large areas all at once.<br>• 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.<br>• Some herbicides can be used effectively in spot treatments.<br>• 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.<br>• Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly.<br>• 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.<br>• Many aquatic herbicides are nonselective.<br>• Some herbicides have a combination of use restrictions that must be followed after their application.<br>• Overuse of same herbicide may lead to plant resistance to that herbicide. |

### *Application to Silver Lake*

As mentioned, herbicides are used to control non-native aquatic plants like Eurasian water milfoil in Wisconsin's lakes and have been used on Silver Lake. However, while Eurasian water milfoil can be controlled, there has never been a documented case in Wisconsin where it was completely eliminated from a lake following its introduction. Therefore, ongoing annual herbicide treatments are generally required to maintain a small Eurasian water milfoil population. A detailed discussion on the treatments that have occurred in Silver Lake can be found in the Non-Native Aquatic Plants Section.

## 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.<br>• Likely environmentally safe and little risk of unintended consequences. | • Stocking and monitoring costs are high.<br>• This is an unproven and experimental treatment.<br>• 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.<br>• Once released, considerably less effort than other control methods is required.<br>• Augmenting populations many lead to long-term control. | • Although considered “safe,” reservations about introducing one non-native species to control another exist.<br>• Long range studies have not been completed on this technique. |

### Application to Silver Lake

Milfoil weevils have generally been used in lakes with Eurasian water milfoil populations that are larger and denser than that found in Silver Lake. The goal of milfoil weevil application is to supplement the lake's native weevil population to reduce Eurasian water milfoil. Lakes that have seen good control utilizing weevils have seen a reduction in Eurasian water milfoil density while most of the plants are prevented from reaching the surface where they create nuisance conditions. Weevils are generally used to control larger areas of colonized Eurasian water milfoil, and the Eurasian water milfoil population in Silver Lake is mainly comprised of widely scattered plants and clumps of plants. There is likely not enough Eurasian water milfoil in Silver Lake to sustain an introduced weevil population. In addition, as mentioned, research is still being conducted on weevil use in Wisconsin and they are currently not a WDNR grant-eligible method for Eurasian water milfoil control.

## 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 Silver 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 Silver 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 Silver Lake. Comparisons will be displayed using boxplots that showing

A 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.

median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-1) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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

**Floristic Quality Assessment**

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Silver Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1). Ecoregional and state-wide medians were calculated from whole-lake point-intercept surveys conducted on 392 lakes throughout Wisconsin by Onterra and WDNR ecologists.

> 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.

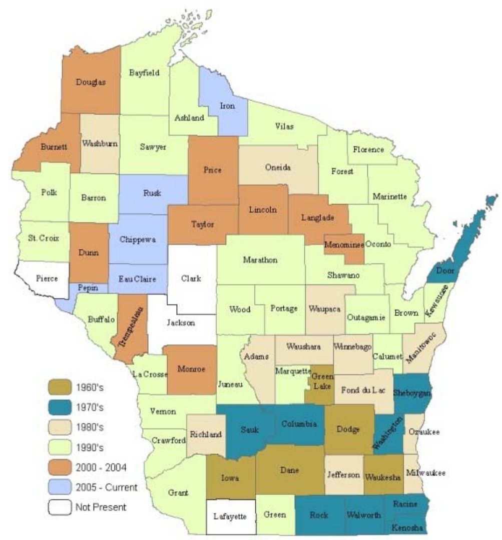



**Figure 3.4-1. Spread of Eurasian water milfoil within WI counties.** WDNR Data 2011 mapped by Onterra.

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 previously, numerous plant surveys were completed as a part of this project. On June 19, 2014, an Early-Season AIS (ESAIS) Survey was completed on Silver Lake that focused upon locating any potential occurrences of the non-native curly-leaf pondweed. During this meander-based survey of the *littoral zone,* no occurrences of this invasive plant were located. It is believed that curly-leaf pondweed is currently not present in Silver Lake or it exists at an undetectable level.

The whole-lake aquatic plant point-intercept and community mapping surveys were conducted on Silver Lake on July 22 and 23, 2014 by Onterra (Appendix F). During these surveys, a total of 38 aquatic plant species were located, one of which is considered to be non-native, invasive species: Eurasian water milfoil (EWM) (Table 3.4-1). Because of its ecological significance, the population of EWM in Silver Lake is discussed in the Non-Native Aquatic Plant Section. Table 3.4-1 also includes the 27 aquatic plant species located during a whole-lake point-intercept survey conducted by the WDNR in 2010. All of the species located in 2010, with the exception of leafy pondweed and white-stem pondweed, were re-recorded in 2014; 16 species were located in 2014 that were not recorded in 2010. Changes in the occurrence of certain aquatic plant species between 2010 and 2014 are discussed later in this section.

Information regarding Silver Lake's substrate types was collected during the 2014 whole-lake point-intercept survey with a pole-mounted rake at locations less than 15 feet. These data show the majority (68%) of sampling locations in less than 15 feet of water contain soft sediments, while 27% are comprised of sand, and 5% are comprised of rock (Figure 3.4-2). Like terrestrial plants, aquatic plants vary in their preference for a particular substrate type; some species are usually only found growing in soft sediments, others only course substrates like sand, while some are more generalists and can be found growing in either. Lakes with varying types of substrates generally support a higher number of aquatic plant species because of the different habitat types that are available.

During the 2014 point-intercept survey, aquatic plants were found growing out to the maximum depth of the lake at 21 feet, indicating the entire area of Silver Lake is comprised of littoral zone (Figure 3.4-2). As discussed in the Water Quality Section, Silver Lake has very high water clarity which allows sunlight to penetrate deeper into the water column and support aquatic plants at greater depths. Typically, aquatic plants grow to a depth of two to three times the average Secchi disk depth. In Silver Lake, average growing season Secchi disk transparency is high at 13.2 feet. Of the 473 point-intercept sampling locations visited in 2014, 89% contained aquatic vegetation, indicating Silver Lake is highly vegetated. The 2014 occurrence of vegetation in Silver Lake was slightly higher than the 85% occurrence recorded in 2010. Aquatic plant total rake fullness data collected in 2014 indicates that 87% of the point-intercept sampling locations contained rake fullness ratings of 1 or 2, while 1% had a rake fullness rating of 3. This indicates that the density or biomass of aquatic plants in Silver Lake is low to moderate.

**Table 3.4-1. Aquatic plant species located in Silver Lake during WDNR 2010 and Onterra 2014 aquatic plant surveys.**

| Growth Form | Scientific Name | Common Name | Coeffecient of Conservatism (C) | 2010 (WDNR) | 2014 (Onterra) |
|---|---|---|---|---|---|
| Emergent | *Calamagrostis canadensis* | Blue-joint grass | 5 | | I |
| | *Calla palustris* | Water arum | 9 | | I |
| | *Carex comosa* | Bristly sedge | 5 | | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | | I |
| | *Iris versicolor* | Northern blue flag | 5 | | I |
| | *Juncus effusus* | Soft rush | 4 | | I |
| | *Schoenoplectus tabernaemontani* | Softstem bulrush | 4 | | I |
| | *Scirpus cyperinus* | Wool grass | 4 | | I |
| FL | *Brasenia schreberi* | Watershield | 7 | X | X |
| | *Nuphar variegata* | Spatterdock | 6 | I | X |
| | *Nymphaea odorata* | White water lily | 6 | X | X |
| FL/E | *Sparganium angustifolium* | Narrow-leaf bur-reed | 9 | | X |
| | *Sparganium* sp. | Bur-reed sp. | N/A | I | |
| Submergent | *Bidens beckii* | Water marigold | 8 | X | X |
| | *Chara* spp. | Muskgrasses | 7 | X | X |
| | *Elodea canadensis* | Common waterweed | 3 | X | X |
| | *Eriocaulon aquaticum* | Pipewort | 9 | X | I |
| | *Isoetes* spp. | Quillwort species | 8 | | X |
| | *Myriophyllum spicatum* | Eurasian water milfoil | Exotic | I | I |
| | *Myriophyllum tenellum* | Dwarf water milfoil | 10 | X | X |
| | *Najas flexilis* | Slender naiad | 6 | | X |
| | *Najas guadalupensis* | Southern naiad | 7 | X | X |
| | *Nitella* spp. | Stonewort spp. | 7 | X | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X | X |
| | *Potamogeton berchtoldii* | Slender pondweed | 7 | X | X |
| | *Potamogeton foliosus* | Leafy pondweed | 6 | X | |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X | X |
| | *Potamogeton illinoensis* | Illinois pondweed | 6 | X | X |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | I | X |
| | *Potamogeton praelongus* | White-stem pondweed | 8 | X | |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X | X |
| | *Ranunculus flammula* | Creeping spearwort | 9 | X | X |
| | *Utricularia vulgaris* | Common bladderwort | 7 | | X |
| | *Vallisneria americana* | Wild celery | 6 | X | X |
| S/E | *Eleocharis acicularis* | Needle spikerush | 5 | X | X |
| | *Juncus pelocarpus f. submersus* | Brown-fruited rush | 8 | X | X |
| | *Sagittaria* sp. (rosette) | Arrowhead sp. (rosette) | N/A | X | |
| | *Sagittaria cristata* | Crested arrowhead | 9 | | X |
| | *Sagittaria cuneata* | Arum-leaved arrowhead | 7 | | I |
| FF | *Lemna minor* | Lesser duckweed | 5 | X | I |

*FL = Floating-leaf; FL/E = Floating-leaf & Emergent; S/E = Submergent & Emergent; FF = Free-floating*
*X = Present on rake during point-intercept survey; I = Incidentally located*

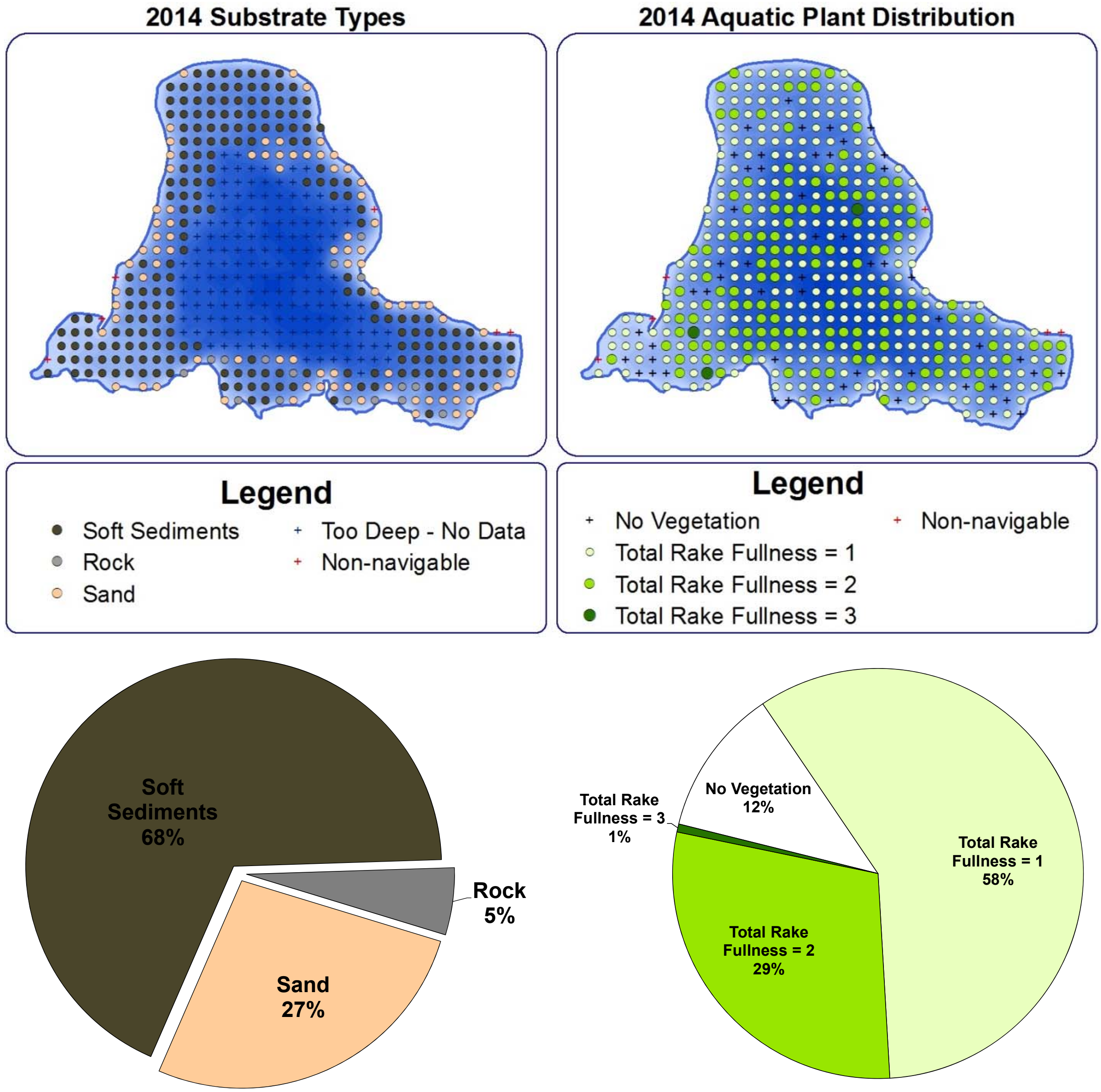



**Figure 3.4-2. Silver Lake 2014 substrate types (left) and aquatic vegetation distribution and total rake fullness (right).** Created using data from Onterra 2014 whole-lake point-intercept survey.

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).

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 more familiar with (Photo 3.4-1). It is important to note that the definition of these two groups is based solely on morphology and physiology 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.

**Photo 3.4-1. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and fern pondweed (*Potamogeton robbinsii*) and variable pondweed (*Potamogeton gramineus*) of the elodeid growth form (right).**

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 within the water and must be supplemented from dissolved 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 their carbon storage (Madsen et al. 2002). 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 Silver Lake with moderate alkalinity levels, the aquatic plant community is comprised of both isoetids and elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

Figure 3.4-3 illustrates the 2014 frequency of occurrence of isoetids, elodeids, characeans (macroalgae - *Chara* spp. and *Nitella* spp.), and floating-leaf aquatic plants across water depths of Silver Lake as determined from the whole-lake point-intercept survey. As illustrated, while elodeids and characeans are present across water depths in Silver Lake, isoetids have a narrower range and are only present between 1-8 feet of water and are the dominant plants in 3-5 feet of water. Floating-leaf plants are restricted to shallower water, and elodeids and characeans are abundant in deeper waters.

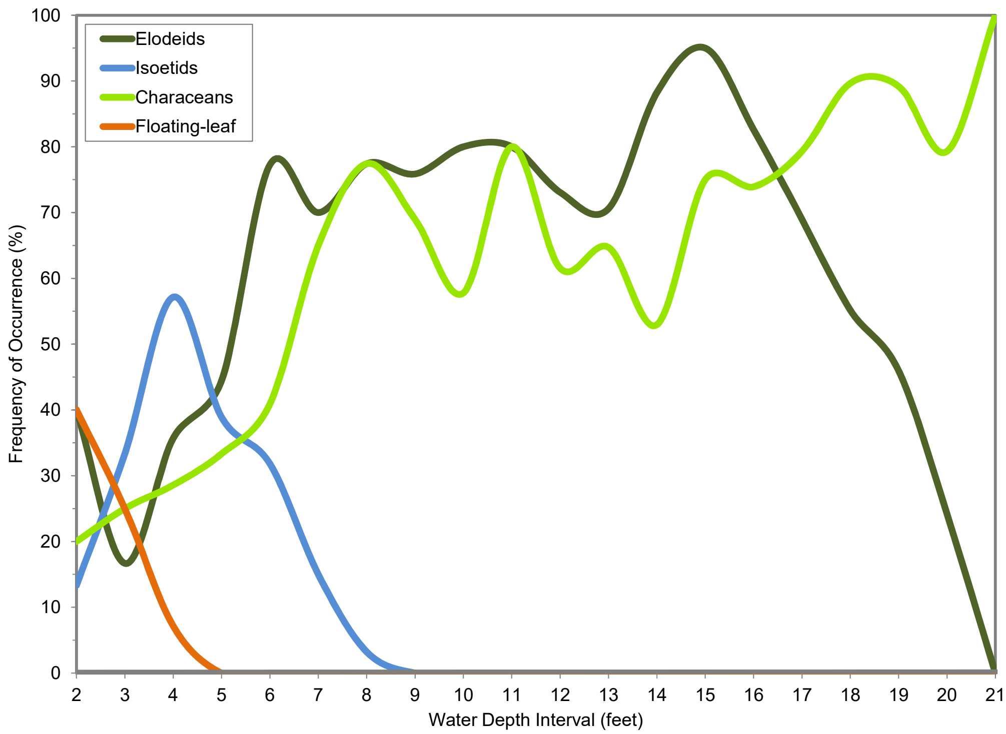



**Figure 3.4-3. Frequency of occurrence of isoetids, elodeids, characeans, and floating-leaf aquatic plant species in Silver Lake in 2014.** Created using data from July 2014 aquatic plant point-intercept survey. Lines smoothed to ease visualization.

Of the 37 native aquatic plant species located during 2014 surveys on Silver Lake, 25 were physically encountered on the rake during the whole-lake point-intercept survey. The remaining 13 species were located incidentally during the point-intercept and/or community mapping surveys. Of the 25 species encountered on the rake, stoneworts, southern naiad, muskgrasses, and fern pondweed were the four-most frequently encountered (Figure 3.4-4). Stoneworts, a genus of macroalgae, were located at approximately 51% of the point-intercept locations and were most abundant between 8 and 21 feet of water. Despite not being a vascular plant, stoneworts can grow relatively large and form dense beds along the lake bottom, supplying oxygen to deeper waters and providing structural habitat for micro- and macroinvertebrates and fish. Little is known about the life histories and distribution of stonewort species in Wisconsin; however, it is known that stoneworts require high quality water and are indicators of good environmental health.

Southern naiad was the second-most frequently encountered aquatic plant in Silver Lake in 2014 with a littoral frequency of occurrence of approximately 42% (Figure 3.4-4). Emerging research is indicating that hybrids between southern naiad subspecies exist and are often observed acting aggressively and growing to levels which may interfere with recreation (Les et al. 2010). In Silver Lake, southern naiad was most abundant in deeper waters of the littoral zone from 7-15 feet and was not observed matting on the surface in any locations. As is discussed further in this section, the occurrence of southern naiad in Silver Lake in 2014 was not statistically different from its occurrence in 2010.

Surveys of other lakes in the northern region are indicating that some southern naiad populations are increasing. The southern naiad population in Silver Lake likely already inhabits most available areas, but future surveys will aid in determining the dynamics of this population in Silver Lake. It is not clear why some southern naiad populations act aggressively, but the population in Silver Lake does not appear to be hindering recreation in any areas. These plants provide aquatic organisms with valuable structural habitat and sources of food. Additionally, it aids in maintaining the water quality of Silver Lake by stabilizing bottom sediments and utilizing nutrients that would otherwise be available to free-floating algae.

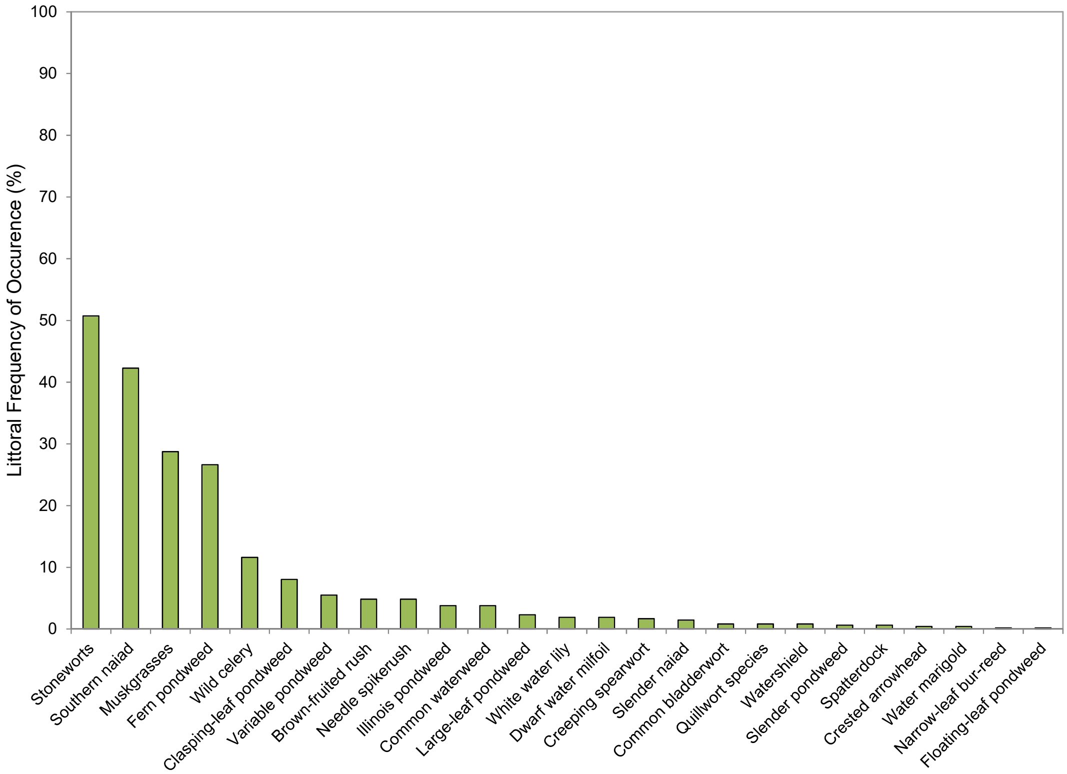



**Figure 3.4-4. Silver Lake 2014 littoral frequency of occurrence of aquatic plant species.** Created using data from July 2014 aquatic plant point-intercept survey. Note: Eurasian water milfoil was not detected at any of the sampling locations in 2014.

The third-most frequently encountered aquatic plant during the 2014 point-intercept survey were the muskgrasses (*Chara* spp.), with a littoral frequency of occurrence of approximately 29% (Figure 3.4-4). Like stoneworts, muskgrasses are a genus of macroalgae and are similar in appearance. In Silver Lake, muskgrasses were found in a relatively similar abundance across water depths from 2-21 feet. Like stoneworts, muskgrasses have long stems with multiple whorls of branches, which provide valuable structural habitat.

Fern pondweed was the fourth-most frequently encountered aquatic plant in Silver Lake in 2014 with a littoral occurrence of 27%. As its name indicates, this plant resembles a fern frond in appearance, and is often a dominant species in plant communities of northern Wisconsin lakes. Fern pondweed is generally found growing in thick beds over soft substrates, where it stabilizes bottom sediments and provides a dense network of structural habitat for aquatic wildlife. In 2014, fern pondweed was present across littoral depths in Silver Lake, and was only absent from near-shore areas with sandy substrates.

In the summer of 2010 following the discovery of Eurasian water milfoil, the WDNR conducted a whole-lake point-intercept survey on Silver Lake. Since the sampling methodology and sampling locations were the same as the survey conducted in 2014, the data that were collected during these surveys can be compared to determine if any changes in plant community composition occurred over this time period. Figure 3.4-5 displays the littoral frequency of occurrence of aquatic plant species from the 2010 and 2014 point-intercept surveys; only those species that had at least an occurrence of 5% were included in the analyses. The muskgrasses and stoneworts are morphologically very similar, and identification between the two is often difficult. For this reason, the occurrences of each plant were combined for this analysis.

The littoral occurrences of five native aquatic plant species were found to be statistically different between 2010 and 2014 (Figure 3.4-5). The occurrences common waterweed and clasping-leaf pondweed saw statistically valid reductions from 2010 to 2014, while muskgrasses\stoneworts, fern pondweed, and wild celery exhibited statistically valid increases. Common waterweed and clasping-leaf pondweed declined in occurrence by 85% and 51%, respectively, while muskgrasses and stoneworts, fern pondweed, and wild celery increased by 14.6%, 101%, and 65%, respectively. The occurrences of southern naiad, variable pondweed, brown-fruited rush, and needle spikerush were not statistically different from 2010 to 2014.

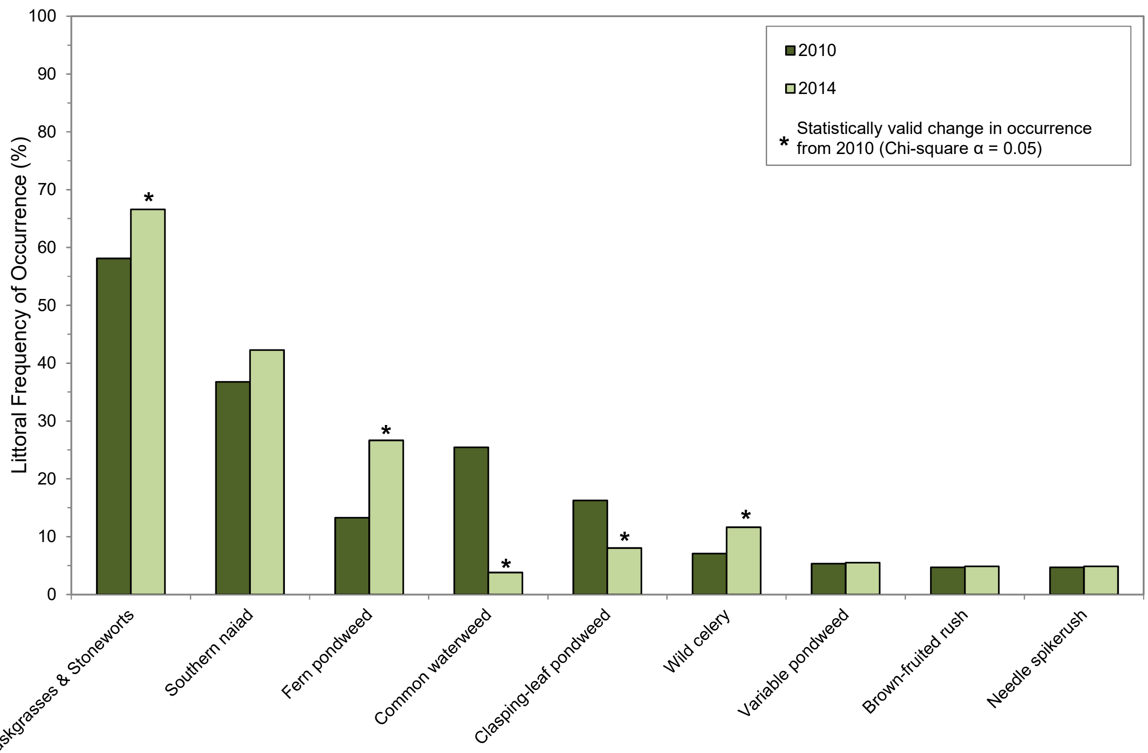



**Figure 3.4-5. Silver Lake littoral frequency of occurrence of select aquatic plant species from WDNR 2010 and Onterra 2014 point-intercept surveys.** Note: only those species with an occurrence of at least 5% in either survey are displayed. Created using data from WDNR 2010 and Onterra 2014 point-intercept surveys.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, herbivory, competition, and disease among other factors. Native aquatic plants can also decline following the implementation of herbicide applications to control non-native aquatic plants; however, as is discussed in detail within the Non-Native Aquatic Plant Section, the declines in occurrence of common waterweed and clasping-leaf pondweed in Silver Lake are not believed to be a result of the herbicide treatments conducted in 2012 and 2014 to control EWM. Rather, these declines and the increases observed in stoneworts/muskgrasses, fern pondweed, and wild celery, are believed to be due to varying interannual environmental conditions.

Factors such as a later-than-normal ice-out and cooler temperatures may have been unfavorable for the growth of common waterweed and clasping-leaf pondweed. In response to reduced competition for resources from common waterweed and the resulting added open space, stoneworts/muskgrasses and fern pondweed may have increased to fill these open niches. Michelle Nault (personal comm. 2014) of the WDNR reported a large decline in a common waterweed population in Seven Island Lake in Langlade County in 2014, similar in magnitude to that observed in Silver Lake. Michelle provided data from 12 other lakes in Wisconsin that have not conducted any herbicide treatments and have had their plant communities monitored annually for a number of years. The common waterweed populations in some of these lakes have also exhibited large declines and subsequent increases between years. The data gathered by the WDNR indicates that common waterweed populations have the capacity to fluctuate markedly from year to year. However, the conditions that cause these fluctuations are not understood.

As discussed in the primer section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. The native species encountered on the rake during the 2010 and 2014 point-intercept surveys and their conservatism values were used to calculate the FQI of Silver Lake's aquatic plant community (equation shown below).

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

Figure 3.4-6 compares the 2010 and 2014 FQI components of Silver Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion and lakes throughout Wisconsin. The number of native plant species found in Silver Lake, or the species richness, falls above the median value for lakes within the NLFL ecoregion and for lakes throughout Wisconsin. Silver Lake has a relatively low shoreline complexity value of 2.5, meaning that the lake has a lower ratio of shoreline perimeter relative to its area. Lakes with higher shoreline complexity generally have higher species richness given the presence of more backwater areas and other variances in habitat. However, despite its low shoreline complexity, Silver Lake still has high species richness. This higher species richness is likely largely driven by the lake's substrate types, water clarity, and water chemistry.

As discussed previously, Silver Lake contains areas of soft sediments, sand, and rock, which create different habitats for aquatic plants. Silver Lake's high water clarity also allows aquatic plants to inhabit the entire area of the lake, but varying amounts of light exist at different depths within the lake. Stoneworts dominate the deepest areas of Silver Lake as they are able to survive in areas with lower light; however, in shallower areas with higher light levels, stoneworts get outcompeted by taller pondweeds and other angiosperms (flowering plants) (Kufel and Kufel 2002). Changing light levels with depth restrict plants to areas that are suitable or to areas where they can grow without competition from other species. Silver Lake's water chemistry, specifically in terms of its alkalinity, also drives its species richness. Mesotrophic lakes like Silver Lake with moderate alkalinity tend to have the highest species richness, supporting a diverse assemblage of isoetids and characeans that can cohabitate below a scattered canopy of larger elodeids (Vestergaard and Sand-Jensen 2000).

The average conservatism value for Silver Lake's aquatic plant community was 6.9 in both 2010 and 2014, indicating that Silver Lake contains a high number of aquatic plant species that are sensitive to environmental degradation and require high-quality conditions to persist. Silver Lake's average conservatism value falls near the upper quartile value for lakes in the NLFL Ecoregion and above the upper quartile value for lakes throughout Wisconsin (Figure 3.4-6). Combining the native species richness and average conservatism values for both 2010 and 2014 yields exceptionally high FQI values of 32.9 and 34.6, respectively, which both exceed the median values for lakes in the NLFL Ecoregion and lakes throughout the state. This analysis indicates that the aquatic plant community of Silver Lake is of higher quality than the majority of the lakes within the NLFL Ecoregion and the entire state of Wisconsin.

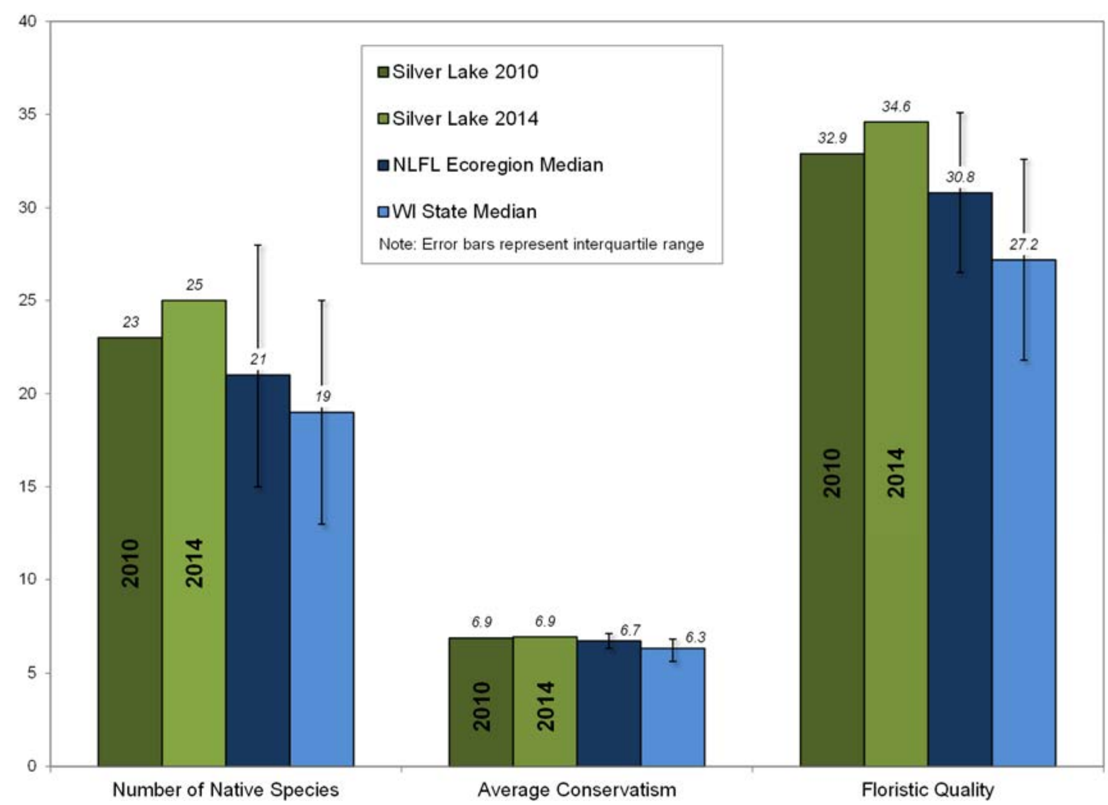



**Figure 3.4-6. Silver Lake Floristic Quality Assessment.** Created using data from WDNR 2010 and Onterra 2014 point-intercept surveys. Analysis follows Nichols (1999).

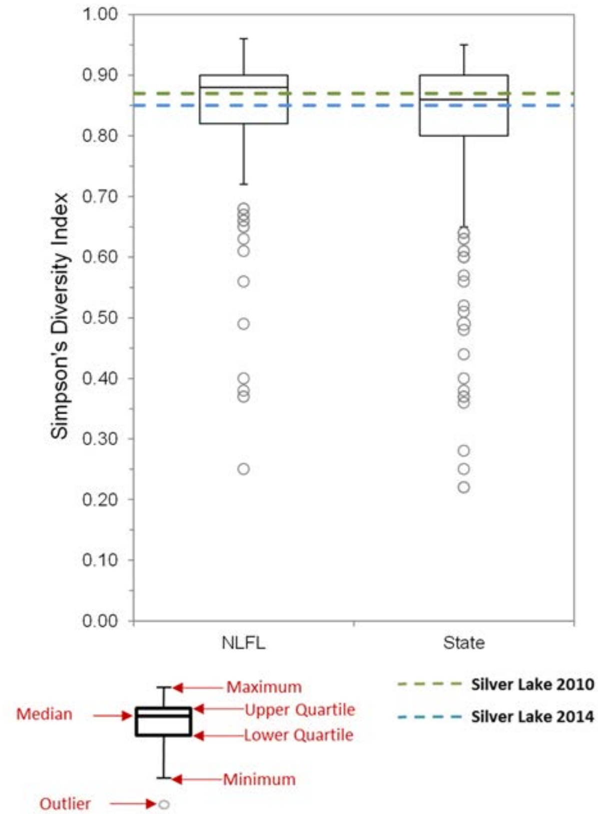



**Figure 3.4-7. Silver Lake species diversity index.** Created using data from WDNR 2010 and Onterra 2014 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

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 Silver 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 Silver Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 3.4-7). Using the data collected from the 2010 and 2014 point-intercept surveys, Silver Lake's aquatic plant community was shown to have moderate species diversity with Simpson's diversity values of 0.87 and 0.85, respectively. These diversity values fall below the median for lakes within the NLFL Ecoregion and near the median value for lakes throughout Wisconsin (Figure 3.4-7). In other words, if two individual aquatic plants were randomly sampled from Silver Lake in 2014, there would be an 85% probability that they would be different species.

As explained earlier, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while stoneworts were found at 51% of the littoral sampling locations in Silver Lake in 2014, its relative frequency of occurrence is 25%. Explained another way, if 100 plants were randomly sampled from Silver Lake, 25 of them would be stoneworts. Figure 3.4-8 displays the relative occurrence of aquatic plant species from Silver Lake in 2014, and illustrates that 72% of the aquatic plant community is comprised of four species: stoneworts, southern naiad, muskgrasses, and fern pondweed. This dominance of the plant community by these four species and thus relatively uneven distribution of aquatic plants within the community leads to the lower Simpson's Diversity Index value.

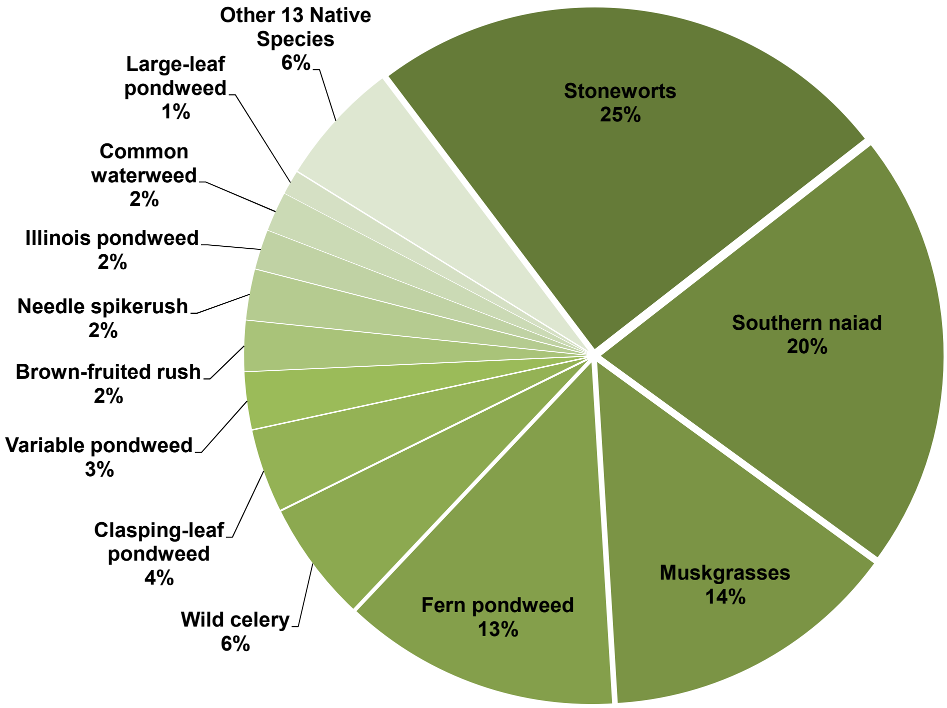



**Figure 3.4-8. Silver Lake 2014 relative frequency of occurrence analysis.** Created using data from Onterra 2014 point-intercept survey.

The 2014 aquatic plant community mapping survey indicated that approximately 7.5 acres (2.3%) of Silver Lake's 320 acres contains emergent and floating-leaf aquatic plant communities (Table 3.4-2 and Map 5). These communities were comprised of fourteen emergent and/or floating-leaf aquatic plant species (Table 3.4-1). The majority of these communities were found within the shallow and protected bay on the southwest side of the lake (Map 5). 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.

**Table 3.4-2. Acres of emergent and floating-leaf aquatic plant communities on Silver Lake.** Created using data from 2014 aquatic plant community mapping survey.

| Plant Community | Acres |
|---|---|
| Emergent | 0.0 |
| Floating-Leaf | 5.8 |
| Mixed Emergent & Floating-Leaf | 1.7 |
| **Total** | **7.5** |

The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Silver Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. A stakeholder survey of SLA members indicates that motorboats with a 25 horsepower or greater motor are the second-most prevalent watercraft on the lake (Appendix B, Question #13). Additionally, stakeholders indicated throughout the survey that lakeshore development is one of their top concerns regarding Silver Lake (Questions #21).

## *Non-native Aquatic Plants in Silver Lake*

### Eurasian water milfoil

Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was first located in Silver Lake in 2010. Following its discovery, meander surveys were conducted by SLPA volunteers and the AIS Coordinator for Forest County. In addition, the WDNR also conducted a whole-lake point-intercept survey in 2010 and hand-removal of the known EWM colony near the lake's boat landing. Data regarding the locations of EWM located in 2010 were given to Onterra, and Onterra ecologists conducted a lake-wide meander survey aimed at locating and mapping EWM in July of 2011. During this survey, more EWM was located than had been located in 2010 (Map 6). With Onterra's assistance, the SLPA successfully applied for a WDNR AIS-Early Detection and Response (EDR) Grant to aid in funding the monitoring and implementation of an EWM control strategy in the spring of 2012.

#### *Background on Herbicide Application Strategy*

Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to dilute herbicide concentration within aquatic systems. Understanding concentration-exposure times are important considerations for aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Much information has been gathered in recent years, largely as a result of a joint research project between the WDNR, US Army Corps of Engineers (USACE), and private consultants. Based on their preliminary findings, lake managers have adopted two main treatment strategies; 1) whole-lake and 2) spot treatment strategies.

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. This strategy is utilized when the target plant is widespread throughout a lake or basin. Because the EWM in Silver Lake was only present within an area in the southwestern portion of the lake, the whole-lake treatment strategy was not utilized.

Spot treatments are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant effects outside of that area. Herbicide application rates for spot treatment are formulated volumetrically, typically targeting EWM with 2,4-D at 3.0-4.0 ppm acid equivalent (ae). This means that sufficient 2,4-D is applied within the *Application Area* such that if it mixed evenly with the *Treatment Volume*, it would equal 3-4.0 ppm ae. This standard method for determining spot treatment use rates is not without flaw, as no physical barrier keeps the herbicide within the *Treatment Volume* and herbicide dissipates horizontally out of the area before reaching equilibrium (Figure 3.4-9). While lake managers may propose that a particular volumetric dose be used, such as 3.0-4.0 ppm ae, it is understood that actually achieving 3.0-4.0 ppm ae within the water column is not likely due to dissipation and other factors. This has been the EWM control strategy utilized most on Wisconsin lakes, and was the strategy utilized on Silver Lake in 2012 and 2014.

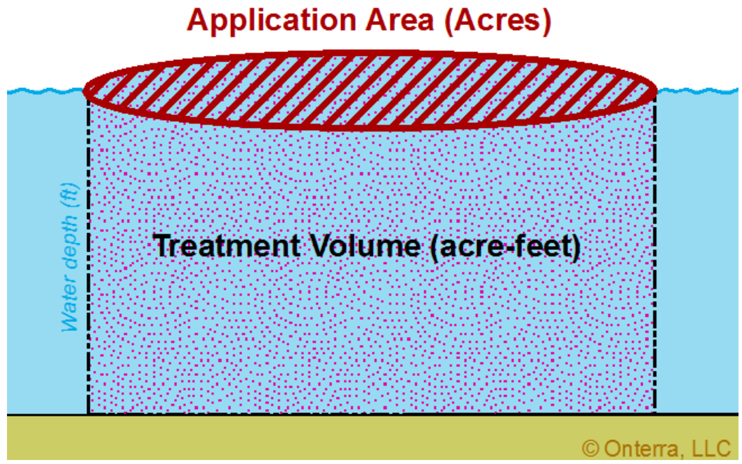


**Figure 3.4-9. Herbicide Spot Treatment diagram**.

### *Silver Lake Treatment History*

Following Onterra's assessment of EWM within Silver Lake in 2011, a 2012 control strategy was developed using the spot treatment strategy where a specific area within the southwestern portion of the lake was to be targeted for control in the spring of 2012. This 10.4-acre area of EWM was proposed to be applied with granular 2,4-D to achieve a concentration of 2.5 ppm ae within this area. Because this was the first herbicide treatment to be conducted on the EWM within Silver Lake and it was in a relatively protected location where water movement was likely to be minimal, a more conservative approach in terms of herbicide dosage was utilized. The 10.4 acre area in Silver Lake was applied with granular 2,4-D in the spring of 2012 by Stantec, Inc. (Map 6). Surveys of the treatment site by Onterra later in the summer of 2012 indicated that the treatment was highly successful, with very little EWM plants being located (Map 7).

While sufficient EWM had not been located in 2012 to warrant another treatment in the spring of 2013, the SLPA submitted a conditional treatment permit to be able to initiate a treatment in 2013 in the event that EWM had rebounded and sufficient levels warranting treatment were located in the spring of 2013. However, while slightly more EWM was observed in the spring of 2013, Onterra ecologists did not feel it warranted herbicide treatment. Instead, SLPA volunteers spent just over 50 hours hand-removing EWM through snorkeling and scuba diving methods within the southwestern portion of the lake (Table 3.4-3).

**Table 3.4-3. SLPA 2013 EWM hand-harvesting efforts.**

| | Snorkling Effort (hrs) | Scuba Diver Effort (hrs) | Total Effort (hrs) |
|---|---|---|---|
| 7/21/2013 | 20 | 5.5 | 25.5 |
| 8/20/2014 | 18.5 | 4 | 22.5 |
| 9/14/2014 | 2.5 | | 2.5 |
| | | | **50.5** |

In the late-summer of 2013, Onterra ecologists completed a Late-Summer EWM Peak-Biomass Survey. During this survey, numerous single plant and clumps of plants were located within the area that had been treated in 2012 indicating that regrowth and/or re-colonization of EWM was occurring in this area (Map 8). The increase of EWM occurrences within the 2012 treatment area was most likely the result of regrowth from plants that were greatly injured, but survived the treatment. The 2012 treatment area was located in a semi-protected part of Silver Lake where water exchange was anticipated to be less than in more open areas of the lake. Longer herbicide exposure times are associated with these conditions and therefore a conservative herbicide dose was prescribed for this treatment in 2012 (2.5 ppm ae). However, it appears that this concentration was not quite sufficient to cause complete EWM control in this area, as some regrowth occurred.

Because of this regrowth, a two-tiered control strategy was proposed for Silver Lake in 2014, where an herbicide application would occur over the area containing the highest densities of EWM (Map 8), and volunteer-based hand-harvesting would target additional EWM occurrences that were located elsewhere around the lake. Approximately 8.4 acres were applied with granular 2,4-D at an increased application rate to achieve a concentration of 3.5 ppm ae in the spring of 2014 by Stantec, Inc. Onterra ecologists completed an Early-Season AIS Survey on Silver Lake in mid-June 2014 to map areas of EWM and provide these locations to the SLPA hand-harvest volunteers. The volunteers reported removing at least two plants in the southwestern portion of the lake where the treatment occurred.

Onterra ecologists visited Silver Lake again in late-August 2014 to complete the Late-Summer EWM Peak-Biomass Survey to assess the 2014 treatment area and map any potential occurrences of EWM throughout the lake. During this survey, no EWM could be located within the 2014 treatment area, indicating the treatment was successful. Only one EWM plant was observed during the survey, and was located within the bay in the southwest area of the lake (Map 9). Many Wisconsin lakes observed a suppressed EWM population in 2014 likely as a result of a later than usual ice-off and cooler temperatures affecting general plant growth. The overall EWM population reductions in Silver Lake were likely a result of a combination of the 2014 herbicide treatment, volunteer hand-harvesting, and environmental factors.

As discussed in the previous section, the whole-lake point-intercept surveys indicated that the littoral occurrences of common waterweed and clasping-leaf pondweed were statistically different between the 2010 and 2014 surveys; common waterweed had declined in occurrence by 85% and clasping-leaf pondweed had declined by 51%. While ongoing research is indicating that common waterweed in particular is sensitive to 2,4-D treatments, it is not believed its observed decline in Silver Lake between 2010 and 2014 is due to the 2012 and 2014 2,4-D treatments. The 2012 and

2014 treatments conducted on Silver Lake were designed as spot treatments, meaning that if the herbicide that was applied to the application area diffused throughout the entire lake, it would be at too low of a concentration to have detectable impacts to native aquatic plants lake-wide.

When spot treatment strategies are being developed, ecologists use the volume of the lake to calculate if the proposed amount of herbicide being applied has the potential to have lake-wide impacts. In the case of the 2012 and 2014 treatments in Silver Lake, if the amount of herbicide applied dissipated throughout the entire volume of the lake, lake-wide concentrations would have been approximately 0.04 and 0.06 ppm ae, respectively, below levels which have been shown to have detectable impacts to native aquatic plants. As discussed previously, it is believed that the declines detected in common waterweed and clasping-leaf pondweed are due to natural environmental causes, and these fluctuations have been observed in other lakes.

Given the low densities of EWM observed in Silver Lake in 2014, no herbicide control strategy was proposed for 2015. However, it was recommended that hand-harvesting be implemented in these low-density areas to attempt to remove them and prevent further expansion and spread. In 2015, the SLPA contracted with Aquatic Plant Management, LLC (APM), a professional hand-harvesting firm, to conduct hand-removal of EWM in Silver Lake. These hand-harvest areas would be deemed successful if the density of EWM within these areas was found to have decreased from the June 2015 Early-Season AIS (ESAIS) Survey (pre-hand-harvest) to the Late-Summer EWM Peak-Biomass Survey (post-hand-harvesting).

On June 3-4, 2015, Onterra ecologists completed the ESAIS Survey on Silver Lake to refine areas of EWM mapped in 2014 and locate any potential new areas of EWM for hand removal. The locations of EWM mapped during this survey were provided to APM and SLPA volunteers to guide their hand-removal efforts. During the ESAIS Survey, only *clumps of plants* and *single or few plants* were located, and areas with *clumps of plants* were given priority for removal by the professional hand-harvesters.

Members of APM visited Silver Lake on July 8 and August 4, 2015 to conduct their hand-removal efforts. They spent a total of approximately 31 combined diver hours harvesting EWM in 13 of the 14 designated hand-harvesting sites and removed a total of 108.5 gallons of EWM (Table 3.4-4 and Map 10). Onterra ecologists visited Silver Lake again on September 15, 2015 to conduct the Late-Summer EWM Peak-Biomass Survey and assess the 2015 hand-removal areas as well as to search the rest of the lake for new occurrences of EWM. Of the 13 areas APM conducted hand-removal, six (1, 2, 8, 9, 10, and 13) saw declines in EWM density, four (3, 4, 5, and 11) saw increases, and three (6, 7, and 12) saw no noticeable change in density from pre- and post-hand-harvesting (Table 3.4-4 and Map 10).

Onterra ecologists visited Silver Lake again on September 15, 2015 to conduct the Late-Summer EWM Peak-Biomass Survey and to assess the 2015 hand-removal areas as well as to search the rest of the lake for new occurrences of EWM. Prior to hand-harvesting, all of the proposed hand-harvesting areas contained EWM mapped with point-based mapping techniques, and defining success in these areas is difficult. For this reason, areas containing EWM mapped with point-based techniques are deemed successful if EWM did not increase to a colonized level, or a level at which could be mapped using polygons.

While a few hand-harvest sites in 2015 were found to contain *small plant colonies* post-harvesting compared to *clumps of plants* pre-harvesting, these areas were still deemed successful because the density was maintained at a point-based mapping level. Using this definition of success, all of the 13 areas harvested by APM divers in 2015 were deemed successful (Table 3.4-5). Eurasian water milfoil was still present within eight of the areas harvested, while it could not be located in the remaining five. Two EWM occurrences were located outside of the 2015 hand-harvesting areas; a *small plant colony* on the north side of the lake and *single or few plants* in the bay on the southwest side (Map 1).

**Table 3.4-4. Aquatic Plant Management, LLC EWM hand-harvesting efforts on Silver Lake in 2015.**

| 7/8/2015 | | |
|---|---|---|
| **Site** | **Combined Diver Time (hours)** | **EWM Removed (gallons)** |
| 1 | 2.00 | 10.0 |
| 2 | 2.00 | 3.0 |
| 3 | 1.33 | 10.0 |
| 4 | 2.00 | 4.0 |
| 5 | 2.00 | 10.0 |
| 6 | 1.67 | 6.0 |
| 7 | 1.33 | 6.0 |
| 8 & 9 | 3.00 | 15.0 |
| 11 | 1.00 | 1.0 |
| 12 | 0.67 | 2.0 |
| **Total** | **17.00** | **67.0** |

| 8/4/2015 | | |
|---|---|---|
| **Site** | **Combined Diver Time (hours)** | **EWM Removed (gallons)** |
| 1 & 9 | 2.00 | 7.0 |
| 5 | 2.25 | 5.0 |
| 6 | 2.25 | 10.0 |
| 7 | 1.75 | 4.0 |
| 10 | 3.50 | 15.0 |
| 13 | 2.00 | 0.5 |
| **Total** | **13.75** | **41.5** |
| **Grand Total** | **30.75** | **108.5** |

**Table 3.4-5. Silver Lake June 2015 pre- and September 2015 post-hand-harvesting results within the Aquatic Plant Management, LLC hand-harvesting areas.**

| Site | June 2015 EWM (Pre-Hand-Harvesting) | September 2015 (Post-Hand-Harvesting) | Success Criteria Met |
|---|---|---|---|
| 1 | Clumps of Plants | - | Yes |
| 2 | Clumps of Plants | Single or Few Plants | Yes |
| 3 | Clumps of Plants | Small Plant Colony | Yes |
| 4 | Clumps of Plants | Clumps of Plants/Small Plant Colony | Yes |
| 5 | Clumps of Plants | Small Plant Colony | Yes |
| 6 | Clumps of Plants | Clumps of Plants | Yes |
| 7 | Clumps of Plants | Clumps of Plants | Yes |
| 8 | Clumps of Plants | - | Yes |
| 9 | Clumps of Plants | - | Yes |
| 10 | Clumps of Plants | - | Yes |
| 11 | Single or Few Plants | Clumps of Plants/Single or Few Plants | Yes |
| 12 | Single or Few Plants | Single or Few Plants | Yes |
| 13 | Single or Few Plants | - | Yes |
| 14 | Not Harvested (Single or Few Plants) | Not Harvested (Single or Few Plants) | Not Applicable |

Again, the low level of EWM found in Silver Lake in 2015 does not warrant an herbicide control strategy for 2016. The low density of EWM lends itself to hand-harvesting, and it is recommended that professional hand-harvesting occur again in 2016. All areas containing *small plant colonies* or *clumps of plants* will be designated as priority sites for the professional hand harvesters. All remaining areas of EWM should be targeted for hand-removal by SLPA volunteers. The SLPA volunteers should prioritize their efforts near the public boat landing, and should record when, where, and how much time (effort) was spent harvesting in 2016. The SLPA currently has grant monies remaining to fund both an ESAIS and Late-Summer EWM Peak-Biomass Survey in 2016. Results from the June 2016 ESAIS Survey will be used to guide hand-harvesting efforts while the results of the Late-Summer EWM Peak-Biomass Survey will assess 2016 hand-harvest efforts and aid in developing a strategy for 2017. A strategy for managing EWM in Silver Lake into the future is discussed within the Implementation Plan Section (Section 5.0).

## 3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing Silver Lake. The goal of this section is to provide an overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc.) that were brought forth by the SLPA 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 2015 & GLIFWC 2015A and 2015B).

### *Silver Lake Fishery*

#### Silver Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing ranked highly within a list of activities stakeholders enjoy on Silver Lake (Question #14). Roughly 35% of survey respondents indicated they have fished the lake for over 25 years (Question #8). Though 45% of respondents believe the quality of fishing on Silver Lake is fair (Question #11), 63% believe this quality has gotten worse since they began fishing the lake (Question #12). Bluegill/sunfish ranked as the species residents enjoy catching the most, followed by walleye and then bass (Question 10).

Table 3.5-1 shows the popular game fish that are present in the system. When examining the fishery of a lake, it is important to remember what "drives" that fishery, or what is responsible for determining its mass and composition. The gamefish in Silver Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

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

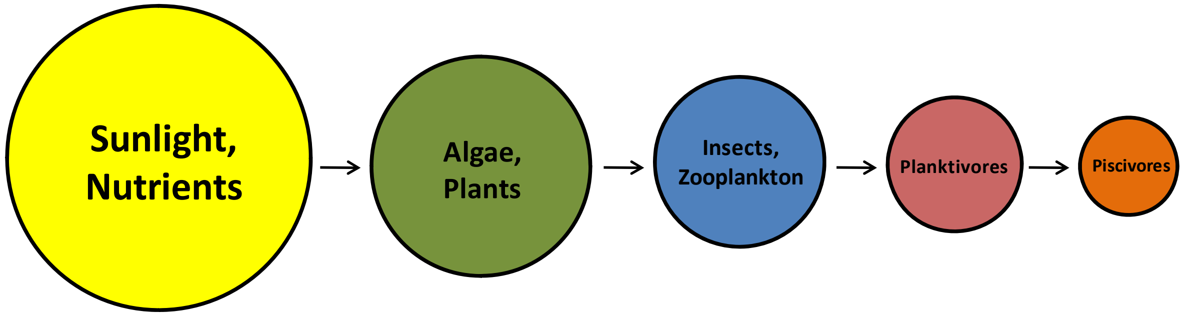



**Figure 3.5-1. Aquatic food chain.** Adapted from Carpenter et. al 1985.

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

**Table 3.5-1. Common northern Wisconsin gamefish with corresponding biological information** (Becker, 1983)**.**

| Common Name | Scientific Name | Max Age (yrs) | Spawning Period | Spawning Habitat Requirements | Food Source |
|---|---|---|---|---|---|
| Black Crappie | *Pomoxis nigromaculatus* | 7 | May - June | Near *Chara* or other vegetation, over sand or fine gravel | Fish, cladocera, insect larvae, other invertebrates |
| Bluegill | *Lepomis macrochirus* | 11 | Late May - Early August | Shallow water with sand or gravel bottom | Fish, crayfish, aquatic insects and other invertebrates |
| Largemouth Bass | *Micropterus salmoides* | 13 | Late April - Early July | Shallow, quiet bays with emergent vegetation | Fish, amphipods, algae, crayfish and other invertebrates |
| 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 pikes, crayfish, small mammals, water fowl, frogs |
| 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, wave-washed shallows, inlet streams on gravel bottoms | Fish, fly and other insect larvae, crayfish |
| Yellow Perch | *Perca flavescens* | 13 | April - Early May | Sheltered areas, emergent and submergent veg | Small fish, aquatic invertebrates |

## Silver Lake Spear Harvest Records

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

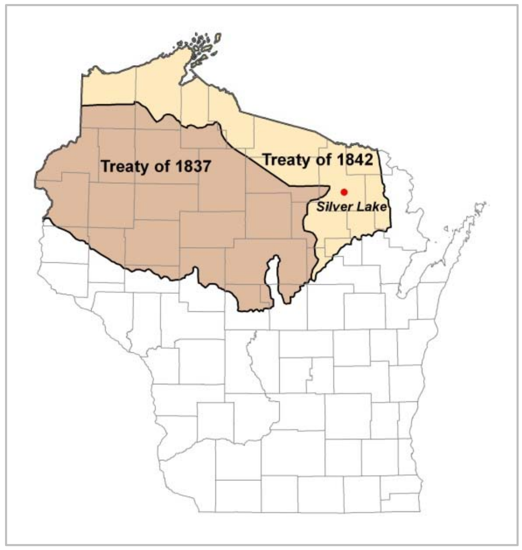



**Figure 3.5-2. Location of Silver Lake within the Native American Ceded Territory (GLIFWC 2015A).** This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2015B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Records indicate that members of the Mole Lake tribe have set a declaration (quota) on Silver Lake walleye and muskellunge in past years, though typically a harvest has not occurred. Walleye open water spear harvest records are provided in Figure 3.5-3. One common misconception is that the spear harvest targets the large spawning females. Tribal spearers may only take two walleyes over 20 inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2015B). This regulation limits the harvest of the larger, spawning female walleye. In 2014, the first open water spear season harvest of walleye occurred, with WDNR records indicating four fish were harvested from Silver Lake.

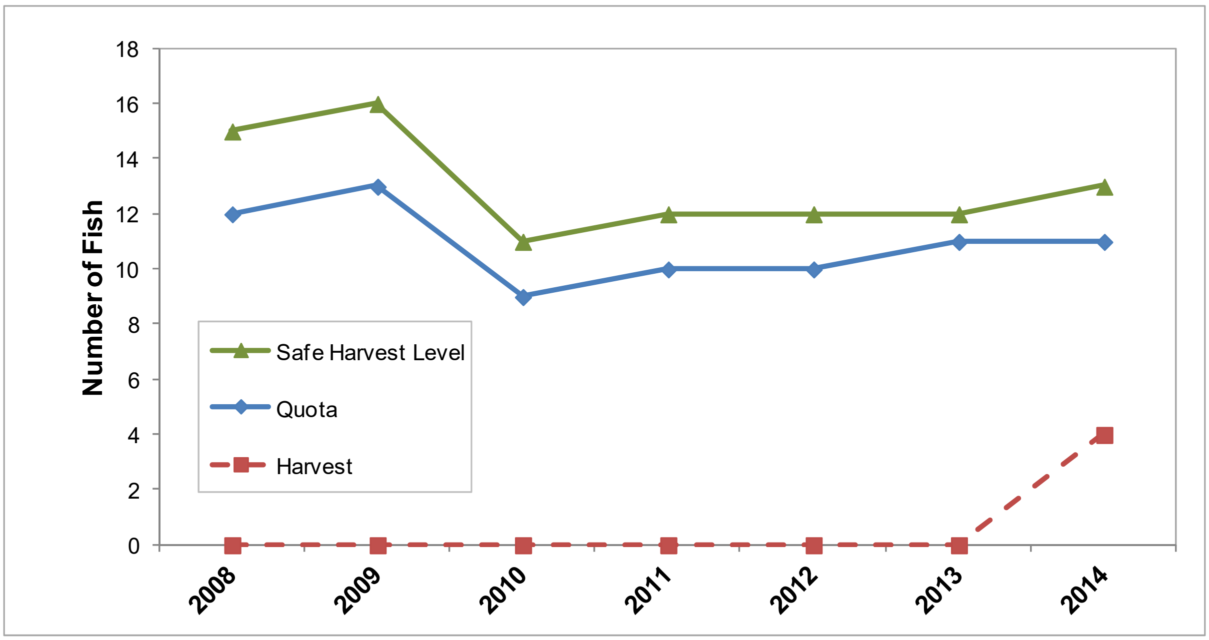



**Figure 3.5-3. Silver Lake walleye spear harvest data.** Annual walleye spear harvest statistics are displayed from WDNR datasets (T. Cichosz, personal communication).

Muskellunge, like walleye, had for several years not been harvested through open water spearing on Silver Lake. In 2014, tribal spearers met the declared quota for this species with four fish taken during the spring open water spear season (Figure 3.5-4).

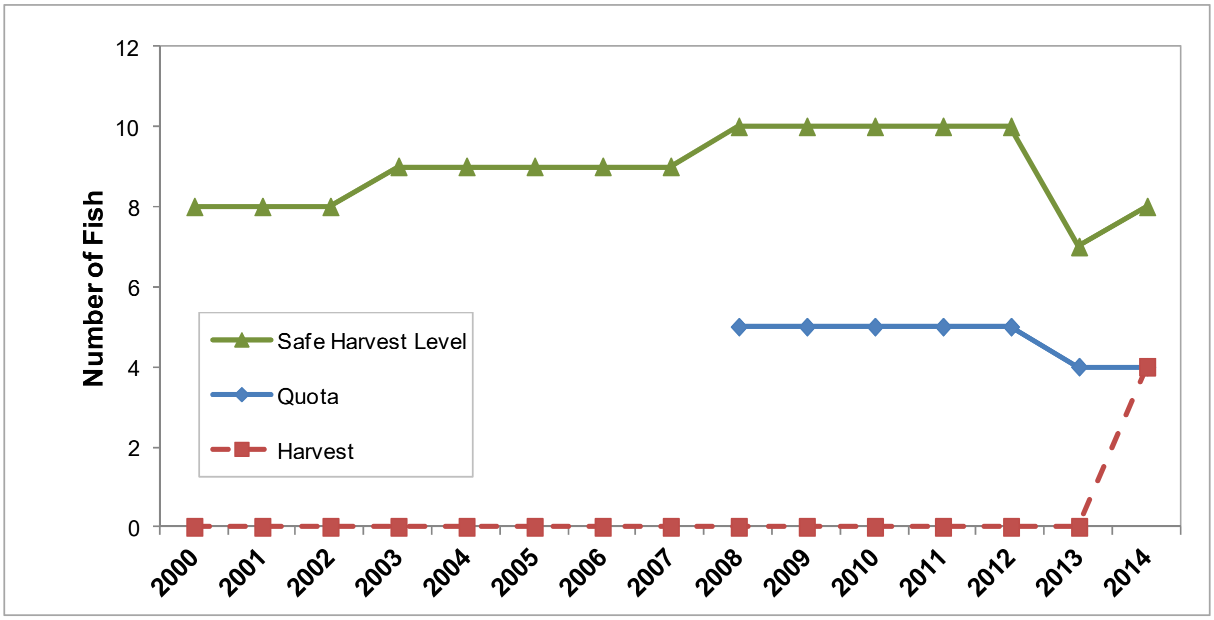



**Figure 3.5-4. Silver Lake muskellunge spear harvest data.** Annual walleye spear harvest statistics are displayed from WDNR datasets (T. Cichosz, personal communication).

## Silver Lake Substrate and Near Shore Habitat

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

According to the point-intercept survey conducted by Onterra in 2014 on Silver Lake, 68% of the point-intercept locations within the littoral zone contained sand, 27% were classified as soft organic muck and 5% being classified as rock. Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

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

## Silver Lake Regulations and Management

Because Silver Lake is located within ceded territory, special fisheries regulations may occur, specifically in terms of walleye. Table 3.5-3 displays the 2015-2016 regulations for species that may be found in Silver Lake. Please note that this table is intended to be for reference purposes only, and that anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

**Table 3.5-3. WDNR fishing regulations for Silver Lake, 2015-2016.**

| Species | Season | Regulation |
|---|---|---|
| Panfish | Open All Year | No minimum length limit and the daily bag limit is 25. |
| Largemouth bass | May 2 to March 6 | The minimum length limit is 14" and the daily bag limit is 5 (in combination with smallmouth bass). |
| Smallmouth bass | May 2 to June 19 | Catch and release only |
| | June 20 to March 6 | The minimum length limit is 14" and the daily bag limit is 5 (in combination with largemouth bass). |
| Northern pike | May 2 to March 6 | No minimum length limit and the daily bag limit is 5. |
| Muskellunge | May 23 – November 30 | The minimum length limit is 40" and the daily bag limit is 1. |
| Walleye, sauger, and hybrids | May 4 to March 2 | The minimum length limit is 15", but fish from 20" to 24" may not be kept and only 1 fish over 24" is allowed. The daily bag limit is 3. |
| Bullheads | Open All Year | No minimum length limit and the daily bag limit is unlimited. |
| Rock, yellow, and white bass | Open All Year | No minimum length limit and the daily bag limit is unlimited. |

WDNR fisheries biologist Greg Matzke, in personal communication, stated that Silver Lake is best characterized as a panfish, bass, northern pike and muskellunge fishery, based upon its characteristics. Panfish, bass, pike and other non-game species have been reproducing naturally, however walleye and muskellunge reproduction is not sufficient to maintain this fishery. The lake is actively managed for walleye and muskellunge through stocking. The muskellunge stocking program has been successful, resulting in a low density, high quality fishery for this species. Walleye stocking has been less effective. Walleye were previously stocked at a rate of 35 small fingerling per acre, but now will be stocked at a rate of 15 large fingerling per acre. The large fingerling have a better survival rate, so Mr. Matzke is optimistic that with this new stocking opportunity the fishery should improve. The end goal would be to produce a walleye population that reaches 2 or more adult fish per acre. Stocking records are included within Table 3.5-4.

Mr. Matzke states that the panfish size structure is poor within Silver Lake, which can likely be attributed to the abundant northern pike population. Angler harvest, though not a direct influence on the population, only reduces the adult panfish further. With the WDNR currently examining panfish populations and regulations statewide, there may be a different approach taken to panfish management in Silver Lake (and others in the state) soon. A 2011 WDNR report, written by Greg Matzke, is included as Appendix G.

**Table 3.5-3. WDNR stocking records for Silver Lake, 1980-2015.**

| Year | Species | Age Class | # Stocked |
|---|---|---|---|
| 1980 | Muskellunge | Fingerling | 600 |
| 1981 | Muskellunge | Fingerling | 300 |
| 1983 | Muskellunge | Fingerling | 300 |
| 1984 | Muskellunge | Fingerling | 400 |
| 1985 | Muskellunge | Fingerling | 300 |
| 1987 | Muskellunge | Fingerling | 1,200 |
| 1989 | Muskellunge | Fingerling | 400 |
| 1991 | Muskellunge | Fingerling | 200 |
| 1992 | Walleye | Fingerling | 1,384 |
| 1993 | Muskellunge | Fingerling | 320 |
| 1993 | Walleye | Fingerling | 2,240 |
| 1995 | Muskellunge | Fingerling | 320 |
| 1996 | Walleye | Fingerling | 1,548 |
| 1997 | Walleye | Large fingerling | 995 |
| 1997 | Muskellunge | Large fingerling | 160 |
| 1999 | Muskellunge | Large fingerling | 160 |
| 1999 | Walleye | Small fingerling | 650 |
| 2000 | Walleye | Small fingerling | 2,925 |
| 2000 | Muskellunge | Small fingerling | 10,000 |
| 2001 | Muskellunge | Large fingerling | 320 |
| 2001 | Walleye | Small fingerling | 5,000 |
| 2001 | Walleye | Small fingerling | 5,000 |
| 2002 | Walleye | Small fingerling | 2,750 |
| 2003 | Walleye | Small fingerling | 1,600 |
| 2003 | Walleye | Large fingerling | 420 |
| 2003 | Muskellunge | Large fingerling | 320 |
| 2004 | Walleye | Small fingerling | 3,400 |
| 2005 | Walleye | Small fingerling | 2,450 |
| 2005 | Muskellunge | Large fingerling | 320 |
| 2007 | Muskellunge | Large fingerling | 213 |
| 2009 | Muskellunge | Large fingerling | 320 |
| 2011 | Muskellunge | Large fingerling | 318 |
| 2011 | Walleye | Small fingerling | 11,200 |
| 2013 | Walleye | Large fingerling | 4,799 |
| 2013 | Muskellunge | Large fingerling | 237 |

# 4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill three primary objectives:

1. Collect baseline data to increase the general understanding of the Silver Lake ecosystem.
2. Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian water milfoil.
3. Collect sociological information from Silver Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

These three objectives were fulfilled during this project, and the studies conducted have led to a comprehensive understanding of the Silver Lake ecosystem, the people who care about the lake, and the actions that need to be taken to protect and enhance it. The data collected as a part of this study along with historical data indicate that overall Silver Lake is an exceptional waterbody. Water quality data show that Silver Lake's water quality is excellent with low nutrient and algae concentrations and high water clarity, and has some of the best water quality when compared to other shallow, headwater drainage lakes in Wisconsin. Long-term trends analysis of available water quality data collected since 1994 indicate that no trends (positive or negative) are occurring over time. Given the exceptional water quality found in Silver Lake, the SLPA has developed management strategies within the Implementation Plan that follows to maintain these conditions into the future.

The lake's exceptional water quality is largely due in part to the excellent condition of its watershed. The small watershed to lake area ratio (2:1) in combination with land cover that is mainly comprised of intact forests and wetlands results in minimal amounts of nutrients and sediments being delivered to the lake. In addition, greater than half of the lake's 3.9-mile shoreline is minimally developed which buffers runoff and reduces shoreline erosion. However, while Silver Lake has a large portion of minimally developed shoreline, approximately 20% was found to be highly developed in 2014, or contained little natural vegetative cover. The SLPA understands the importance of maintaining healthy shorelines, and strategies for protecting and enhancing the lake's shoreline are outlined within the Implementation Plan.

In addition to a healthy watershed, Silver Lake's large native aquatic plant community also aids in maintain the lake's excellent water quality. Surveys in 2014 found that the entire lake area, even down to the lake's maximum depth of 21 feet, supports aquatic plant growth. High water clarity allows the plants to receive adequate amounts of sunlight at these deeper depths. These plants stabilize bottom sediments, take in nutrients, and provide habitat for zooplankton, all which aid in improving water quality. Silver Lake contains a high number of native aquatic plant species, all of which provide various sources of habitat and food. While EWM is present within the lake, the SLPA has taken a proactive approach in its management since its discovery in 2010, and has thus far been able to maintain a small population which has minimal ecological impacts. Preservation of the lake's native plant community, including the management of EWM, will maintain the lake's ecological integrity. A strategy for the continued management of EWM in Silver Lake can be found in the Implementation Plan.

Through the process of this lake management planning effort, the SLPA has learned much about Silver Lake, both in terms of its positive and negative attributes. Overall, the lake is very healthy, but there are certain aspects which require attention. It is now the SLPA's responsibility to maximize the positive attributes while minimizing the negative attributes as much as possible. The Implementation Plan that follows is a result of discussions between Onterra ecologists, the SLPA Planning Committee, and the WDNR, and includes action items the SLPA will implement to properly protect and enhance Silver Lake into the future.

# 5.0 IMPLEMENTATION PLAN

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

## *Management Goal 1: Maintain Current Water Quality Conditions*

**Management Action:** Continue monitoring of Silver Lake's water quality through WDNR Citizens Lake Monitoring Network (CLMN).

**Timeframe:** Continuation of current effort

**Facilitator:** Allen Bluhm (current CLMN volunteer)

**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. As discussed in the Water Quality Section, Silver Lake's water quality is excellent, and early detection of potential negative trends may lead to the reason as of why the trend is developing.

The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the Silver Lake Preservation Association (SLPA) have been collecting water quality data from Silver Lake since 1992. The SLPA realizes the importance of continuing this effort, which will supply them with valuable data about their lake. Moving forward, it is the responsibility of Allen Bluhm, current CLMN volunteer, to coordinate new volunteers as needed. When a change in the collection volunteer occurs, Paul Skawinski or the appropriate WDNR/UW-Extension staff will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

**Action Steps:**

1. Allen Bluhm, current CLMN volunteer, recruits new volunteer(s) as needed.
2. Volunteer contacts Paul Skawinski (715.346.4853) as needed.

3. Coordinator reports results to WDNR and to SLPA members during annual meeting.

## Management Goal 2: Lessen the Impact of Shoreline Development on Silver Lake

| | |
|---|---|
| **Management Action:** | Investigate restoring highly developed shoreland areas on Silver Lake. |
| **Timeframe:** | Initiate 2016 |
| **Facilitator:** | SLPA Board of Directors |
| **Funding Source:** | WDNR Healthy Lakes Grant |
| **Description:** | The 2014 Shoreland Condition Assessment on Silver Lake found that approximately 20% of the 3.9-mile shoreline is either *urbanized* or *developed-unnatural* – the two categories that denote the least amount of natural habitat present. When these immediate shoreline areas are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of the proximity to the waters of a lake, even small disturbances to natural shoreland areas can produce negative effects. This is especially pertinent to lakes like Silver Lake which have small watershed to lake area ratios; small changes within the lake's watershed and shoreline can lead to large changes in water quality.<br><br>Fortunately, restoration of the shoreland zone can be less expensive, less time-consuming and much easier to accomplish than restoration efforts in other parts of the watershed. Cost-sharing grants and Forest County staff devoted to these types of projects give private property owners the funds and informational resources to restore quality shoreland habitat to their lakeside residence.<br><br>The shoreland areas on Silver Lake delineated as *urbanized* and *developed-unnatural* should be prioritized for restoration. The SLPA would acquire information from and work with appropriate entities such as Pamela LaBine (715.478.3893), the department head for the Forest County Land and Water Conservation Department to research grant programs, shoreland restoration techniques, and other pertinent information that will help the SLPA.<br><br>Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, properties with restoration on their shorelands could serve as demonstration sites. Other lakeside property owners could have the opportunity to view a shoreland that has been restored to a more natural state, and learn about the maintenance, labor, and cost-sharing opportunities associated with these projects. |

The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county and the WDNR Lake Protection Grant Program.

- 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
- Maximum of $1,000 per 350 $ft^2$ of native plantings (best practice cap)
- Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances
- Must be at least 350 $ft^2$ of contiguous lakeshore; 10 feet wide by 35 feet deep
- Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years
- Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available

However, for a larger project that may include a number of properties, it may be more appropriate to seek funding through a WDNR Lake Protection Grant. While more funding can be provided through a Lake Protection Grant and there are no limits to where that funding utilized (e.g. technical, installation, etc.), the grant does require that the restored shorelines remain undeveloped in perpetuity.

**Action Steps:**

1. SLPA Board of Directors recruits shoreland restoration/protection facilitator(s).
2. Facilitator contacts Pamela LaBine (715.478.3893) from Forest County Land and Water Conservation to gather information on initiating and conducting shoreland restoration projects. If able, Pamela would be asked to speak to the SLPA members about shoreland restoration at their annual meeting.
3. The SLPA would encourage property owners that have restored their shorelines to serve as demonstration sites to other lake property owners.

| | |
|---|---|
| **Management Action:** | Preserve natural shoreland areas on Silver Lake. |
| **Timeframe:** | Initiate 2016 |
| **Facilitator:** | SLPA Board of Directors |

**Description:** While the 2014 Shoreland Condition Assessment found that approximately 20% of Silver Lake's immediate shoreland areas are highly developed, approximately 52% (2.1 miles) are minimally developed, delineated as either *natural/undeveloped* or *developed-natural*, and 28% (1.1 miles) are *developed-semi-natural*, or moderately developed. It is very important that owners of these properties become educated on the benefits their shoreland is providing to Silver Lake, and that these shorelands remain in a natural or semi-natural state.

These shoreland areas should be prioritized for education initiatives and physical preservation. An appointed shoreland restoration/protection facilitator(s) will work with appropriate entities to research grant programs and other pertinent information that will aid the SLPA in preserving Silver Lake's shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of.

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

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

**Action Steps:**

1. SLPA Board of Directors recruits shoreland restoration/protection facilitator(s) (potentially the same facilitator as previous management action).
2. Facilitator(s) gathers appropriate information from sources as described above.

**Management Action:** Investigate with the WDNR and private landowners to enhance course woody habitat in Silver Lake.

**Timeframe:** Initiate 2016

**Facilitator:** SLPA Board of Directors

**Funding Source:** WDNR Healthy Lakes Grant

**Description:** Silver Lake Preservation Association, Inc. stakeholders must realize the complexities and capabilities of the Silver Lake ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish.

During the 2014 Shoreland Condition Assessment, Silver Lake was found to contain 29 pieces of course woody habitat per shoreline mile. This was one of the highest ratios of course woody habitat per shoreline mile that Onterra ecologists have recorded since the initiation of this survey in 2012. However, the SLPA should work with the WDNR fisheries biologist that oversees Silver Lake (Greg Matzke) to determine how the benefits of course woody habitat can be maximized. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. In addition, the SLPA should educate and encourage their membership to leave fallen trees in the lake if they are not hindering lake access or presenting a safety hazard to lake users.

The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.

- 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
- Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
- Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
- Buffer area (350 $ft^2$) at base of coarse woody habitat cluster must comply with local shoreland zoning or :
    - The landowner would need to commit to leaving the area un-mowed
    - The landowner would need to implement a native planting (also cost share thought this grant program available)
- Coarse woody habitat improvement projects require a general permit from the WDNR

- Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years

**Action Steps:**

1. SLPA Board of Directors recruits shoreland restoration/protection facilitator(s) (potentially the same facilitator as previous management action).
2. Facilitator contacts Jim Kreitlow (WDNR Lakes Coordinator – 715.365.8947) and Greg Matzke (WDNR Fisheries Biologist – 715.528.4400) to gather information on initiating and conducting coarse woody habitat projects.
3. The SLPA would encourage property owners that have enhanced course woody habitat to serve as demonstration sites.

## *Management Goal 3: Assure and Enhance the Communication and Outreach of the Silver Lake Preservation Association, Inc. with Silver Lake Stakeholders*

**Management Action:** Support an Education and Communication Committee to promote stakeholder involvement, inform stakeholders on various lake issues, as well as the quality of life on Silver Lake.

**Timeframe:** Initiate in 2016

**Facilitator:** SLPA Board of Directors

**Description:** Education represents an effective tool to address lake issues like shoreline development, invasive species, water quality, lawn fertilizers, as well as other concerns such as community involvement and boating safety. An Education and Communication Committee will be created to promote lake preservation and enhancement through a variety of educational efforts.

Currently, the SLPA regularly publishes and distributes a yearly newsletter and maintains an association website that provides association-related information including current association projects and updates, meeting times, and educational topics. Both of these mediums are an excellent source for communication and education to both association and non-association members.

While 85% of respondents indicated that the SLPA keeps them either *fairly well informed* or *highly informed* regarding issues with Silver Lake and its management (Appendix B, Question #30), the SLPA would like to increase its capacity to reach out to and educate association and non-association members regarding Silver Lake and its preservation. In addition to creating a yearly newsletter, a variety of educational efforts will be initiated by the Education and Communication Committee. These may include educational materials such as a tri-fold brochure and/or a new membership informational packet containing information about the SLPA (projects, finances, etc.) as well as facts about Silver Lake and steps lake residents can take to maintain and enhance the quality of the lake, as well as quality of life for those who live and recreate on it. The Education and Communication Committee will also organize workshops and speakers surrounding lake-related topics.

Education of lake stakeholders on all matters is important, and a list of educational topics that were discussed during the planning meetings can be found below. These topics can be included within the association's newsletter and/or website or distributed as separate educational materials. In addition, the SLPA can invite professionals who work within these topics to come and speak at the association's annual meeting or hold workshops if available.

*Example Educational Topics*

- Shoreline restoration and protection
- Importance of maintaining course woody habitat
- Effect lawn fertilizers/herbicides have on the lake
- Fishing rules and regulations
- Catch-and-release fishing
- Information pertaining to Native American spear harvests in Silver Lake
- Boating regulations and safety
- Pier regulations and responsible placement to minimize habitat disturbance
- Importance of maintaining a healthy native aquatic plant community
- Respect to and maintaining a safe distance from wildlife (e.g. loons) within the lake
- Aquatic invasive species (AIS) prevention and updates for AIS in Silver Lake
- Water quality monitoring updates from Silver Lake
- Septic system maintenance
- Littering on the ice and year-round

**Action Steps:**

1. The SLPA Board of Directors recruits volunteers to form Education and Communication Committee.
2. Investigate if WDNR Small-Scale Lake Planning or AIS Education, Planning, and Prevention Grants would be appropriate to cover initial setup costs.
3. The SLPA Board of Directors will identify a base level of financial support for educational activities to be undertaken by the Education and Communication Committee on an annual basis.

**Management Action:** Increase SLPA membership and participation.

**Timeframe:** Initiate in 2016

**Facilitator:** SLPA Board of Directors

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

To increase membership within the SLPA, volunteers from the association will meet face-to-face with lake property owners who are not yet members for friendly conversations about the benefits of association membership, what a SLPA membership entails, etc. This type of membership drive is not only more effective than a limited form of contact, but helps to build a sense of community and friendship amongst neighbors. These non-members or those who are new property owners on the lake would be provided with a packet or brochure describing the functions of the SLPA and the benefits of being a member. These face-to-face drives may also be utilized to ask for assistance in volunteer-heavy tasks, such as the CLMN water quality monitoring program and EWM monitoring/removal.

In addition to meeting with neighbors face-to-face, the Planning Committee also suggested offering a free year of membership to families with a recently-deceased association member. The Planning Committee is going to investigate this further with the SLPA Board of Directors.

**Action Steps:**

1. See description above.

**<u>Management Action:</u>** Enhance the SLPA's involvement with other entities that manage aspects of Silver Lake.

**Timeframe:** Continuation of current effort.

**Facilitator:** SLPA Board of Directors

**Description:** The waters of Wisconsin belong to everyone and, therefore, this goal of protecting and enhancing these share resources is also held by other agencies and entities. It is important that the SLPA actively engage with all management entities to enhance the association's understanding of the common management goals and to participate in the development of these 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 Silver Lake are the WDNR (fisheries, AIS, and lake management personnel), the Forest County Chamber of Commerce, the Town of Laona, the Forest County Potawatomi, Forest County Association of Lakes, Forest County Land and Water Conservation Department, and Wisconsin Lakes. Each entity is specifically addressed in the table on the next page.

**Action Steps:**

1. See the following table guidelines below.

| Partner | Contact Person | Role | Contact Frequency | Contact Basis |
|---|---|---|---|---|
| **Forest County Chamber of Commerce** | General staff (715.478.3450) | Provides information and networking related to the advancement of the Silver Lake community. | Once a year, or more as needed. May check website (http://www.visitforestcounty.com/) for updates. | The Chamber of Commerce serves a valuable role in promoting local businesses, tourism, and community within the Silver Lake area. |
| **Forest County Lakes Association** | Les Schramm (715.478.5197) | Protects Forest County waters through facilitating discussion and education. | Twice a year or as needed. May check website (https://www.wisconsinrivers.org/local-groups/directory/item/forest-county-association-of-lakes) for updates | Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Forest County waterways. |
| **Forest County AIS Coordinator** | AIS Coordinator (John Preuss – 715.369.9886) | Oversees AIS monitoring and prevention activities locally. | Twice a year or more as issues arise. | Spring: AIS training and ID, AIS monitoring techniques<br>Summer: Report activities to Mr. Preuss. |
| **Forest County Land and Water Conservation Department** | Land and Water Resources Administrator (Pamela LaBine – 715.478.3893) | Oversees conservation efforts for land and water projects. | Twice a year or more as needed. | |

| | | | | |
|---|---|---|---|---|
| **Town of Laona** | Chairman (Al Murray – 715.674.4071) | Silver Lake falls within the Town of Laona. | As needed. | Town staff may be contacted regarding ordinance reviews or questions, and for information on community events. |
| **Forest County Potawatomi** | Executive Council (715.478.7200) | The Forest County Potawatomi enact conservation efforts through research, documentation, education, and outreach. | As needed. | Potential partnering in special projects, or networking on other topics pertaining to Silver Lake. |
| **Wisconsin Department of Natural Resources** | Fisheries Biologist (Greg Matzke– 715.528.4400) | Manages the fishery of Silver Lake. | Once a year, or more as issues arise. | Scheduled surveys, survey results, and volunteer opportunities for improving fishery. |
| | Lakes Coordinator (Jim Kreitlow– 715.365.8947) | Oversees management plans, grants, all lake activities. | Once a year, or more as issues arise. | Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues. |
| | Warden (Brad Dahlquist – 715.478.5610) | Oversees regulations handed down by the state. | As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367, 24 hours a day). | Contact regarding suspected violations pertaining to recreational activity on Silver Lake, include fishing, boating safety, ordinance violations, etc. |
| | Citizens Lake Monitoring Network contact (Paul Skawinski – 715.346.4853) | Provides training and assistance on CLMN monitoring, methods, and data entry. | Twice a year or more as needed. | Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities. |

| | | | | |
|---|---|---|---|---|
| **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. | SLA 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 4: Control existing Aquatic Invasive Species and Prevent New Introductions to and Spread from Silver Lake

**Management Action:** Continue EWM monitoring and snorkel/scuba diver hand-harvesting strategy to control Eurasian water milfoil population in Silver Lake.

**Timeframe:** Continuation of current effort

**Facilitator:** SLPA Board of Directors

**Description:** As is discussed within the Aquatic Plant Section, Eurasian water milfoil (EWM) was first discovered in Silver Lake in 2010. Following two herbicide applications in 2012 and 2014 and a combination of volunteer and professional hand-harvesting, the EWM population in Silver Lake has remained small, comprised of isolated colonies that are conducive for hand-harvesting via snorkelers and/or scuba divers. There are a few different options for hand-removal of AIS, including both professional and volunteer. In 2013 and 2014, the SLPA recruited volunteer scuba divers and snorkelers from the association to conduct hand-harvesting of EWM, and in 2015, the SLPA hired professional scuba divers for hand-removal. The Silver Lake Stakeholder Survey found that Silver Lake riparians are supportive of this management strategy, with approximately 78% of stakeholder respondents being supportive (either *Highly Supportive* or *Moderately Supportive*) of using hand-removal by divers (Figure 5.0-1; Question 26, Appendix B).

*Question 26: What is your level of support for the responsible use of EWM hand-removal by divers in Silver Lake?*

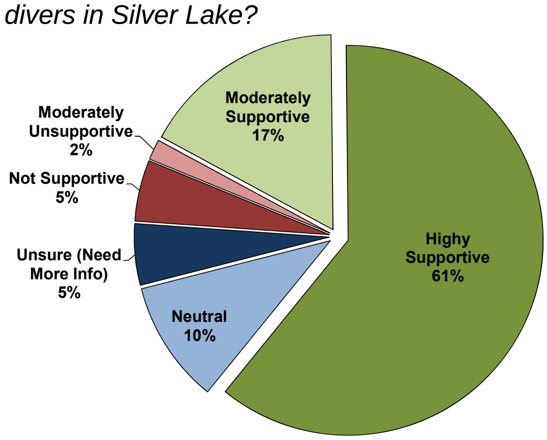



**Figure 5.0-1. Select survey responses from the Silver Lake Stakeholder Survey.** Additional questions and response charts can be found in Appendix B.

During the planning meetings with Onterra ecologists, the SLPA Planning Committee indicated they wanted to continue annual EWM control to maintain a small population that has minimal impacts to lake ecology and recreation. The SLPA will investigate whether volunteer hand-harvesting, professional hand-harvesting, or a combination of both suits their needs the best on an annual basis depending on the level of EWM within the lake, availability of SLPA volunteers, and availability of funding for professional hand-harvesting. The SLPA understands that prioritization of areas to be hand-harvested will be necessary due to factors such as volunteer recruitment and professional hand-harvesting costs. Professional monitoring of EWM in Silver Lake is scheduled to occur through 2016 under the current AIS Early-Detection and Response (EDR) Project.

Given the small size of Silver Lake and the present low population of EWM within the lake, the SLPA will likely not qualify for a WDNR AIS-Established Population Control Grant to aid in funding monitoring/hand-harvesting after 2016. However, if the SLPA decides to utilize professional hand-harvesting and/or the level of EWM within the lake meets or exceeds the threshold for triggering an herbicide treatment (see management action for initiating herbicide treatments on Silver Lake), the SLPA could seek a WDNR AIS-Maintenance and Containment Grant which would reimburse permit fees issued by the WDNR. The SLPA could also investigate applying for a WDNR AIS-Education, Planning and Prevention (EPP) Grant to aid in funding the cost of the monitoring of EWM within Silver Lake. A requisite of AIS-EPP grant requires that the applicant conduct watercraft inspections at the public landing as part of the Clean Boats Clean Waters Program for a minimum of 200 hours between May 1 and October 30.

The objective of this management action is not to eradicate EWM from Silver Lake, as that is impossible with current tools and techniques. The objective is to maintain an EWM population that exerts little to no detectable impact on the lake's native aquatic plant community and overall ecology, recreation, and aesthetics. Monitoring is a key aspect of any AIS control project, both to prioritize areas for control and to monitor the strategy's effectiveness. The monitoring also facilitates the *tuning* or refinement of the control strategy as the control project progresses. The ability to tune the control strategies is important because it allows for the best results to be achieved within the plan's lifespan. It must be noted that hand-removal methodology is still experimental, and success criteria for assessing the efficacy of hand-removal have not yet been defined. Because of this, the following series of steps to manage EWM via hand-removal in Silver Lake should remain flexible to allow for modifications as the project progresses. The series includes:

1. A professional lake-wide assessment of EWM (Late-Summer Peak-Biomass Survey) completed while the plant is at or near its peak growth (late-summer). This meander-based survey of the lake's littoral zone is designed to locate all possible occurrences of EWM, and the findings would be compared to results from the previous summer's Peak-Biomass Survey to assess the efficacy of the control strategy implemented (e.g. hand-harvesting or herbicide application).

2. Using EWM findings from the most recent Peak-Biomass Survey, professional ecologists will work with the SLPA to delineate defined EWM hand-harvesting sites (Site A, B, etc.). The hand-harvesters will then be able to record the amount of hours (effort) spent within each site, allowing for a more accurate assessment of the level of effort spent within each area.

   Colonized areas of EWM (polygons) exert the greatest ecological strain as they are the largest sources for future spread. The SLPA will investigate the use of the Diver-Assisted Suction Harvester (DASH) to target denser colonies or those located in deeper water (see next management action). Other areas not containing EWM polygons would prioritized the following way: areas containing *small plant colonies* would be first priority, areas containing *clumps of plants* would be second priority, and areas containing *single or few* plants would be third priority.

3. A professional lake-wide assessment of EWM (Early-Season AIS Survey) would be completed in early June to reassess areas of EWM located during the previous year's Peak-Biomass Survey to ensure the presence of EWM within the proposed hand-harvest areas and refine/reprioritize hand-removal areas if necessary.

4. Hand-removal efforts begin using the finalized strategy that resulted from the ESAIS survey.

5. Professional Late-Summer EWM Peak-Biomass Survey conducted to determine hand-removal efficacy and determine hand-removal sites/strategy for the following year. The crux of this activity is included within Step 1.

6. Reports generated on hand-removal success and recommendations for following year's strategy.

Typically, AIS control programs (mainly with herbicides) incorporate both established qualitative (EWM mapping) and quantitative (sub-sample point-intercept survey) evaluation methodologies. However, quantitative monitoring of hand-removal areas using sub-sample point-intercept methodology is likely not applicable at this time as there are no areas of EWM large enough to attain the number of sampling locations required to meet the assumptions of statistical analyses. Therefore, each hand-removal site would be monitoring using qualitative methods.

The qualitative monitoring would be completed by comparing pre-hand-harvesting (summer before hand-harvesting) with post-hand-harvesting (summer immediately following hand-harvesting) EWM Peak-Biomass Surveys. A hand-removal site would be deemed successful if the level of EWM is maintained at the point-based mapping level; for example, a site would be considered unsuccessful if it contained *single or few plants* (point-based mapping) prior to hand-harvesting and expanded to contain colonized EWM (polygons) following hand-harvesting. If the DASH system is utilized on Silver Lake, these sites would be deemed successful if they are reduced by at least two density ratings (e.g. *highly dominant* to *scattered*) following the implementation of the DASH system.

**Action Steps:**

1. Retain qualified professional assistance to develop a specific project design utilizing methods described above.
2. Investigate possible funding sources (WDNR AIS-Maintenance and Control and WDNR AIS-Education, Planning and Prevention Grants) to aid in funding EWM control and monitoring beyond 2016.
3. Initiate control plan.
4. Modify control plan methodology annually, as needed.
5. Update management plan to reflect changes in control needs and those of the lake ecosystem.

**Management Action:** Investigate implementing the use of the Diver-Assisted Suction Harvest (DASH) system to control EWM on Silver Lake.

**Timeframe:** Initiate 2016

**Facilitator:** SLPA Board of Directors

**Description:** The DASH system involves scuba divers removing EWM plants by hand and feeding them into a suction hose attached to a pontoon boat for removal. It is believed that the DASH system will be able to remove/reduce areas of EWM more efficiently than standard manual removal by scuba divers, particularly in areas with denser EWM or those located in deeper water. In addition, the DASH system likely reduces the amount of EWM fragments created during hand-removal. The SLPA will not only investigate hiring a firm to implement DASH methodologies, but they also intend on investigating the feasibility of constructing and building their own. The SLPA understands they will also need to investigate proper insurance and liability concerns with owning and operating their own DASH system.

**Action Steps:**

1. See description above.

| **Management Action:** | Initiate EWM herbicide control strategy. |
|---|---|
| **Timeframe:** | As EWM population dictates. |
| **Facilitator:** | SLPA Board of Directors |
| **Funding Source:** | WDNR-AIS Maintenance and Control Grant |

**Description:** As discussed within the Aquatic Plant Section, aquatic invasive plants become problematic when they form large, dense monotypic colonies which begin to affect the lake's ecology, recreation, and aesthetics. Fortunately, the combination of hand-harvesting and herbicide control of EWM in Silver Lake has maintained a population of EWM that is mainly comprised of single plants and small colonies. However, continued monitoring will be essential to determine if and when future herbicide control strategies will need to be initiated for EWM in Silver Lake.

As discussed in the first management action under this goal, professional surveys for EWM are scheduled to be conducted in 2016 under the current AIS-EDR Project and the SLPA will likely be seeking and AIS-EPP Grant to aid in funding professional monitoring of EWM beyond 2016. While the previous management action outlines methodologies for EWM monitoring and the implementation of hand-harvesting, a threshold or 'trigger' needs to be established to determine when an herbicide control strategy would be implemented on Silver Lake.

Figure 5.0-2 displays the level of stakeholder respondent support for the responsible use of herbicides on Silver Lake to control EWM. Approximately 69% of respondents were supportive (either *Highly Supportive* or *Moderately Supportive*) of herbicide (chemical) control, whereas 7% were not supportive (*Not Supportive* or *Moderately Supportive*). Approximately 22% of stakeholder respondents indicated they were *Neutral* (9%) or *Unsure* (14%) regarding the responsible use of herbicide methods to control EWM in Silver Lake (Appendix B, Question 26).

*Question 26: What is your level of support for the responsible use herbicide (chemical) control of EWM on Silver Lake?*

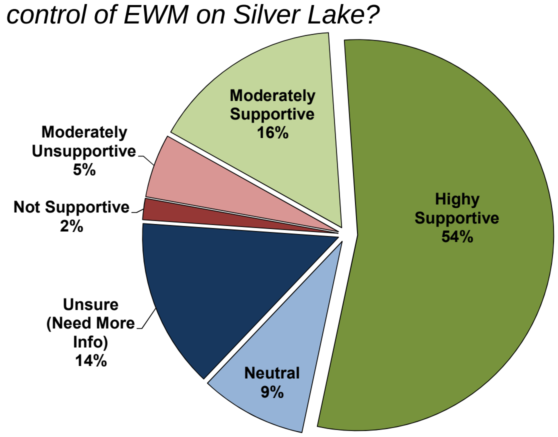



**Figure 5.0-2. Select survey responses from the Silver Lake Stakeholder Survey.** Additional questions and response charts can be found in Appendix B.

The SLPA would like to prevent the EWM population in Silver Lake from forming larger, monotypic colonies. If hand-harvesting efforts are unable to keep the EWM population from increasing in size and density, the SLPA would again consider implementing herbicide control techniques. The threshold or trigger for considering an herbicide treatment on Silver Lake would be the occurrence of colonized areas of EWM (i.e. mapped using polygon-based methods). Areas of less dense EWM adjacent to colonized areas (e.g. small plant colonies) would also be considered to inclusion within the herbicide application area. Additionally, larger areas comprised of EWM mapped using point-based techniques would also be considered if they exceeded three acres in size.

Given what has been learned about the rapid dissipation rate of herbicide from application areas and the unpredictable efficacy of spot treatments under five acres, all designed herbicide application areas would attempt to exceed five acres in size and no treatments would occur when at least a three-acre treatment site could not be logistically constructed. The shape (round versus long and narrow) and location (secluded versus deep, open, or flowing water) would also be considered in the strategy development.

The goal of EWM management on Silver Lake is to reduce the population at the lake-wide scale. If the EWM population expands to a level at which the population cannot be managed at the lake-wide scale through the use of spot-treatments, a whole-lake treatment strategy may be more applicable and may be more aligned with future grant opportunities. If an herbicide treatment strategy is implemented, spot or whole-lake, the appropriate quantitative monitoring using WDNR protocols and qualitative mapping would be implemented.

**Action Steps:**

1. See description above.

**<u>Management Action:</u>** Initiate aquatic invasive species rapid response plan upon discovery of new infestation.

**Timeframe:** Initiate upon invasive species discovery.

**Facilitator:** SLPA Board of Directors

**Description:** In the event that another aquatic invasive species, such as curly-leaf pondweed, is located by the trained volunteers, the areas would be marked using GPS and the SLPA should contact resource managers immediately. The areas marked by volunteers would serve as focus areas for professional ecologists, and these areas would be surveyed by professionals during the plant's peak growth phase (early summer for curly-leaf pondweed), and the results would be used to develop potential control strategies.

**Action Steps:**

1. See description above.

**Management Action:** Reinstitute Clean Boats Clean Waters watercraft inspections at Silver Lake's public access location.

**Timeframe:** Initiate 2016

**Funding:** WDNR Education Planning and Prevention Grant

**Facilitator:** SLPA Board of Directors

**Description:** The SLPA last monitored watercraft at Silver Lake's public access location through the Clean Boats Clean Waters (CBCW) Program in 2004. Silver Lake is a popular destination by recreationalists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional exotic species from entering the lake through the public access point, but also to prevent the infestation of other waterways with exotic species that originated in Silver Lake. The goal would be to monitor the landing for a total of 200 hours during the busiest times (e.g. holiday weekends) in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on our lakes and educating people about how they are the primary vector of their spread.

Often, it is difficult for lake groups to recruit and maintain a volunteer base to oversee CBCW inspections throughout the summer months. Recruitment outside of the SLPA may be necessary in order to have sufficient coverage of the Silver Lake public access. Education efforts outside of the lake community help to not only raise awareness about the threat of AIS, but also potentially recruit new volunteers to participate in activities such as CBCW.

Members of the SLPA, as well as other volunteers, will need to be trained on CBCW protocols in order to participate in public boat landing inspections. Fully understanding the importance of CBCW inspections, paid watercraft inspectors may be sought to ensure monitoring occurs at the public boat landing. These paid inspectors may be purchased alone or in conjunction with volunteers through the SLPA or in the community.

**Action Steps:**

1. Members of the SLPA periodically attend CBCW training sessions through the WDNR (Erin McFarlane – 715.346.4978) to update their skills to current standards.
2. Training of additional volunteers completed by those previously trained.

3. Begin inspections during high-use weekends.
4. Report results to WDNR and SLPA.
5. Promote enlistment and training of new volunteers to keep program fresh.

# 6.0 METHODS

## Lake Water Quality

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

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

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

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

## Watershed Analysis

The watershed analysis began with an accurate delineation of Silver 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 for curly-leaf pondweed were completed on Silver Lake during a June 19, 2014 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 Silver 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 22 and 23, 2014. A point spacing of 52 meters was used resulting in 479 points.

### *Community Mapping*

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

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

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